DETERMINATION OF GENETIC COEFFICIENTS FROM FIELD EXPERIMENTS FOR CERES-MAIZE AND SOYGRO CROP GROWTH MODELS

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ABSTRACT

Lack of genetic coefficients is a reason crop models are not widely used. A project was therefore developed to evaluate a field method to calculate genetic coefficients for crop models.

The phenology models from SOYGRO v. 5.42 and CERES-Maize v. 2.1, with the existing genetic coefficients, were tested using data for soybean and maize grown under extreme photoperiods. Identical experiments were performed at two sites on Maui Island, Hawaii, over three years. The treatment design was a factorial of photoperiods (natural, natural + 0.5 h, 14-, 17-, and 20-h) and cultivars ('Bragg', 'Evans', 'Jupiter', and 'Williams' for soybean and Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 for maize). Observations included development stage dates, yield, yield components, aboveground biomass weight, soil chemical analysis, and weather. Comparisons between observed and simulated results showed that soybean and maize development was well simulated. However, soybean yield and maize growth and yield were not well simulated. Further analysis suggested that model bias and parameter uncertainty accounted for nearly equal proportions of variation in soybean grain yield, whereas most maize growth and yield variation was due to model bias.

SOYGRO and CERES-Maize genetic coefficients were calculated from the data in the above experiments. One method to recalculate genetic coefficients was to incrementally change the genetic coefficients until simulated matched observed results. Another method was performed according to the maize modeler's suggestion. The fitting method adequately established development genetic coefficients, whereas growth coefficients had similar biases as the original genetic coefficients. The explicit method did not well simulate maize growth.

Using the fitted genetic coefficient means ± standard error, a sensitivity analysis was done. The genetic coefficient error that caused the greatest variation in simulated yield and aboveground biomass was identified. The most problematic genetic coefficients and associated model routines for yield and growth was the pod production relationship to nightlength in SOYGRO and juvenile phase duration in CERES-Maize.

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CHAPTER 1

REVIEW OF LITERATURE

Introduction

One approach to efficiently produce crops is to match crop requirements to land characteristics. Crop development and growth depend on land characteristics such as temperature, solar radiation, photoperiod, rainfall, and soil nutrients. Weather factors are especially variable among years. To characterize crop production at a location, the effect of the variable weather on crop yield must be recognized. A whole probability distribution on yield can be used to assess crop production because the shape of the disribution characterizes the risk of crop failure. Developing the probability distribution requires observing yield over many years so that a wide range of weather has affected the crop. In addition, probability distributions for each genotype need defining since genotypes differently respond to environment. A quicker method to develop the probability distribution is to use crop simulation models. Crop simulation models can define whole probability distributions because they quantify environment-by-genotype interactions. After estimating the risk of crop failure from the probability distributions, the crop and genotype suited for the land area can be selected.

Some crop models were developed to quickly assess the crop production potential under specified management practices for different locations. Simulation models were designed to account for genotype response to major environmental factors. The basis for these responses came from research in disciplines such as meteorology, soil science, plant physiology, agronomy, and plant breeding. These responses were converted to equations that described growth and development. With this description of plant response to its environment, the modeled factors are manipulated to find better management practices or location.

Crop models simulate genotype-by-environment interactions based on physiological principles. Genes control plant growth and development. The genetic potential for growth and development is modified by environmental conditions and results in genotype-by-environment interactions. The genotype-environment interactions can be simplified if physiological principles are known. The physiological principles can explain the genotype-by-environment interaction. The following review of published literature shows these connections between genetics, genotype-environment interaction, and plant physiology and its application to modeling crop growth and development.

Genetic Control of Crop Development and Growth

Development and growth of soybean and maize depend on the genetic constitution of the plant. Genes are known to control photoperiodism, phase duration, yield, yield components, and seed growth rate in both crops.

Five loci have been found to control photoperiod sensitivity of flowering and maturation in soybean: namely E_1, E_2, E_3, E_4, and E_5 (Saindon et al., 1989b). The five loci have two alleles each. Alleles E_1, E_2, E_3 (McBlain et al., 1987), E_4 (Saindon et al., 1989a; Saindon et al., 1990), and E_5 (McBlain and Bernard, 1987) were responsible for photoperiod sensitivity that caused late flowering and late maturation under long photoperiod. In addition, the alleles e_1, e_2, e_3, e_4, and e_5 generally did not affect photoperiod response. Partially dominant gene action (i.e., an intralocus action where heterozygous progeny's phenotype was between the parents but closer to one or the other) was exhibited at loci E_1 (Saindon et al., 1990), E_2 and E_5 (McBlain and Bernard, 1987). Dominant gene action, an intralocus action that gives heterozygous progeny's phenotype the same as the homozygous dominant parent, occurred at loci E_3 and E_4 (Saindon et al., 1989a). The photoperiod sensitive alleles E_1, E_2, E_3, E_4, and E_5 were dominant to the photoperiod insensitive alleles e_1, e_2, e_3, e_4, and $e_{5.}$

Interactions among alleles, known as epistasis, accounted for a large range of photoperiod sensitivities observed in soybean cultivars. Epistatic interaction occurred between loci E_1 and E_4 (Saindon et al., 1990). In the presence of allele E_4, allele E_1 delayed flowering and maturity more than twice as long than its effect in the presence of allele e_4. Similarly, in the presence of E_1, E_4 delayed flowering and maturity more than twice than its effect in the presence of allele e_1. Other epistatic interactions occurred with alleles E_1, E_2, and E_3 (McBlain et al., 1987). The delay in flowering was greater for allele E_3 when E_1 and E_2 were present. Saindon et al. (1989b) deduced that allele E_4 had epistatic interaction with other unidentified maturation alleles. Thus, these five known loci accounted for most of the variation in soybean photoperiod sensitivity (McBlain and Bernard, 1987; Saindon et al., 1989b; Saindon et al., 1990) and adaptability to a wide range of latitudes.

The response of days to anthesis to photoperiod in maize is under control of several loci. Photoperiod response has been documented as a function of three parameters: basic vegetative phase, maximum optimal photoperiod, and photoperiod sensitivity (Rood and Major, 1981). Basic vegetative phase was defined as the time to anthesis under optimum photoperiod. Maximum optimal photoperiod was the longest photoperiod that did not delay time to anthesis. Photoperiod sensitivity was the time anthesis delayed per hour of photoperiod beyond the maximum optimal photoperiod. The basic vegetative phase was shown to be under partial dominant gene action where short basic vegetative phase was dominant to long (Rood and Major, 1981). The gene action for maximum optimal photoperiod was variable and no conclusions were made (Rood and Major, 1981). Photoperiod sensitivity was observed to be under control of several loci (Brewbaker, 1981; Russell and Stuber, 1983) with additive gene action (Brewbaker, 1981; Russell and Stuber, 1983; Russell and Stuber, 1985), basically interlocus action among several loci where an allele at each locus added or subtracted a unit of phenotypic value. Broad sense heritabilities (i.e., the proportion of phenotypic variation due to genetics of all gene action types) were very high for the three parameters. Heritability was 96.5% for basic vegetative phase, 70.8% for maximum optimal photoperiod, and 70.6% (Rood and Major, 1981) or 94.7% (Brewbaker, 1981) for photoperiod sensitivity. Therefore, photoperiod response in maize was mainly under genetic control.

Genes control the time between two developmental stages (i.e., a phase) in soybean. The genes that control flowering in soybean similarly control maturation. Flowering and maturation is controlled by non-additive gene action with non-additive interaction between alleles (McBlain and Bernard, 1987). Other evidence for the genetic control of phases came from heritability studies. The results of these broad sense heritability studies showed that most of the phenotypic variation was under genetic control. In soybean experiments conducted across locations and years, broad sense heritability for days to flowering ranged from 71 to 91% and for days to maturity from 71 to 87% (Chan et al., 1986; Kwon and Torrie, 1964; Bartley and Weber, 1952; Anand and Torrie, 1963; Johnson et al., 1955). The reproductive phase from flowering to maturity had estimated heritabilities between 43 and 82% with a mean of 62% (Kwon and Torrie, 1964; Bartley and Weber, 1952; Anand and Torrie, 1963; Johnson et al., 1955). Another measure of genetic control of phenotype was narrow sense heritability. Narrow sense heritability is the proportion of phenotypic variance attributed to additive gene action. Narrow sense heritability measures how amenable a trait is to breeding methods because additive gene action is stable and passed from generation to generation unlike dominance or epistatic gene action. Seed filling phase, from beginning seed fill to physiological maturity, had heritabilities -20% to 24% (Smith and Nelson, 1987) and 16% to 63% (Pfeiffer and Egli, 1988).

Thus, while soybean vegetative and reproductive phases were under genetic control, manipulating the phases with breeding methods may be difficult for some phases because of the low narrow sense heritability.

The phase emergence to silking and the grain filling phase was under genetic control in maize. In a six by six diallel cross experiment over two years and two locations, days to silk had a broad sense heritability of 96.6% and narrow sense heritability of 68.5% (Dhillon et al., 1990). The heritability showed that gene action was predominantly additive for days to silking. In a similar experiment, Bonaparte (1977) found that days to silk was under additive gene action with incomplete dominance where early silking was dominant. Furthermore, at least four genes regulated days to silk. Grain filling period had broad sense heritability of 84.2% (Perenzin et al., 1980) which suggests the importance of genetics over environment for this phase. The effective grain filling period, defined as the ratio of final kernel weight to kernel growth rate or duration of the linear kernel growth, is almost equivalent to the grain filling period. Effective grain fill period was shown to be under additive gene action (Ottaviano and Camussi, 1981). Two studies showed that the effective grain filling period in progeny was much longer than either parent demonstrating that heterosis may have occurred (Poneleit and Egli, 1979; Djisbar and Gardner, 1989). These experiments showed that the phase emergence to silking and grain filling phase were under genetic control.

Environment affects soybean yield and yield components more than the genotype. Soybean yield per plant had a broad sense heritability of -1.7 to 67% with a mean of 32% (Chan et al., 1986; Faluyi, 1990; Anand and Torrie, 1963; Johnson et al., 1955; Kwon and Torrie, 1964; Bartley and Weber, 1952). The yield components of pods per plant, seeds per pod, and seed size had broad sense heritabilities of 0 to 71%, 0 to 60%, and 44 to 92% (Bartley and Weber, 1952; Kwon and Torrie, 1964; Johnson et al., 1955; Anand and Torrie, 1963; Chan et al., 1986; Faluyi, 1990). The wide range in heritabilities for yield and yield components may be attributed to differences in environment (Anand and Torrie, 1963; Chan et al., 1986) and genotypes (Faluyi, 1990). In general, genes contributed to the phenotypic variation, but environment was the major determinant for yield and yield components in soybean.

Genes affect maize yield, yield components and kernel growth rate, but the gene action was fully described for all traits. Broad sense heritability for grain yield was shown to be 96.7% (Perenzin et al., 1980), but narrow sense heritability ranged from 23.3% to 67.0% (Singh et al., 1989). The low narrow sense heritability showed the gene action for yield was non-additive. The non-additive gene action for yield had been identified as dominance in earlier experiments (Gamble, 1962a; Gamble, 1962b; Stuber et al., 1966). The yield components kernel weight, kernels per ear row, and rows per ear had fairly low narrow sense heritabilities: 33.8 to 34.9%, 48.9%, and 28.2% (Singh et al., 1989). The low narrow sense heritabilities supported the studies that found the yield components kernel weight and rows per ear were under dominant gene action (Gamble, 1962b; Gamble 1962c). Contrary to these results, Russell (1976) showed kernel weight and rows per ear were under additive gene control. The difference in results may be attributed to the use of material that had undergone selection for yield that imparted stability to additive effects (Gamble, 1962c). Kernel growth rate had broad sense heritability of 97% (Perenzin et al., 1980). There are indications that gene action for kernel growth rate may be dominant (Poneleit and Egli, 1979), additive (Ottaviano and Camussi, 1981), and heterotic (Poneleit and Egli, 1979). The mixed results in gene action may be due to environmental effects that influenced phenotype (Singh et al., 1989). While the gene action for yield and yield components had been characterized as dominance, the gene action for kernel growth rate has not been well established.

Thus, the evidence shows that genes are important contributors to phenotypic variation in development and growth of soybean and maize. The genetics of photoperiodism and the large broad sense heritabilities of vegetative and reproductive phases, yield, yield components, and growth supported the importance of genetics in phenotypic variation. However, environment substantially contributed to the phenotypic variation and cannot be ignored.

Interaction of Genotype and Environment on Crop Development and Growth

Environment differently influences phase duration, yield, yield components, and growth among genotypes. Environmental factors such as temperature, daylength, soil moisture, and soil fertility modify development and growth among crop varieties. The distinct environmental modification among genotypes is manifest in the genotype-by-environment interaction in an analysis of variance.

In soybean, environment factors differently influence the time to flowering, maturity, and flowering to maturity among cultivars. Days from planting to flowering have been observed in field experiments that altered environment through varying the year, location, and for planting date. The genotype-year interaction was significant in an experiment conducted over two years and two locations (Kwon and Torrie, 1964). The interaction was presumably caused by differences in temperature and moisture among the years. Kaw and Madhava Menon (1978) found the genotype-location interaction highly significant and suggested the cause was difference in soil texture, fertility, moisture, and salinity. In a study of 86 cultivars and 96 locations over three years, Schutz and Bernard (1967) found significant genotype-year and genotype-location interactions, but the variance for genotype-location was larger than genotype-year interaction. The genotype-planting date interaction was found significant and attributed to differing photoperiod sensitivity among cultivars (Pathak and Nema, 1988; Kaw and Madhava Menon, 1978). The genotype-environment interaction for time from planting to maturity was determined from field experiments that altered environment through different planting dates, locations, and years. In experiments where planting date was varied over one, three, and 10 months, genotype-planting date interactions were significant

(Raymer and Bernard, 1988; Pathak and Nema, 1988; Kaw and Madhava Menon, 1978). Examination of the genotype-planting date interaction revealed that the variation in time to maturity was much less for early than for the late maturing varieties (Pathak and Nema, 1988; Raymer and Bernard, 1988). The supposed cause of the significant interaction was different photoperiod sensitivity among genotypes (Kaw and Madhava Menon, 1978). The phase from flowering to maturity exhibited significant genotype-environment interaction. Kwon and Torrie (1964) showed that location and year differently affected genotypes for this phase. In an experiment where the genotype-planting date interaction was significant, as planting date was delayed, the early varieties flowering to maturity phase was shortened more than the late varieties (Pathak and Nema, 1988). Thus, environment distinctly affected the phases emergence to flowering, emergence to maturity, and flowering to maturity according to genotype.

Soybean yield and yield components display genotype-environment interactions. Environment was varied in several studies by conducting the same experiment over different years, locations, or planting. The variation in yield across years was significantly different among genotypes, that is, the genotype-year interaction was significant (Kwon and Torrie, 1964; Khadem et al., 1985a; Raymer and Bernard, 1988; Kang et al., 1989). The genotype-year interaction variance was much larger than the genotype variance (Kwon and Torrie, 1964; Schutz and Bernard, 1967) implied that yield response to environment among genotypes was greater than the differences in yield among genotypes. Genotype-location interaction was found significant for yield (Kwon and Torrie, 1964; Schutz and Bernard, 1967; Kang et al., 1989; Kaw and Madhava Menon, 1978). Kang et al. (1989) attributed the genotype-location interaction to differences among genotypes in their response to fertility, cultural practices, and rainfall but not temperature or relative humidity. The significance of the genotype-planting date interaction for yield was variable. In one experiment the genotype-planting date interaction was significant (Konwar and Talukdar, 1986), in two others it was not significant (Raymer and Bernard, 1988; Kaw and Mahava Menon, 1978). Raymer and Bernard (1988) found that genotype-planting date interactions were significant in two of three years. However, when the experiments were combined, the genotype-planting date interaction was not significant. Therefore, the significance and non-significance of the genotype-planting date interaction among the different experiments may be due to years. Nevertheless, soybean yield response to environment varies among genotypes.

The yield components number-of-pods-per-plant, number-of-seeds-per-pod, and mass-per-100-seeds showed significant genotype-environment interactions. The response in number-of-pods-per-plant to environment was different among genotypes where environment was varied over years (Khadem et al., 1985b), locations (Kaw and Madhava Menon, 1978), and planting dates (Konwar and Talukdar, 1986). Seeds per pod also showed significant genotype-environment interaction (Konwar and Talukdar, 1986). While 100-seed-mass was shown to have a significant genotype-environment interaction (Khadem et al., 1985b; Raymer and Bernard, 1988; Konwar and Talukdar, 1986), the magnitude of the interaction variance was smaller than the genotype variance (Kwon and Torrie, 1964; Schutz and Bernard, 1967). The difference in variance magnitudes indicated that the genotype effect was more important than genotype-environment interaction in determining 100-seed-mass. Thus, yield component response to environment was significantly different among genotypes.

In maize, genotype-environment interactions are significant for photoperiodism, phase durations, yield, and yield components. The significant interactions demonstrated that genotypes responded differently to their environment.

Photoperiod sensitivity displays significant genotype-environment interaction in maize. Photoperiod sensitivity, measured as days to tassel initiation or total leaf number, has shown significant genotype-environment interaction in multi-location experiments (Russell and Stuber, 1985; Russell and Stuber, 1983a). Photoperiod sensitivity decreased as temperature increased (Hunter et al., 1974; Russell and Stuber, 1983b) and may partially account for the differences in sensitivity among locations.

Phase durations in maize are subject to significant genotype-environment interactions. The phase from planting to flowering has displayed significant genotype-environment interaction as environment was varied by location (Russell and Stuber, 1985; Bonaparte and Brawn, 1976), planting date (Brewbaker, 1981), or year

(Ottaviano and Camussi, 1981; Dhillon et al., 1990). The phase from silking to maturity in days had significant genotype-environment interaction in an experiment of 36 genotypes and six locations (Jha et al., 1986). Similarly, effective fill period duration, the duration of linear kernel growth rate in days, was found to have large genotype-environment interaction (Ottaviano and Camussi, 1981). So, the phase planting to flowering and the grain filling period differently responded to the environment among genotypes.

Maize yield and yield components respond to environment according to their genotype. Genotype-environment interaction was highly significant for yield in multi-location and -year studies (Jha et al., 1986; Ottaviano and Camussi, 1981). The observed interaction was mostly attributed to differences in soil fertility and cultural practices (Kang and Gorman, 1989). However, while genotypes from temperate climates had significant genotype-environment interaction, hybrids of temperate by tropical origin displayed stable yields across environments and no significant genotype-environment interaction (Brewbaker, 1981). The yield components kernel weight, kernel number per row, and row number per ear showed variable genotype-environment interactions. Kernel weight had significant genotype-environment interactions in experiments where environment was varied by planting date, year, and location (Brewbaker, 1981; Carter and Poneleit, 1973; Ottaviano and Camussi, 1981). Kernel number per row and row number per ear had significant and non-significant genotype-environment interactions (Ottaviano and

Camussi, 1981; Brewbaker, 1981). Nevertheless, genotype-environment interactions were present for yield and yield components in maize.

Grain fill rate in maize has significant genotype-environment interaction. In two experiments that varied environments across locations and years, significant genotype-environment interaction for grain fill rate was determined (Jha et al., 1986; Carter and Poneleit, 1973). However, Ottaviano and Camussi (1981) did not observe significant genotype-environment interaction for grain fill rate in an experiment with 45 genotypes and three environments. While grain fill rate may be stable across environments among genotypes, change may occur under certain conditions.

Thus, genotype-environment interactions were present in development and growth of soybean and maize. The significant genotype-environment interactions observed for photoperiod sensitivity, phase durations, yield, yield components, and grain fill rate demonstrated that distinct response to environmental factors existed among genotypes. Hence, plant growth and development is contingent on both genetic and environmental factors.

Physiology of Environmental Effects on Crop Development and Growth

Plant physiology gives insight into the dependence of growth and development on environmental factors and genetics. While an analysis of variance can identify factors that affect plant traits, it cannot explain the mechanisms involved in the crop's response to the environment. Soybean and maize growth and development respond to photoperiod, temperature, available moisture, and soil fertility. These factors were known to affect photoperiodism, phase duration, yield, yield components, and grain growth rate.

Temperature affects soybean time to flowering, but not photoperiod sensitivity. Soybean plants had two phases that constituted the time from sowing to flowering: a pre-floral initiation phase that was relatively photoperiod-insensitive and a post-floral initiation phase that was more photoperiod-sensitive. Board and Settimi (1988) found that soybean plants were completely insensitive to photoperiod for 8 to 16 days after emergence. Once the soybean plants became photoperiod-sensitive, the phase from floral initiation to flowering was found much more sensitive to photoperiod than pre-floral initiation phase and caused most of the flowering delay under long photoperiod (Thomas and Raper, 1983). The pre-floral initiation phase was sensitive mostly to temperature (Thomas and Raper, 1983). Most studies have not separated the pre- and post-floral initiation phases in determining time to flower. Instead of time to flower, Hadley et al. (1984) used the inverse of time to flower, the rate of development to flower, that gave a linear relation between rate of development on photoperiod. The rate of development to flower was photoperiod dependent and had three components (Hadley et al., 1984). When photoperiods were shorter than a threshold photoperiod, rate of development to flowering proceeded at maximum. The threshold photoperiod was defined as the shortest photoperiod that delayed flowering. At photoperiods greater than the threshold, the rate of development to flowering decreased linearly with increasing photoperiod. A minimum rate of development existed and was independent of photoperiod (Hadley et al., 1984; Thomas and Raper, 1983; Cregan and Hartwig, 1984). At photoperiods less than the threshold, rate of development increased linearly with increasing temperature (Hadley et al., 1984). Also, the threshold photoperiod increased by approximately 11 minutes per °C with increasing temperature. At photoperiods greater than the threshold, the consequent reduction in rate of development linearly decreased with decreasing temperature. Thus, decreasing temperature reduced the rate of development to flowering, but there was no interaction with the photoperiod response, i.e., temperature did not change photoperiod sensitivity (Hadley et al., 1984; McBlain et al., 1987).

Environmental factors modify soybean phase durations. The vegetative phase from emergence to flowering is affected by photoperiod, temperature, drought stress, and nitrogen fertilization. Long photoperiod delays flowering in photoperiod sensitive genotypes. In addition, inadequate number of short photoperiods can delay flowering. In a photoperiod experiment where plants were switched from short to long photoperiod, nine days of short photoperiod showed delayed flowering, while 18 days of short photoperiod did not (Mann and Jaworski, 1970). This suggested that flowering have a requirement for photoperiod length and number of photoperiod cycles. The time to flower was delayed under low temperature and was similar among genotypes (Brown and Chapman, 1960). Flowering delay seemed to depend on when the lowered temperature occurs during the day or night. Lowering night temperature from 24 to 19 °C delayed flowering 11 days while lowering day temperature from 33 to 27 °C only delayed flowering two days (Huxley et al., 1976). However, Hadley et al. (1984) concluded that development rate to flowering was dependent on mean daily temperature rather than night temperature alone. Moisture stress during vegetative growth delayed flowering 10 days in Phaseolus vulgaris (L.) (Robins and Domingo, 1956) and was likely to be similar in soybean (Brown and Chapman, 1960). Low nitrogen fertilization slightly delayed flowering two days (Huxley et al., 1976). Thus, inadequate photoperiod, temperature, moisture, and nitrogen fertilization delayed flowering. The reproductive phase from flowering or pod set to maturity was modified by the same environmental factors. Photoperiod affected the phase from flowering to maturity. Short photoperiod hastened flowering to maturity (Major et al., 1975). The photoperiod effect may be dependent on genotype (Constable and Rose, 1988). Two photoperiod characteristics other than length that seemed to affect the reproductive phase were rate of change in photoperiod and non-changing photoperiod. In a multiple regression analysis study, the variable rate of change in photoperiod from one day to another significantly reduced the variation in predicting maturity in a planting date and location experiment (Constable and Rose, 1988). Long constant photoperiod prolonged the phase from pod set to maturity, but long naturally changing photoperiod did not increase the phase length (Johnson et al., 1960). The difference in response to constant and naturally changing photoperiod may be attributed to the alleles E_1 and

E_3. McBlain et al. (1987) found that soybean isolines with the alleles E_1 and E_3 had delayed maturity under long constant photoperiod, but had little effect under long naturally changing photoperiod. Temperature did not affect the reproductive phase from flowering to maturity. The days from flowering to maturity were fairly constant for soybean grown in temperatures from 21 to 30 °C (Hesketh et al., 1973). Similarly, the seed growth duration was unaffected by increasing night temperature from 10 to 24 °C (Seddigh and Jolliff, 1984). Brown and Chapman (1960) observed development rate became less responsive to temperature as soybean plants progressed from vegetative stages to reproductive stages to maturity. Hence, the reproductive phase was relatively unresponsive to temperature irrespective of genotype (Brown and Chapman, 1960; Major et al., 1975). Drought stress and low nitrogen availability hastened the reproductive phase. Drought stress imposed during seed filling shortened the phase 2 to 11 days (Meckel et al., 1984; Dornbos et al., 1989) depending on the severity of the stress. Removing nitrogen fertilization from non-inoculated soybean during pod filling or seed filling stage hastened maturity 12 and seven days (Egli et al., 1978). Thus, inadequate photoperiod prolongs vegetative and reproductive development, non-optimal temperature prolongs vegetative development, and inadequate moisture and nitrogen fertilization prolongs vegetative development but hastens reproductive development.

Environmental factors affected grain yield through its effects on yield components in soybean. Photoperiod differently affected the yields of early and late cultivars. Long photoperiod did not affect yield from a late soybean variety, but decreased yield from an earlier variety. Huxley et al. (1976) found that increasing photoperiod did not affect yield because pods-per-plant increased but was offset by slight decreases in seeds-per-pod and mass-per-seed. However, Raper and Thomas (1978) observed that increasing photoperiod reduced yield through decreased pods-per-plant and mass-per-seed. The differences in photoperiod effects on yield may be attributed to better compensating ability in late than early varieties (Schweitzer and Harper, 1985). Temperature effects on yield resulted from its effects on yield components. Mass-per-seed seemed to have an optimum temperature of 27 °C (Hesketh et al., 1973). So, increasing day temperature from 27 to 33 °C reduced weight per seed (Huxley et al., 1976) while increasing night temperature from 17 to 24 °C increased weight per seed (Huxley et al., 1976; Saito, 1961). Temperature did not affect seeds-per-pod (Huxley et al., 1976). Pods-per-plant response to temperature interacted with photoperiod and genotype. Raper and Thomas (1978) observed increased pods-per-plant as temperature increased under short photoperiod, but pods-per-plant decreased as temperature increased under long photoperiod. Other researchers observed an opposite effect on pods-per-plant. Pods-per-plant decreased as temperature increased under short photoperiod (Huxley et al., 1976; Saito, 1961) and pods-per-plant increased as temperature increased under long photoperiod (Hesketh et al., 1973). The two opposite effects of increasing temperature on pods-per-plant under short and long photoperiods were observed in two different genotypes (van Schaik and Probst, 1958). So, the temperature effects on pods-per-plant seemed dependent on photoperiod and genotype. Generally, grain yield per plant decreased as temperature increased. Increasing day temperature from 27 to 33 °C reduced yield regardless of genotype (Huxley et al., 1976; Saito, 1961). Increasing night temperature above 16 °C reduced yield (Huxley et al., 1976; Peters et al., 1971; Saito, 1961; Seddigh and Jolliff, 1984). The yield reduction with increased temperature was attributed to a large decrease in pods per plant (Huxley et al., 1976). The effect of drought stress on grain yield and yield components depended on the severity and timing of the stress. Drought stress significantly reduced grain yield (Hunt et al., 1983). The yield reduction increased as drought severity increased (Momen et al., 1979) and was attributed to decreased photosynthetic rate (Dornbos et al., 1989). Yield reduction was also dependent on the stage of development that drought stress occurred. Drought stress during pod-formation or pod-fill reduced yield more than stress at flower induction or flowering (Sionit and Kramer, 1977; Momen et al., 1979). Drought stress at pod-formation or pod-fill reduced mass-per-seed (Wien et al., 1979; Sionit and Kramer, 1977; Dornbos et al., 1989; Meckel et al., 1984). The reduced mass-per-seed resulted because the number of pods-per-plant and seeds-per-pod was already set at the time that stress was imposed. So, drought reduced photosynthetic rate or photosynthate transport that reduced seed size (Momen et al., 1979). Drought stress at flowering reduced pods per plant (Wien et al., 1979; Sionit and Kramer, 1977), but did not reduce seeds-per-pod (Wien et al., 1979; Momen et al., 1979) or mass-per-seed (Sionit and Kramer, 1977). Hence, the yield reduction induced at flowering resulted from the decrease in number of pods. Soybean grain yield increased with increasing nitrogen availability. Fertilizer N application increased yield in nodulated (Hanway and Weber, 1971) and non-nodulated (Weber, 1966; Ashour and Thalooth, 1983) soybean. Increasing N availability increased mass-per-seed (Hanway and Weber, 1971; Weber, 1966) and pods-per-plant (Huxley et al., 1976; Ashour and Thalooth, 1983), but not seeds-per-pod (Huxley et al., 1976; Ashour and Thalooth, 1983). Thus, environmental effects on yield are governed by the effects on pods-per-plant and mass-per-seed since seeds-per-pod is relatively stable.

Soybean seed growth rate depends on photoperiod and temperature, but not drought stress. Short photoperiod increased seed growth rate (Thomas and Raper, 1976; Raper and Thomas, 1978). The increased seed growth rate was attributed to an oxygen dependent process, not photosynthesis or dark respiration (Raper and Thomas, 1978). One possible explanation was that under short photoperiod the cambium produced more xylem than phloem cells (Thomas and Raper, 1976). The relative reduction in phloem may have reduced export of photosynthate from leaf to stem or root and, consequently, more likely to seeds, while the relative increase in xylem increased the N transported from the roots to seeds. So, the overall effect was increased seed growth under short photoperiod. Increased temperature increased seed growth rate, but at high temperature seed growth rate decreased. As day/night temperature increased from 18/13 °C to 27/22 °C seed growth rate increased, and decreased when temperature continued increasing to 33/28 °C (Egli and Wardlaw, 1980). Similarly, increasing night temperature from 10 to 16 °C increased seed growth rate, and decreased when night temperature increased to 24 °C (Seddigh and Jolliff, 1984). The increased seed growth rate was attributed to direct effects on the seed, possibly photosynthate unloading to the seed, rather than on increased photosynthate supply (Egli and Wardlaw, 1980; Seddigh and Jolliff, 1984). Interestingly, seed growth was also dependent on temperature during flowering and pod development (Egli and Wardlaw, 1980). Supposedly, high temperature during flowering and pod development raised the potential seed growth and increased seed growth rate during seed-fill. Drought stress did not affect seed growth rate. Drought stress reduced photosynthesis, but mobilized carbohydrate reserves from vegetative organs were able to support seed growth rate (Meckel et al., 1984; Westgate et al., 1989). However, when the carbohydrate reserves were depleted, seed fill duration was shortened and seed size was reduced (Meckel et al., 1984). So, while seed fill duration was sensitive to drought stress, seed growth rate was conserved (Westgate et al., 1989).

The relationship between photoperiod and the time to tassel initiation is dependent on genotype in maize. The photoperiod response for tassel initiation was defined with two parts: a photoperiod-insensitive phase, also called the juvenile phase, and a photoperiod sensitive phase (Kiniry et al., 1983a). The photoperiod insensitive phase after emergence varied among three cultivars between six and 24 d (Kiniry et al., 1983b). The photoperiod sensitive phase began at the end of the photoperiod-insensitive phase and ended at tassel initiation (Kiniry et al., 1983a). When maize plants became photoperiod sensitive, tassel initiation delay was dependent on the photoperiod, threshold photoperiod, and photoperiod sensitivity. Threshold photoperiod was defined when delay in tassel initiation occurred at photoperiod greater than the threshold. Threshold photoperiod varied from 10.0 to 13.5 h for cultivars of diverse maturity groups (Kiniry et al., 1983a). The delay in tassel initiation was linearly related to photoperiod hours greater than the threshold photoperiod. The slope of the line was photoperiod sensitivity in °C days$\cdot$h^{-1}. Photoperiod sensitivity values for the cultivars ranged from four, for relatively photoperiod insensitive, to 36 (Kiniry et al., 1983a). Bonhomme et al. (1994) found temperate adapted cultivars relatively photoperiod insensitive while tropically adapted cultivars were highly photoperiod sensitive with sensitivities from 24 to 110 °C days$\cdot$h^{-1}. So, tassel initiation delay in response to photoperiod is dependent on genotype.

Temperature, photoperiod, soil fertility, and drought stress modifies the length of the phases from planting to tassel or silk emergence, and silking to maturity. In general, warm temperature shortened the planting to tassel emergence phase as much as 27 to 53 days (Bonaparte, 1975; Cooper, 1979; Shaw and Thom, 1951). The shortened planting to tassel emergence may be due to increased leaf emergence rate and respiration (Bonaparte, 1975). Long photoperiod increased the time from planting to tassel emergence that was cultivar dependent (Bonaparte, 1975). Long photoperiod affected planting to tassel emergence mainly through its delaying effect on tassel initiation (Ellis et al., 1992). Interestingly, long photoperiod prior to tassel initiation shortened the tassel initiation to tassel emergence duration. This photoperiod effect was attributed to the greater leaf number, hence greater leaf area, produced when tassel initiation was delayed under long photoperiod. Presumably, greater leaf area resulted in increased photosynthate production for growth and tassel extrusion (Ellis et al, 1992). However, photoperiod had little true effect on the tassel initiation to tassel emergence phase and may be ignored (Breuer et al., 1976; Ellis et al., 1992). High soil fertility shortened the planting to tassel or silk emergence phase (Bonaparte, 1975). High N fertilization reduced the planting to silk emergence interval 14 days (Bhatnagar and Jain, 1989), while high P or K fertilization reduced the interval 4 to 7 days (Peaslee et al., 1971). Drought stress increased the length of the planting to tassel emergence phase. Drought stress applied sometime during vegetative growth increased the planting tassel emergence phase 2 to 4 days (NeSmith and Ritchie, 1992c), and 5.1 days (Bonaparte, 1975). Generally, the planting to tassel or silk emergence phase is increased when low temperature, long photoperiod, and soil fertility or drought stress is applied to maize plants during vegetative growth.

Temperature, soil fertility, and drought stress modifies the silk emergence to maturity and grain filling phases, but photoperiod effects are minimal. Warm temperature hastens the silk emergence to maturity phase. Temperature affected the silk emergence to maturity phase more than photoperiod, but a temperature by photoperiod interaction has been observed (Breuer et al., 1976). At 20 °C, silk to maturity phase was shorter under 10 h than 20 h photoperiod. However, at 30 °C, silk to maturity phase was longer under 10 h photoperiod. This interaction may not be a true photoperiod effect, but may be carryover effect from photoperiod on the planting to tassel initiation phase (Breuer et al., 1976). Soil fertility had mixed effects on the grain filling phase. N fertilization increased the grain filling period about 6 days (Bhatnagar and Jain, 1989). P fertilization shortened the grain filling phase and was suggested that P actually accelerated grain development (Peaslee et al., 1971). In contrast to N and P effects, K fertilization lengthened the grain filling phase, possibly through a similar mechanism as its effect on delaying leaf senescence (Peaslee et al., 1971). Drought stress reduced the grain filling phase 5 to 8 days (NeSmith and Ritchie, 1992b). So, warm temperature, drought stress, and P fertilization shortens the grain filling phase while N and K fertilization lengthen the phase.

Temperature, soil fertility, and drought stress affect corn grain yield components and yield. In an experiment conducted on maize at 1268, 1890 and 2250 m elevation, grain yield was reduced with decreasing altitude, i.e., increasing temperature (Cooper, 1979). The yield reduction was mostly attributed to decreased kernel number, but also decreased kernel weight. N, P, and K fertilization increased maize yield (Bhatnagar and Jain, 1989; Peaslee et al., 1971). Drought induced yield reduction are related to kernel number or kernel weight depending on the timing of the stress. Drought stress before anthesis reduced yield 15 to 25% because kernel weight or kernel number was decreased (NeSmith and Ritchie, 1992c). Drought stress from tassel emergence to 18 days after silk extrusion reduced yield 22 to 92% and was primarily caused by reduced kernel number (NeSmith and Ritchie, 1992a). The reduced kernel number may be a result of drought stress depressing photosynthetic activity during the time of endosperm cell division (Hunter, 1980; Kiniry and Ritchie, 1985). The limited photosynthate availability during endosperm cell division may reduce the number of cells in kernels, especially in kernels near the ear tip, and thereby preventing maximum filling. When applied later in the grain filling period, drought stress reduced yield 21 to 40% through decreased kernel weight (NeSmith and Ritchie, 1992b). The reduced yield was attributed to shortened grain-fill duration, 5 to 8 days shorter, and not change in grain-fill rate. So, stress affects maize yield through its effects on yield components.

Maize kernel growth rate is a relatively stable attribute, but temperature does modify it. Reduced photosynthate production, obtained from drought or reduced leaf area, did not affect kernel growth rate (NeSmith and Ritchie, 1992b; NeSmith and Ritchie, 1992c; Frey, 1981). The conservation of kernel growth rate under low photosynthate supply may be attributed to compensating effects of reduced kernel number, shortened grain-fill period, and increased carbohydrate translocation from stem tissue. When low photosynthate production occurred, kernels near the ear tip did not fill, had reduced fill rate, or shortened fill duration. So, basal and mid ear kernels were able to maintain normal grain fill rates because of the reduced photosynthate demand (Frey, 1981). Temperature modifies grain-fill rate. Temperature may affect photosynthate absorption capacity of the kernel and the conversion rate from sugar to starch within a kernel that resulting in modified grain-fill rate. Low or high temperature, 15 or 35 °C, during the lag phase when endosperm cell division occurred, may have reduced the number of endosperm cells in the kernel (Jones et al., 1984). The reduced endosperm cell number would have reduced the photosynthate capacity and decreased grain fill rate. Low temperature has also been conjectured to reduce the conversion of sugar to starch within the kernel (Jones et al., 1981). The slowed conversion rate accounted for the reduced kernel growth rate in low temperature despite adequate photosynthate supply.

Environment greatly affects crop development and growth. Photoperiod, temperature, soil fertility, and drought stress modify the timing of developmental stages, yield, yield components, and grain growth rate. In some cases, the mechanisms of environmental sensitivity were shown to be different among genotypes. Thus, the genotype-environment interactions can be partitioned into through the physiological processes that can be quantified through genotype-specific parameters.

SOYGRO and CERES-Maize Description

SOYGRO simulates soybean development as a function of temperature and photoperiod (Jones et al., 1986). SOYGRO simulates development from planting through emergence, unifoliolate, end of juvenile phase, floral initiation, flowering, beginning pod, full pod, end of leaf production, end of flower set, and physiological maturity. The duration from one stage to the next is dependent on temperature or temperature and photoperiod. Temperature sensitive phases have development rates that linearly increase from 7.0 to 30.0 °C, remains at maximum between 30.0 and 35.0 °C, and linearly decreases from 35.0 to 45.0 °C. The developmental progress is accumulated each day until a threshold is reached, then the next growth stage is attained. The temperature sensitive phases include planting to emergence, planting to unifoliolate, unifoliolate to end of juvenile phase, and floral induction to flowering. Temperature and photoperiod regulate the development rate for the remaining phases. Development rate is maximum above a given critical night length. Below the critical night length, development rate decreases with decreasing night length until a second critical night length is reached where rate is constant. The development rate based on night length is modulated by the temperature function described above. The next growth stage is realized when the accrued daily development reaches a threshold value.

Soybean growth is simulated by partitioning carbohydrate to plant organs (Jones et al., 1986). When no drought or nutrient stress is present, carbohydrate is produced from intercepted solar radiation, a function of leaf area and daily solar radiation. The carbohydrate fraction directed to a plant organ depends on the development stage. As development progresses from planting to maturity, the carbohydrate fraction to stem increases while leaf and root fractions decrease. From V5 stage onward, stem fraction is greater than leaf and root fractions. Though the carbohydrate fractions differ among plant organs, carbohydrate is partitioned to leaf before being distributed to other organs. When pod growth starts, carbohydrate is first supplied to satisfy pod demand, then the remaining carbohydrate is given to other organs.

During the pod growth phase, numbers of pods and seeds, and their growth rates are simulated from the amount of available carbohydrate and temperature (Jones et al., 1986; Boote et al., 1987). Pods are added to soybean plants during the podding phase. Each day, the maximum pod addition rate is modified by the available carbohydrate amount and temperature. Pod shell growth is given priority on carbohydrate distribution. After all shells have been given their portion of the carbohydrate pool, the remaining amount is directed to adding new pods. If inadequate carbohydrate remains, the maximum pod addition rate is proportionally attenuated. Temperature modifies the number of pods added each day. Maximum pod addition rate occurs between 20 and 27 °C. These same factors that affect pod addition also modify shell growth. The number of seeds set depends on the average photosynthetic production during shell growth. The number of pods that set seed is proportional to the average carbohydrate production when less than 0.6 of the potential production during that time. Once seeds are set, seed growth rate is a function of the maximum seed growth rate, carbohydrate availability, and temperature. For seed growth, optimum temperature is 23.2 °C. Seed growth continues until the seed:pod weight ratio reaches 0.8. Physiological maturity occurs when the given photothermal threshold value is reached.

CERES-Maize simulates maize development using temperature and photoperiod functions (Jones et al., 1986). Development from one growth stage to another is based on temperature with one exception. The quantity average temperature minus base temperature 8 °C is daily summed until a pre-determined value is matched. At this time, the next growth stage occurs. The temperature dependent phases include planting to emergence, emergence to end of juvenile phase, tassel initiation to silk appearance, and silk appearance to physiological maturity. The end of juvenile phase to tassel initiation duration is the only phase dependent on photoperiod. Photoperiod greater than 12.5 h increases the duration of the phase in proportion to the number of hours daylength is over 12.5. Then, temperature and photoperiod control the simulated maize lifecycle.

Maize growth simulation is based on partitioning photosynthate to plant organs (Jones et al., 1986). Under no drought or nutrient stress, the photosynthetically produced carbohydrate is a function of intercepted solar radiation calculated from leaf area and daily incident solar radiation. The optimum temperature for simulated photosynthesis is 26 °C. Before silking, the carbohydrate is first used to grow leaf area that intercepts more solar radiation. Stem and roots receive the remaining carbohydrate. After silking, leaf growth stops and grain growth is given priority in carbohydrate partitioning. The grain carbohydrate demand is calculated from a temperature function with optimum at 26 °C, and a pre-determined maximum kernel growth rate and kernel number plant^{-1}. The remaining carbohydrate is used for stem and root growth. When the accumulated thermal time value is attained, physiological maturity occurs and growth stops.

Genetic Coefficients in Crop Models

Genetic coefficients are used in SOYGRO and CERES-Maize (Ritchie et al., 1986; Jones et al., 1986) to describe the genetically controlled development and growth characteristics of a particular genotype. The phenological genetic coefficients quantitatively express a plant's physiological response to its environment, including photoperiodism and phase durations. The genetic coefficients for growth quantify maximum growth rates and other plant variables such as seed growth rate, seed number, and leaf area. Both types of genetic coefficients describe plant growth and development according to its genetic constitution. From these genetic coefficients, yield and ontogeny can be simulated based on the physiological sensitivities of a genotype.

Many crop models use principles of photoperiodism to simulate plant development. The corn growth model CERES-maize utilizes a genotype specific photoperiod sensitivity coefficient to calculate time of tassel initiation (Ritchie et al., 1986). Threshold photoperiod is assumed to be 12.5 hours, civil twilight inclusive. When daylength is greater than 12.5 hours, tassel initiation is delayed in direct proportion to the difference between daylength and the threshold photoperiod, as prescribed by the photoperiod sensitivity coefficient. Similarly, in the soybean growth model SOYGRO, the photoperiod sensitivity coefficient regulates simulation of the timing of flowering stage R1 (Jones et al., 1986). However, unlike CERES-Maize, the threshold photoperiod is genotype specific. The model requires accurately determined photoperiod characteristics to correctly simulate plant development.

The simulation models measure developmental progress with phase durations based on temperature and photoperiod. CERES-maize utilized growing degree days to govern the duration of two temperature dependent phases: namely emergence to end of juvenile phase, and silking to maturity (Ritchie et al., 1986). The summed growing degree days between the two pairs of development stages are genetic coefficients. SOYGRO employed a night length accumulator and a physiological day accumulator to quantify time between stages (Jones et al., 1986). The night length dependent phases based the rate of development on the current night length. Long nights (i.e., the same as short days) developed at a high rate and were given a high night length accumulator value. The night length accumulator values were summed over successive nights until a threshold value was attained. When the threshold value was reached, the next growth stage occurred. The night time accumulator threshold determines the length of the phases end of juvenility to floral initiation, and first flower to beginning-pod, full-pod, last-leaf-fully-opened, last-flower-produced, and physiological maturity. The remaining phases were temperature dependent. The temperature dependent phases based development rate on temperature where plants developed fastest under optimal temperature, 30 to 35 °C. Under optimal temperature, one physiological day, the temperature dependent unit, accumulated in one chronological day. When a threshold number of physiological days are accumulated, the next development stage occurs. The threshold number of physiological days is a genetic coefficient. The phases that use the physiological day units are planting to emergence, planting to unifoliolate, unifoliolate to end of juvenile stage, and floral initiation to first flower bloom. Although the genetic coefficients are calculated in different ways for SOYGRO and CERES-Maize, both models require inputs for effects of temperature and photoperiod phase duration.

The genetic coefficients in CERES-Maize include one for maximum limit for kernel number (G2) and kernel growth rate (G3). The number of kernels in maize plants depended upon conditions a few days before and just after silking (Kiniry and Ritchie, 1985). Therefore, the genetic coefficient G2 represents the maximum number of kernels a plant produces under optimal conditions that the model modifies according to calculated stresses. The G3 genetic coefficient represents the maximum kernel growth rate that a cultivar would produce under optimal condition.

SOYGRO growth genetic coefficients encompass seed, pod shell, and leaf growth (Jones et al., 1986). Maximum seed growth rate, in mg$\cdot$seed$^{-1}\cdot$day^{-1}, and number of seeds per pod are genetic coefficients that describe seed growth. Pod growth is characterized with maximum rate of pod addition under optimal night length and photosynthetic rate, and maximum shell growth rate. Leaf growth has three genetic coefficients: number of trifoliolates produced in a physiological day, leaf area of a normal leaf at nodes 8 to 10, and specific leaf area of a leaf later than the fifth node. These seven characteristics define the major growth differences among soybean cultivars.

Determining Genetic Coefficients

Researchers have estimated genetic coefficients in several ways. Howell et al. (1989) obtained the coefficients from the model developer. Others adjusted the coefficients until simulated data fitted the observed field data (du Pisani, 1987; Hodges et al., 1987; Liu et al., 1989). However, genetic coefficients are usually determined explicitly with a combination of controlled-environment chamber and field experiments (Ritchie et al., 1986; Wilkerson et al., 1989). Coefficients obtained by these methods were used successfully to simulate crop yields (Howell et al., 1989; du Pisani, 1987; Hodges et al., 1987; Liu et al., 1989; Ritchie et al., 1986).

The existing procedures for determining genetic coefficients have disadvantages. Researchers recognize that adjusting the coefficients to fit observed data may make the model only applicable to the location where the data were collected (Hodges et al., 1987; Liu et al., 1989). Thus, experiments at many locations must be conducted (Hodges et al., 1987), or else model results may be applicable to only the specific location where the genetic coefficients were estimated. Using controlled-environment chambers to determine the genetic coefficients for contrasting temperatures and photoperiods may make the model applicable to a wider range of environments, but only researchers with access to growth chambers can use this method. So, only experimenters with access to multi-location fields or growth chambers can estimate genetic coefficients.

Estimating genetic coefficients in developing countries is difficult. There are many locally grown cultivars for which genetic coefficients have not been estimated. The estimation methods mentioned above may not be applicable. Researchers in developing countries may not have access to growth chambers, or the field experiment method may not have photoperiod differences great enough to well estimate cultivar photoperiod sensitivity, especially if the fields are located in the tropics. So, a method to estimate genetic coefficients in developing countries is necessary.

The purpose of this study is to estimate genetic coefficients for SOYGRO and CERES-Maize crop simulation models using a field experiment that can be done in developing countries.

CHAPTER 2

SIMULATING SOYBEAN AND MAIZE DEVELOPMENT AND GROWTH UNDER EXTREME ARTIFICIAL PHOTOPERIODS WITH SOYGRO AND CERES-MAIZE CROP SIMULATION MODELS

Introduction

The crop models SOYGRO (Wilkerson et al., 1983) and CERES-maize (Jones and Kiniry, 1986) are process-oriented models for soybean (Glycine max L.) and corn (Zea mays L.) that have simulated phenology and growth in many environments. SOYGRO accurately simulated yield and phenology in a study on irrigated soybean (Swaney et al., 1983) and in many environments across Taiwan (AVRDC, 1991). CERES-maize was used to simulate yield in studies on drought assessment in South Africa (du Pisani, 1986), irrigation system design in Texas (Howell et al., 1989), and yield forecasting in the U.S. mid-West (Hodges et al., 1987). These experiments demonstrate the applicability of the models to many locations.

An implicit presumption is that the models can simulate crop development and growth anywhere in the world given the proper input data. While the above mentioned experiments were separately conducted at several locations, the purposes and results of those experiments were localized. The simulation models have been applied to several locations, but there have been no experiments to test whether

SOYGRO and CERES-Maize crop simulation models can simulate crop development and growth anywhere in the world. Therefore, the simulation models are presumed to be able to simulate any environment.

The objective of this experiment was to test the development and growth of soybean and maize under extreme artificial photoperiod and whether SOYGRO and CERES-Maize crop simulation models can simulate these conditions. Photoperiod and temperature are two important factors that change with environments, especially among environments at different latitudes. Field experiments were conducted at two elevations in Hawaii, where photoperiod was artificially extended using incandescent lights to create a broad range of environments. If soybean and maize development and growth were normal, then the models should be able to simulate the artificial field conditions that mimic many latitudes. Thus, the hypotheses are soybean and maize will develop and grow under artificial photoperiod extensions as they would at the corresponding latitudes, and SOYGRO and CERES-Maize can simulate development and growth under these conditions.

Methods and Materials

The field experiments were conducted at two sites on Maui island, Hawaii. The sites, the Haleakala Experiment Station and Kuiaha Experiment Site, were located at 20.85° N, 156.30° W and 20.90° N, 156.30° W at 640 m and 282 m elevation. The soils were clayey, oxidic, isothermic Humoxic Tropohumult at the

Haleakala Experiment Station and clayey, ferritic, isohyperthermic Humoxic Tropohumult at Kuiaha.

Identical experiments were conducted at both sites. The experimental design was a modified split-plot with photoperiod treatments as the main-plot, cultivars as the sub-plot, and sites as the replicate. Due to possible effects of light leakage onto adjacent plots, the photoperiod treatments were arranged systematically from short to long daylengths. Five photoperiod treatments were established each on 13.5 by 14.0 m plots separated by 100% black saran partitions 2.1 m high (Manrique and Hodges, 1991). The photoperiod treatments were natural daylength (control), natural daylength + 0.5 h, and constant 14-, 17-, and 20-h. The natural daylength was extended with four quartz lamps (American Electric, stock no. 570-61), each with 500 W capacity, in a photoperiod treatment plot. The lamps produced a minimum irradiance of 4 W m^{-2} at the soil surface that was approximately equal to 132 lux. The threshold illuminance for soybean to detect photoperiod was approximately 2 to 100 lux (Summerfield and Roberts, 1985).

Two sub-plots per cultivar were randomly assigned within a photoperiod treatment. Each sub-plot was 1.5 by 3 m. There were four soybean and five maize cultivars used in this experiment that represented a broad range of maturity types. The soybean cultivars were 'Evans', 'Bragg', 'Jupiter', and 'Williams' that belonged to maturity groups 0, VII, IX, and III. The maize cultivars were Pioneer hybrids X304C, 3165, 3324, 3475 and 3790 that had maturity ratings of 142, 136, 121, 114, and 95 days. Because genetic coefficients were available for the four soybean cultivars and Pioneer hybrids X304C and 3475, only these cultivars were considered in the simulations.

The crops were planted over three years. Soybean was planted 3 June 1988 in all photoperiod treatments at both sites. A small experiment that used only the control and control + 0.5 h photoperiod treatments were planted on 19 January 1989 at both sites. The small experiment was to obtain plant development data from an environment with a very short photoperiod to ensure that the threshold photoperiod can be estimated. Due to the crop duration of this planting, the planting date for the experiment conducted in summer 1989 was staggered. The 14-, 17-, and 20-h photoperiod treatments were planted on 16 June 1989 at both sites, while the control and control + 0.5 h main plots were planted on 8 September and 9 September at Kuiaha Experiment Site and Haleakala Experiment Station. The last soybean planting was on and 2 July 1990. The maize hybrids were planted 23 June 1988. A small experiment, similar to the soybean, was planted 28 and 29 December 1988 at Haleakala and Kuiaha to obtain data on development in a short photoperiod environment. Again, the summer 1989 planting was staggered 15 June and 8 or 9 September for the 14-, 17-, and 20-h photoperiod treatments and the control and control + 0.5 h at both sites. All maize hybrids were planted on 17 May 1990 at both sites. Maize hybrids were planted on 12 January 1990 in only the control and control + 0.5 h at both sites to estimate development under short photoperiod. This experiment was terminated at tassel initiation. Soybean plant density was 333,000 plants ha^{-1}, except for Jupiter and Williams in 1989 when it was 222,000 plants ha^{-1}. Maize plant density was 67,000 plants ha^{-1}.

Soil samples were taken to 15 cm depth before all plantings. All crops were well fertilized, irrigated, and pests were controlled chemically. Soybean were inoculated with Bradyrhizobium.

Daily weather data were recorded with automatic weather stations. CR 21 data loggers (Campbell Scientific, Inc., Logan, UT) were used in 1988 and LI-1200S (LI-COR, Inc., Lincoln, NE) from 1989 to 1990. The data loggers were approximately 10 m from the experimental plots and recorded solar radiation, maximum and minimum temperature, and rainfall. In 1988, the weather logger at Haleakala Experiment Station malfunctioned and no data was recorded from 17 May to 18 July. To fill in the missing data, linear regressions of Haleakala weather variables on the nearest weather station, which was Kuiaha at 6 km, weather variables were made. Weather data two months before 17 May and two months after 18 July from the Kuiaha Experiment Site were regressed on the weather data for these same days from the Haleakala Experiment Station. The Haleakala weather variables were estimated using the regression equation and Kuiaha weather data from 3 June to 18 July.

The observed soybean growth stages were first open flower anywhere on the plant (flowering), one pod 0.5 cm long (first-pod), one pod 2 cm (full-pod), one of the pods on plant had mature color (physiological maturity). The corn growth stages were shoot-apex elongated to 1 cm (tassel initiation), silk extrusion from ear (silk), black layer formation in mid-ear (physiological maturity). The growth stages were observed daily except Sundays and the date of growth stages were recorded when approximately 50% of the plants in a sub-plot had attained a particular stage.

Growth observations were done approximately one week after physiological maturity. At harvest, 10 representative plants were selected from each sub-plot. For soybean, the stems, pod shells and seeds were dried at 70 °C to constant weight, usually 2 to 7 d. Pod and seed counts were made. One hundred seed weight was obtained. From these dry weights and counts, the dry stem weight, dry above-ground biomass weight, dry grain yield, and dry pod yield as $kg \cdot ha^{-1}$ and harvest index, $weight \cdot seed^{-1}$, shelling percentage, $seeds \cdot pod^{-1}$, and $seeds \cdot m^{-2}$ were calculated. For maize, the stover and grain were dried separately at 70 °C to constant weight, usually 5 to 7 d. The stover and grain weight were recorded. One hundred seed weight was measured. The observations were averaged over the two sub-plots with the same cultivar within a main-plot.

The development and growth data from both crops were statistically analyzed as a modified split plot. The experiments from both years were combined when possible (McIntosh, 1983). The main plots were photoperiod treatments and the sub plots were cultivars. The factors site, photoperiod, and cultivar were factorially assigned. The data from the different sites were used as replicates. The experimental data was unbalanced because only control and natural photoperiod treatments were planted in the winter 1988, the 1989 plantings among photoperiod treatments were staggered, and in the longer photoperiod treatments some cultivars did not flower. To correct for the imbalance, the winter 1988 and 1989 data, and the non-flowering cultivars were not included in the analysis of variance for development and growth of the crops. Then, one of these experimental designs was used for analysis of variance: 1) randomized complete block with site as block and photoperiod as treatment when data from only one year and one cultivar were available, 2) combined year randomized complete block (McIntosh, 1983) with site as block and photoperiod as treatment when data from two years and one cultivar were available, 3) split-plot with site as replicate, photoperiod treatment as main plot, and cultivar as sub plot when data from one year and more than one cultivar was available, and 4) combined year split plot (McIntosh, 1983) with photoperiod treatment as main plot and cultivar as sub plot when data from two years and more than one cultivar were available. However, because the photoperiod treatments were systematically assigned, the photoperiod source of variation cannot be tested for significance (LeClerg et al., 1962).

Simulations of the field experiments were made using modified SOYGRO v.5.42 and CERES-Maize v.2.1. The modification made on both models was to keep photoperiod at a constant 14-, 17-, or 20-h when appropriate. In the models, the night length or photoperiod values are functions of latitude and day of year. The variable names that retain the nightlength or daylength values are DURNIT in SOYGRO and HRLT in CERES-Maize. To create constant photoperiod in the models, the variables DURNIT and HRLT were set to the nightlength or daylength value corresponding to the photoperiod treatment. The input parameters were set according to the soil analysis results and management practices. The genetic coefficients were those provided with the models (Tables 1 and 2; see definitions in Tables 7 and 8). With CERES-Maize, the simulations were done with nitrogen balance subroutine operating, but the water balance was not used because no water stress in the field was assumed. With SOYGRO, the simulations were performed assuming no water stress. The simulation results were compared with the results from the field.

Observed and simulated data were plotted for several growth and phenological variables. Plots were made of simulated values on observed values. The data were obtained specific to year, site, photoperiod treatment, and cultivar. A simple linear regression was fitted through the data to estimate a trend. To estimate the trend, the observed values were assumed to have little error so that linear regression may be applied. Furthermore, the method of determining the structural relation between observed and simulated data can affect the estimated slope and y-intercept. The preferred method is reduced major axis. However, if the correlation coefficient (r) between the observed and simulated results was greater than 0.7, the slope and y-intercept would be similar whether ordinary least squares, reduced major axis, or

Table 1. Genetic coefficients of soybean cvs. 'Bragg', 'Evans', 'Jupiter', and 'Williams' for SOYGRO v.5.42.

Genetic coefficient	'Bragg'	'Evans'	'Jupiter'	'Williams'
VARN1	5.0	5.0	5.0	5.0
VARN0	11.8	9.5	12.0	10.43
VARTH	13.5	2.0	18.62	6.0
VARDH	1.0	1.0	1.0	1.0
PHTHRS(1)	5.0	5.0	5.0	5.0
PHTHRS(2)	9.0	9.0	9.0	9.0
PHTHRS(3)	0.0	0.0	5.0	0.0
PHTHRS(4)	4.0	3.5	5.5	7.4
PHTHRS(5)	12.86	12.86	12.86	12.86
PHTHRS(6)	6.5	7.0	8.5	6.0
PHTHRS(7)	9.74	10.67	9.5	11.44
PHTHRS(8)	9.0	25.5	9.5	17.0
PHTHRS(9)	34.0	34.0	34.0	34.0
PHTHRS(10)	47.5	44.0	42.0	43.0
PHTHRS(11)	12.0	12.0	12.0	12.0
SHVAR	11.6	9.5	13.0	11.0
SDVAR	6.0	6.0	6.0	6.0
SDPDVR	2.05	2.2	2.1	2.2
PODVAR	200.0	160.0	200.0	120.0
FLWVAR	450.0	320.0	400.0	240.0
TRIFOL	0.33	0.38	0.34	0.35
SIZELF	171.4	173.47	173.7	188.37
SLAVAR	350.0	360.0	350.0	350.0

Table 2. Genetic coefficients of Pioneer hybrids 3475 and X304C for CERES-Maize v.2.1.

Cultivar	P1 GDD[1]	P2 $d \cdot h^{-1}$	P5 GDD[1]	G2 $kernels \cdot plant^{-1}$	G3 $mg \cdot kernel^{-1} \cdot d^{-1}$
3475	200	0.70	800	725	8.6
X304C	320	0.52	980	625	6

[1] Growing degree days with base temperature 8° C.

some other fitting method was used (Flavelle, 1992). The means and standard deviations for the observed and simulated variables were calculated (Little and Hill, 1978). Further statistical analyses were calculated according to equations by Willmott (1981, 1982). Mean square error (MSE), systematic mean square error (MSE(s)), unsystematic mean square error (MSE(u)) were calculated,

$$MSE = \left[\sum_{i=1}^{n} (P_i - O_i)^2 \right] \cdot n^{-1}$$

$$MSE(s) = [\sum_{i=1}^{n} (\overline{P}_i - O_i)^2] \cdot n^{-1}$$

$$MSE(u) = [\sum_{i=1}^{n} (P_i - \overline{P}_i)^2] \cdot n^{-1}$$

where P_i and O_i were the simulated and observed values, P_i bar equaled $a + b \cdot O_i$, and n was the number of observations.

The MSE(s) was partitioned into additive (MSE(a)) and proportional (MSE(p)) components. These two components reflect the magnitude of the systematic error as being additive or proportional. A third component, interdependence (MSE(i)), was related to the correlation between MSE(a) and MSE(p). The three components of MSE(s) were calculated as,

$$MSE(a) = a^2$$

$$MSE(p) = (b-1)^2 \cdot [n^{-1} \sum_{i=1}^{n} O_i^2]$$

$$MSE(i) = 2a \cdot (b-1) \cdot \overline{O}$$

where *a* is the y-intercept of the fitted regression line, *b* is the slope of the line, and *O* is the mean of all observed values. The following relations hold for the mean square errors,

$$MSE = MSE(s) + MSE(u)$$

$$MSE(s) = MSE(a) + MSE(p) + MSE(i)$$

The mean absolute error (MAE) was calculated as,

$$MAE = [\sum_{i=1}^{n} |P_i - O_i|] \cdot n^{-1}$$

Lastly, the index of agreement (*d*) indicated the correspondence between the observed and simulated values. Index of agreement was calculated,

$$d = 1 - \frac{\sum_{i=1}^{n} (P_i - O_i)^2}{\sum_{i=1}^{n} [|P_i - \overline{O})| + |O_i - \overline{O}|]^2}.$$

The index of agreement varies from 0 to 1 where 0 signifies complete disagreement between the observation and simulation and 1 means complete agreement.

A model that perfectly simulated the field experiments would produce a linear regression with slope of 1 and y-intercept of 0 when simulated values were regressed on observed. Any simulation that did not perfectly match the observed value would change the regression line's slope, y-intercept, or increase error about the regression line. The total deviation of simulation from observation is mean square error, MSE. The MSE can be partitioned into unsystematic error, MSE(u), and systematic error, MSE(s) (Willmott, 1981; Willmott, 1982). Unsystematic error is manifested in deviation about the regression line in a simulated vs. observed plot and is a result of uncertainty in model parameters (Flavelle, 1992). Systematic error is revealed in a slope other than 1 and/or y-intercept other than 0 (Willmott, 1981; Willmott, 1982), that is, the deviation of the regression line from the expected line with slope 1 and y-intercept 0. The systematic error results from a biased model or biased input parameters (Flavelle, 1992). The systematic error can be further partitioned into additive and proportional errors, MSE(a) and MSE(p) (Willmott, 1981). MSE(a) and MSE(p) quantify the deviations due to y-intercept and slope. Because a change in slope can necessarily cause a change in y-intercept, the deviations in slope and y-intercept can be interdependent. The interdependence error, MSE(i), is the third partition in the systematic error. When MSE(i) becomes large, MSE(a) and MSE(p) become meaningless, that is MSE(a) and MSE(p) are so greatly interdependent that the systematic error cannot be readily attributed to additive or proportional. While the systematic error can be partitioned into MSE(a), MSE(p), and MSE(i), the relative magnitude of these deviations cannot identify the flaw in the model or input parameters that caused the systematic error (Flavelle, 1992).

Results

Soybean cultivars displayed the expected sensitivity to photoperiod in the field experiments. The analysis of variance indicated that cultivars 'Bragg' and 'Evans' had significantly different number of mainstem nodes (Table 3). Despite not being allowed to test the significance of photoperiod on number of nodes, figure 1 indicated that node number increased with photoperiod. The increased number of nodes indicated that vegetative development was prolonged at longer photoperiod. The analysis of variance showed a significant cultivar-by-photoperiod interaction for days to flowering (Table 3). Long photoperiod differently increased the days from planting to flowering among the cultivars 'Bragg', 'Evans', and 'Williams' (Figure 2). Orthogonal linear trend comparisons resolved the high latitude adapted cultivar 'Evans' had the smallest increase in days to maturity as photoperiod increased while the low latitude adapted cultivar 'Bragg' had the greatest increase. Photoperiod had intermediate effect on days to flowering for the mid-latitude adapted cultivar 'Williams'. In general low latitude adapted soybean are more photoperiod sensitive than high latitude adapted plants, so artificial photoperiod extension was expected to prolong soybean vegetative development.

Table 3. Mean squares from analysis of variance for number of nodes on mainstem and days from planting to flowering for soybean cvs. 'Bragg' and 'Evans' grown at two sites on Maui Island, Hawaii, under five artificial photoperiod extension treatments in 1988.

Source	df	Nodes	df	Days to flower
Site	1	0.18 ns	1	33.1 ns
Photoperiod	4	24.03	4	2131.8
Error a	4	2.07	4	39.0
Cultivar	1	67.34 *	2	3250.4 **
Photo x Cult	4	4.07 ns	8	664.2 **
Error b	5	5.16	10	28.0

ns not significant at the 0.05 probability level.
* significant at the 0.05 probability level.
** significant at the 0.01 probability level.

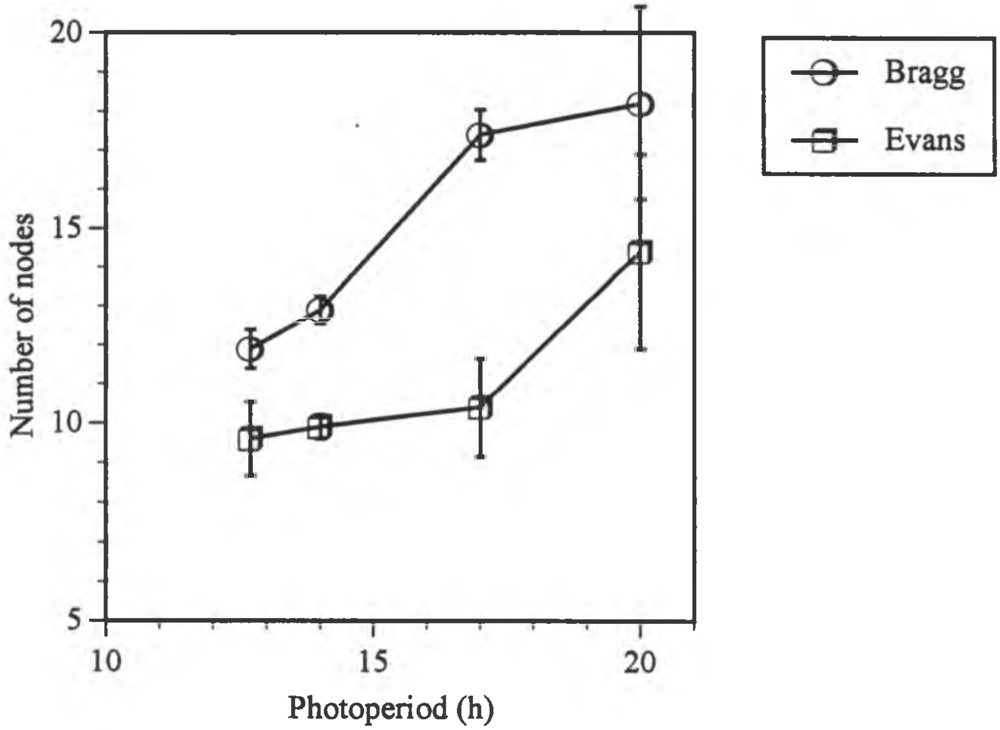

Figure 1. Photoperiod extension effect on number of mainstem nodes per plant for 'Bragg' and 'Evans' soybean cultivars grown on Maui Hawaii in 1988. Vertical bars are the standard errors of the mean.

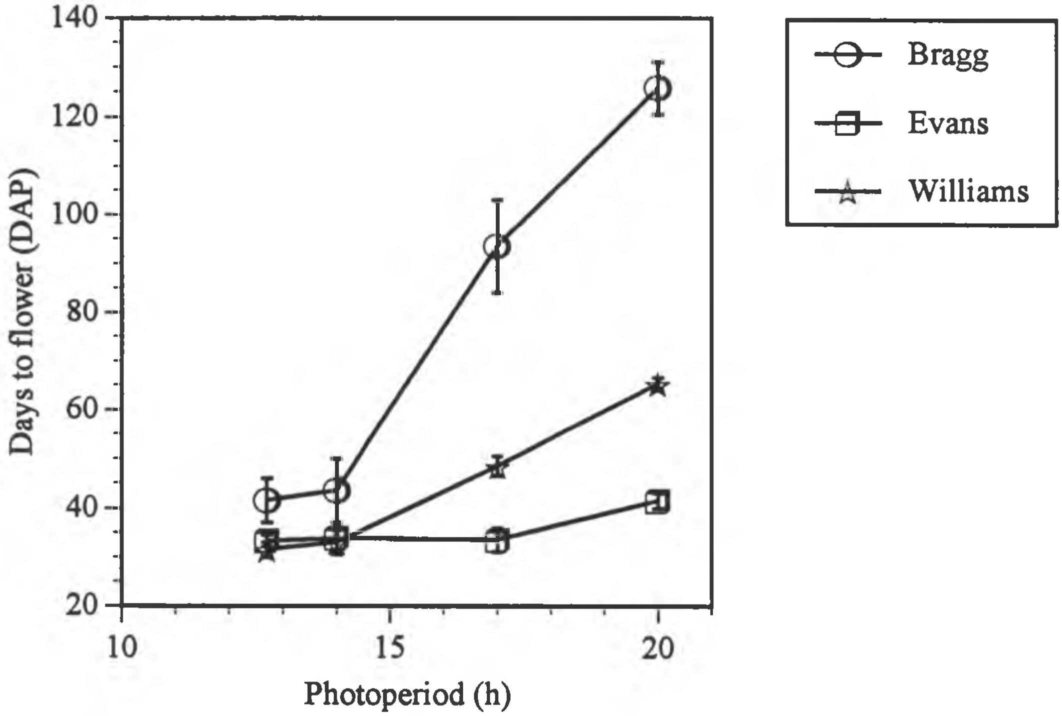

Figure 2. Extended photoperiod effect on days from planting to flower for three soybean cultivars grown on Maui, Hawaii in 1990. Vertical bars are the standard errors of the mean.

Photoperiod effect on grain weight plant^{-1} seemed related to the latitude that cultivars were adapted. Analysis of variance did not indicate a significant cultivar-by-photoperiod interaction for grain weight plant^{-1} (Table 4), but orthogonal linear trend comparison showed a significant ($p>0.05$) difference between 'Bragg' and 'Evans' over photoperiods. The plot of grain weight on photoperiod displayed the greatest grain weight for the low latitude adapted cultivar 'Bragg' was at the shorter photoperiod, while the greatest grain weight was at 20 h photoperiod for the high latitude adapted cultivar 'Evans' (Figure 3). Grain weight plant^{-1} seemed related more to seed number plant^{-1} than single seed weight. The seed number plant^{-1} had significantly different linear trends over photoperiods between the two cultivars ($p>0.05$) and a plot of photoperiod effect on cultivar similar to grain weight plant^{-1} (Figure 4). The linear trend over photoperiods for single seed weight was significantly different between the two soybean cultivars ($p>0.05$). Single seed weight for 'Evans' was relatively constant across photoperiods, while 'Bragg' had single seed weight that decreased as photoperiod increased (Figure 5). The closer relation between grain weight plant^{-1} and seed number plant^{-1} suggested that yield was more dependent on the number of seeds produced. The number of seeds plant^{-1} produced was greatest at the photoperiod the plants were supposingly adapted.

Maize hybrids were distinctly sensitive to photoperiod. The total number of leaves, an indicator of the vegetative phase duration, had significant cultivar-by-photoperiod interaction (Table 5). The leaf number increase with photoperiod was

Table 4. Mean squares from analysis of variance for grain weight plant^{-1}, number of seeds plant^{-1}, and single seed weight for soybean cvs. 'Bragg' and 'Evans' grown at two sites on Maui Island, Hawaii, under five artificial photoperiod extension treatments in 1988.

Source	df	Grain wt.	df	Seed no.	df	Seed wt.
Site	1	1.33 ns	1	285.8 ns	1	0.000299 ns
Photoperiod	4	39.70	4	847.1	4	0.00266
Error a	4	4.83	4	181.9	4	0.00767
Cultivar	1	4.35 ns	1	10.4 ns	1	0.000901 ns
Photo x Cult	4	80.80 ns	4	2128.9 ns	4	0.000162
Error b	5	26.32	5	880.1	5	0.00348 ns

ns not significant at the 0.05 probability level.
* significant at the 0.05 probability level.
** significant at the 0.01 probability level.

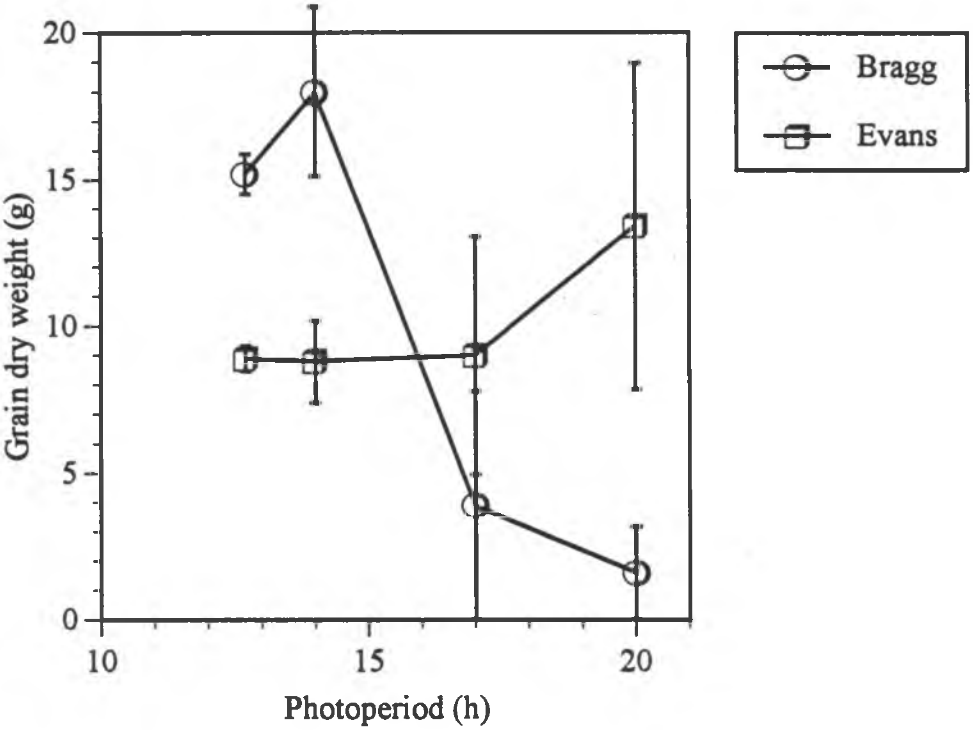

Figure 3. Photoperiod extension effect on grain dry weight per plant for 'Bragg' and 'Evans' soybean cultivars grown on Maui, Hawaii in 1988. Vertical bars are the standard errors of the mean.

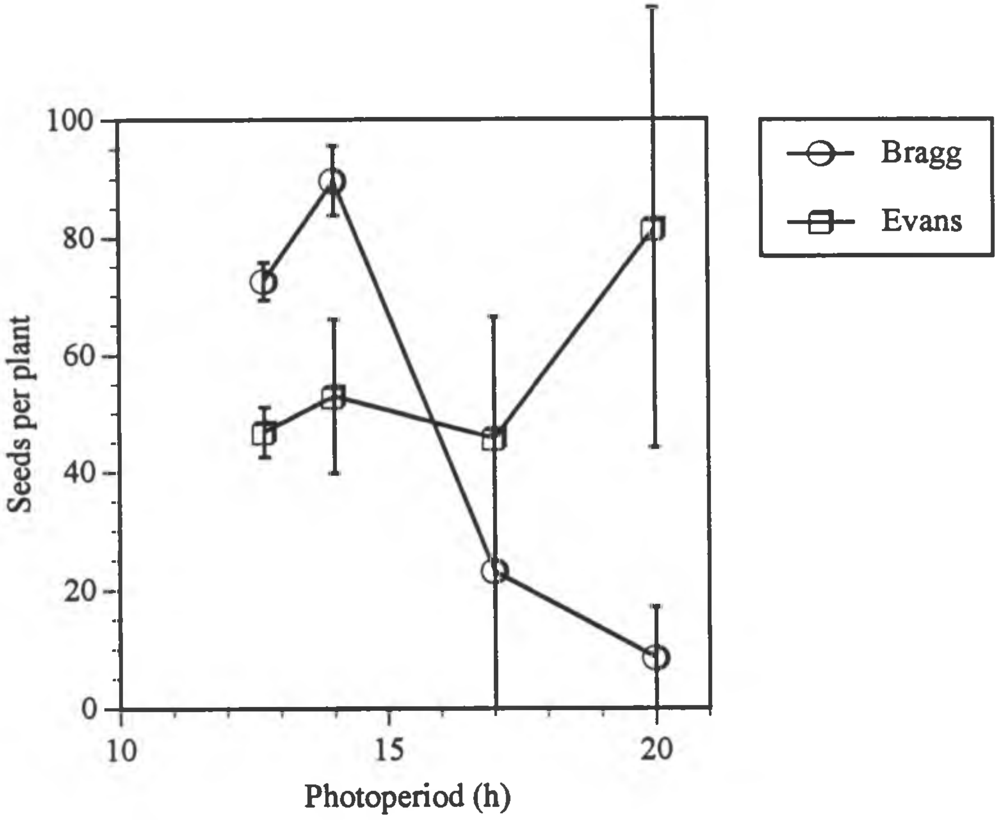

Figure 4. Photoperiod extension effect on seed number per plant for 'Bragg' and 'Evans' soybean cultivars grown on Maui, Hawaii in 1988. Vertical bars are standard errors of the mean.

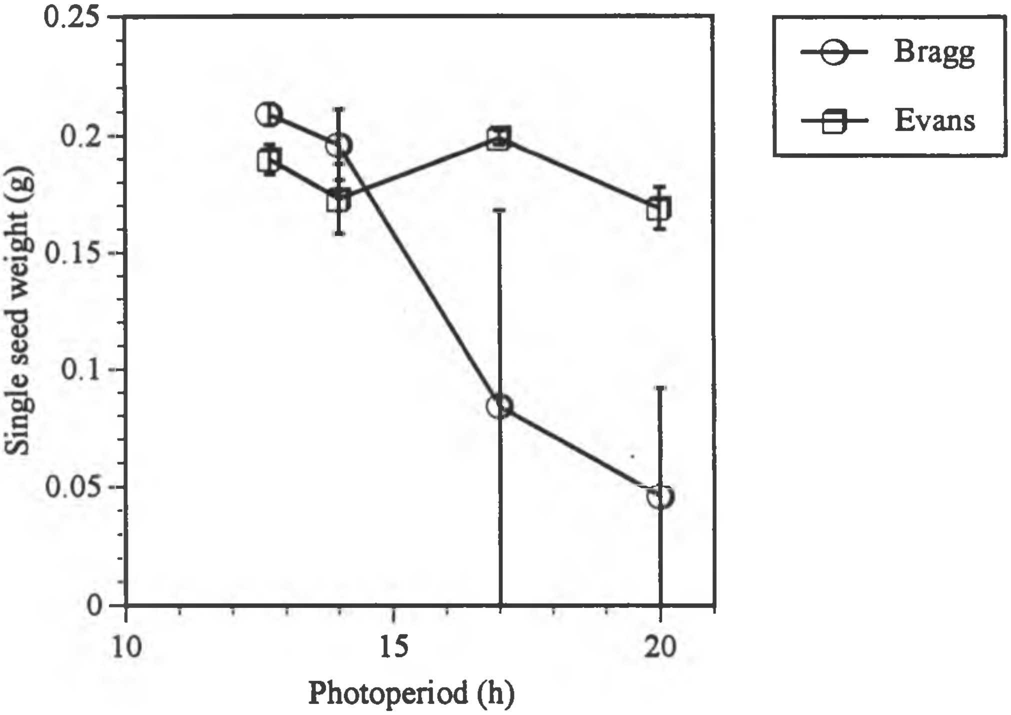

Figure 5. Photoperiod extension effect on single seed weight for 'Bragg' and 'Evans' soybean cultivars grown on Maui, Hawaii in 1988. Vertical bars are the standard errors of the mean.

Table 5. Mean squares from analysis of variance for total number of leaves plant^{-1} for five maize hybrids grown at two sites on Maui Island, Hawaii, under five photoperiod treatments in 1990.

Source	df	Leaf number
Site	1	2.33 *
Photoperiod	4	25.11
Error a	4	0.31
Hybrid	4	108.73 **
Photo x Hybrid	16	3.51 **
Error b	20	0.51

ns not significant at the 0.05 probability level.
* significant at the 0.05 probability level.
** significant at the 0.01 probability level.

greatest for the tropically adapted Pioneer hybrid X304C and least for the shorter season Pioneer hybrids 3790 and 3324 (Figure 6). The days from planting to silking had significant cultivar-by-photoperiod interaction (Table 6). The increase in days to silking as photoperiod increased was greatest for the low latitude adapted Pioneer hybrids X304C and 3165 and least for the high latitude adapted Pioneer hybrid 3790 (Figure 7; orthogonal linear trend comparison not shown). So, maize development response to photoperiod complied with the generalization that low latitude adapted plants are more photoperiod sensitive than those adapted to high latitude.

The maize grain weight plant^{-1} response to photoperiod seemed related to the latitude where the hybrid was adapted. The significant cultivar-by-photoperiod interaction indicated that grain weight plant^{-1} response to photoperiod was different among hybrids (Table 7). Qualitatively, the tropically adapted Pioneer hybrid X304C had a tremendous reduction in grain weight plant^{-1} as photoperiod increased while the high latitude adapted Pioneer hybrid 3790 had the smallest yield reduction (Figure 8). The intermediate latitude adapted Pioneer hybrids 3165 and 3475 had slightly greater yield reduction than Pioneer hybrid 3790 as photoperiod increased. However, orthogonal linear trend comparisons revealed that only Pioneer hybrid X304C significantly differed from the other hybrids across photoperiod treatments. The grain weight plant^{-1} relation to photoperiod was attributable to single kernel weight and kernel number plant^{-1}. The small yield reduction for the high latitude adapted Pioneer hybrids 3165, 3475 and 3790 resulted from a slight decrease kernel weight (figure 9)

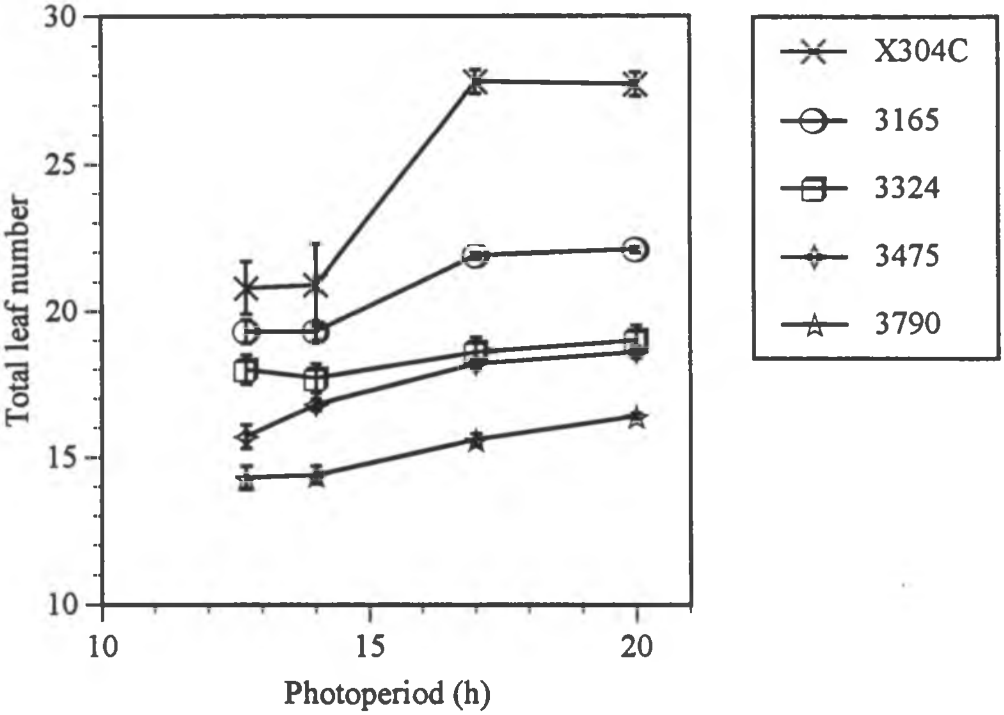

Figure 6. Photoperiod extension effect on total leaf number per plant for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 grown on Maui, Hawaii in 1990. Bars are standard errors of mean.

Table 6. Mean squares from analysis of variance for days from planting to silking for four maize hybrids grown at two sites on Maui Island, Hawaii, under five artificial photoperiod extension treatments in 1988 and 1990.

Source	df	Days to mature
Year	1	1702.01 ns
Site(Year)	2	651.61
Photoperiod	4	1229.40
Year x Photo	4	7.79 ns
Error a	8	3.08
Hybrid	3	2808.97 **
Year x Hybrid	3	7.38 ns
Photo x Hybrid	12	209.22 **
Year x Photo x Hybrid	12	0.40 ns
Error	30	5.26

ns not significant at the 0.05 probability level.
* significant at the 0.05 probability level.
** significant at the 0.01 probability level.

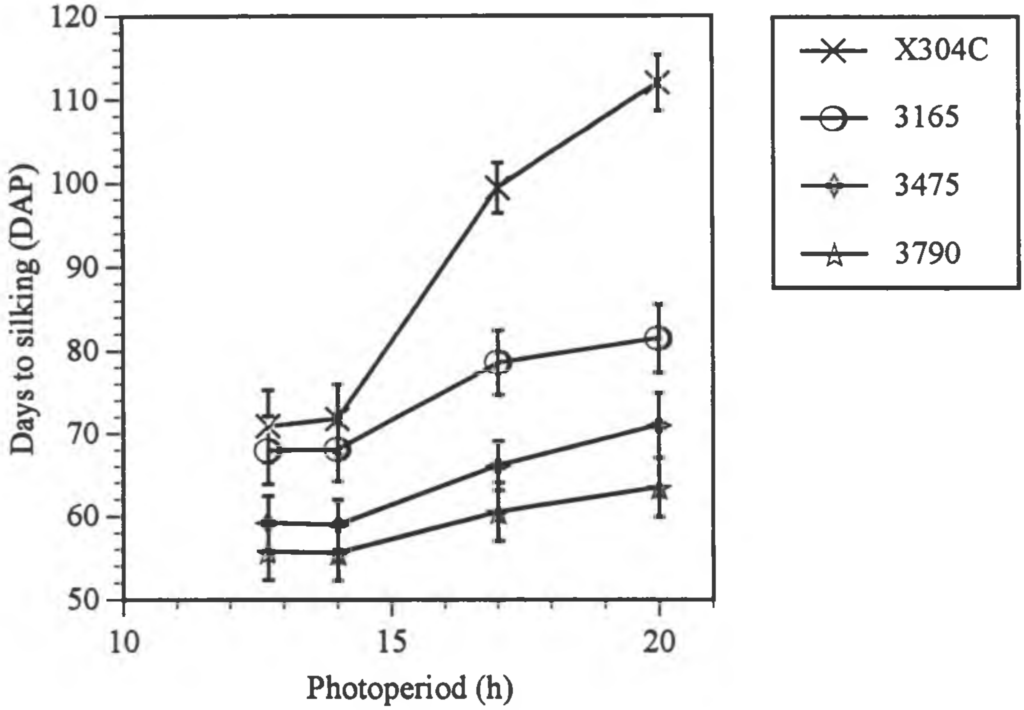

Figure 7. Photoperiod extension effect on days from planting to silking for Pioneer hybrids X304C, 3165, 3475, and 3790 grown on Maui, Hawaii in 1988 and 1990. Vertical bars are standard errors of the mean.

Table 7. Mean squares from analysis of variance for grain weight plant^{-1}, kernel number plant^{-1}, and single kernel weight for four maize hybrids grown at two sites on Maui Island, Hawaii, under five artificial photoperiod extension treatments in 1988 and 1990.

Source	df	Grain wt.	df	Kernel no.	df	Kernel wt.
Year	1	88163. *	1	126821. ns	1	0.0605 ns
Site(Year)	2	4434.	2	24752.	2	0.000267
Photoperiod	4	8767.	4	37314.	4	0.000389
Year x Photo	4	607. ns	4	3211. ns	4	0.000808 ns
Error a	8	831.	8	5911.	8	0.000430
Hybrid	3	36431. **	3	133330.**	3	0.0135 **
Year x Hybrid	3	1312. ns	3	4234. ns	3	0.000991 *
Photo x Hybrid	12	3752. **	12	30100. **	12	0.000418 ns
Year x Photo x Hybrid	12	387. ns	12	5203. ns	12	0.000169 ns
Error b	30	568.	30	3769.	30	0.000312

ns not significant at the 0.05 probability level.

* significant at the 0.05 probability level.

** significant at the 0.01 probability level.

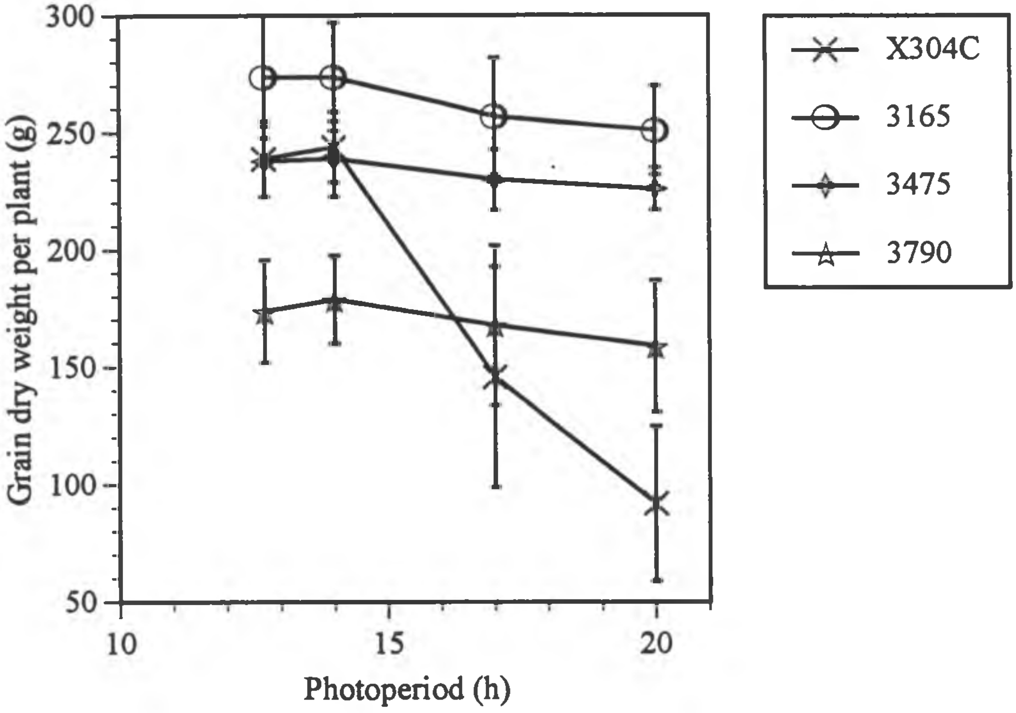

Figure 8. Photoperiod extension effect on grain dry weight per plant for Pioneer hybrids X304C, 3165, 3475, and 3790 grown on Maui, Hawaii in 1988 and 1990. Vertical bars are standard errors of the mean.

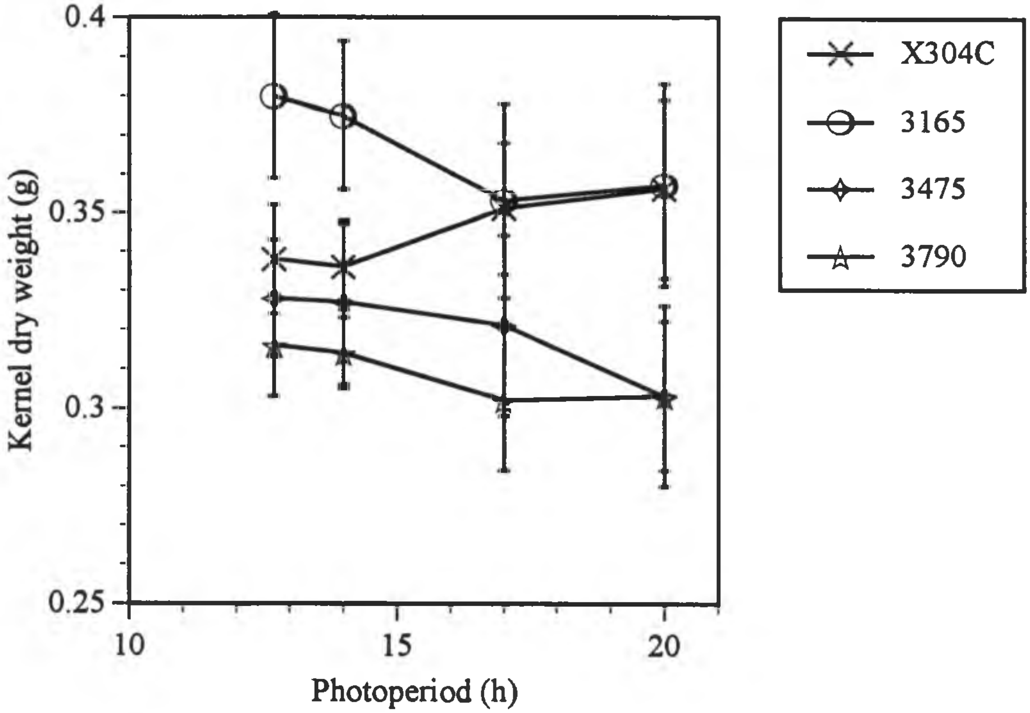

Figure 9. Photoperiod extension effect on single kernel dry weight for Pioneer hybrids X304C, 3165, 3475, and 3790 grown on Maui, Hawaii in 1988 and 1990. Vertical bars are standard errors of the mean.

rather than kernel number plant^{-1} which remained stable across photoperiod (figure 10). The yield components of the tropical adapted Pioneer hybrid X304C had a unique response to photoperiod. The kernel number plant^{-1} greatly decreased as photoperiod was increased from 14 to 20 h (Figure 9). The decrease in kernel number for Pioneer hybrid X304C may be attributed to the increase in the tassel-silk interval from 2.5 to 15 days as photoperiod increased from 12.7 to 20 h. Photoperiod sensitivity of the tasseling-silking interval may be characteristic of tropical adapted genotypes (Bonhomme et al., 1994). The other hybrids had tassel-silk intervals 4 d or less even at 20 h photoperiod. The increased interval for Pioneer hybrid X304C could have resulted in few viable pollen falling on the silk, so fewer kernels were produced (Manrique and Hodges, 1991). As a result of the few kernels produced, the single kernel weight increased (Figure 10) presumably due to increased assimilate supply (Schoper et al., 1982). So, the large yield reduction in Pioneer hybrid X304C and only slight yield reduction in Pioneer 3790 as photoperiod increased demonstrated that the high latitude adapted hybrids tolerated long photoperiods better than the low latitude adapted hybrids.

The validation statistics (Willmott, 1981; Willmott, 1982) in tables 8 to 14 help to interpret the deviations of the simulated values from the observed values in figures 11 to 25.

SOYGRO was able to simulate soybean development across wide ranges of photoperiods and cultivars. The index of agreement (d) for days to flowering was

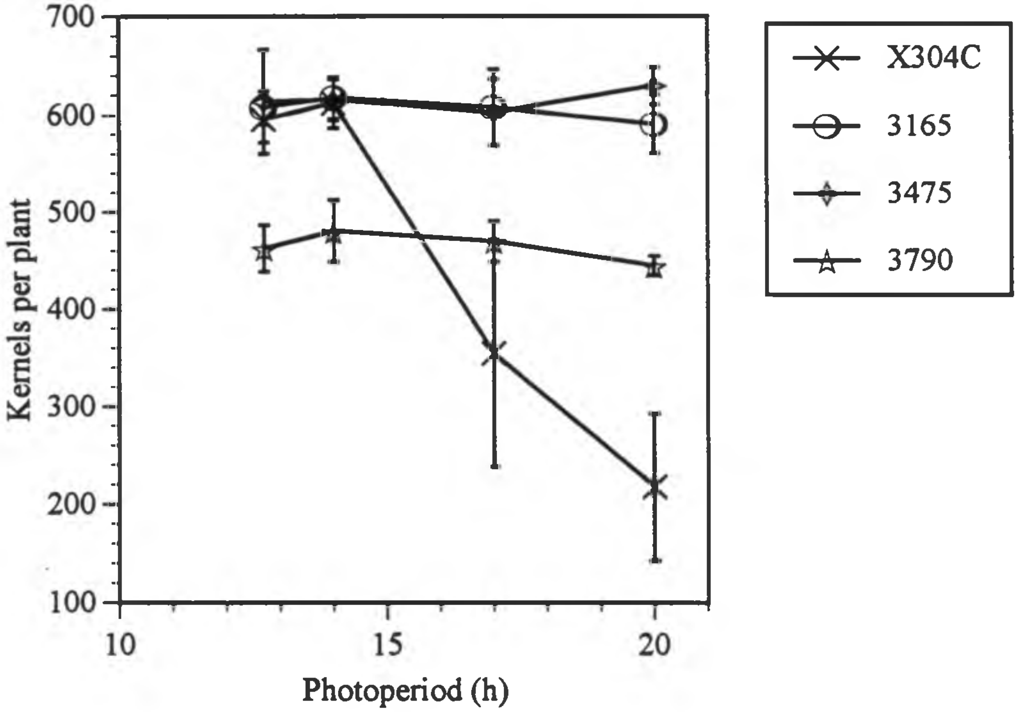

Figure 10. Photoperiod extension effect on number of kernels per plant for Pioneer hybrids X304C, 3165, 3475, and 3790 grown on Maui, Hawaii in 1988 and 1990. Vertical bars are standard errors of the mean.

relatively high and lower for full pod and physiological maturity (Table 8). The observed vs. simulated plots (Figure 11 to 13) illustrate the relationships. The low proportion of systematic error (MSE(s) $\cdot$ MSE^{-1}) in flowering, 19%, suggests that improving the model or input parameter precision will not greatly improve the simulation result. However, the higher proportion of unsystematic error in time to full pod and maturity, 48% and 62% respectively, indicated that model or input parameter bias correction can greatly improve the simulation of development for these stages.

The very low d statistic for yield and the yield components weight$\cdot$seed^{-1} and seed number$\cdot$m^{-2} (Table 9) indicates that these attributes were not well simulated (Figures 14 to 16). Yield had a high proportion of systematic error, 82%, and only 18% unsystematic error. Partitioning the systematic error in yield revealed that proportional error was much larger than additive error. The high proportional error indicated that flaws within the model were multiplicative and should be corrected to increase the slope of the observed vs. simulated plot. Weight$\cdot$seed^{-1} had mean square error that was equally attributable to unsystematic and systematic error. The systematic error was due to additive and proportional error. Improving the simulation for weight$\cdot$seed^{-1} requires reducing the bias in the model or input parameters. However, both yield and weight$\cdot$seed^{-1} had correlation coefficients lower than 0.7, so the accuracy of this interpretation is questionable. Seed number$\cdot$m^{-2} had more systematic than the unsystematic error, 60% versus 40%. The systematic error can be

Table 8. Simple regression and model performance statistics on observed vs. simulated phenology plots for combined soybean cvs. 'Bragg', 'Evans', 'Jupiter', and 'Williams' grown at two sites on Maui Island, Hawaii, under five photoperiod treatments.

Statistic	Flowering[1]	Full Pod[2]	Maturity[3]
d[4]	0.93	0.81	0.77
slope	0.83	1.6	1.6
y-intercept	14	-14	-46
MAE[5]	13	32	39
$\mathrm{MSE(u)\cdot MSE^{-1}}$[6]	0.82	0.48	0.62
$\mathrm{MSE(s)\cdot MSE^{-1}}$[6]	0.18	0.52	0.38
$\mathrm{MSE(a)\cdot MSE^{-1}}$[6]	0.66	0.077	0.47
$\mathrm{MSE(p)\cdot MSE^{-1}}$[6]	0.41	0.91	1.5
$\mathrm{MSE(i)\cdot MSE^{-1}}$[6]	0.88	-0.46	-1.5
Observed mean	59	72	121
Observed s.d.	36	41	48
Simulated mean	63	99	150
Simulated s.d.	34	73	94
r	0.88	0.88	0.83

[1] Days from planting to one open flower anywhere on plant

[2] Days from planting to one pod 2 cm long anywhere on plant

[3] Days from planting to one yellow pod anywhere on plant

[4] d index of agreement

[5] MAE mean absolute error

[6] MSE, MSE(u), MSE(s), MSE(a), MSE(p), MSE(i) are mean square error, and unsystematic, systematic, additive, proportional, and interdependence mean square error.

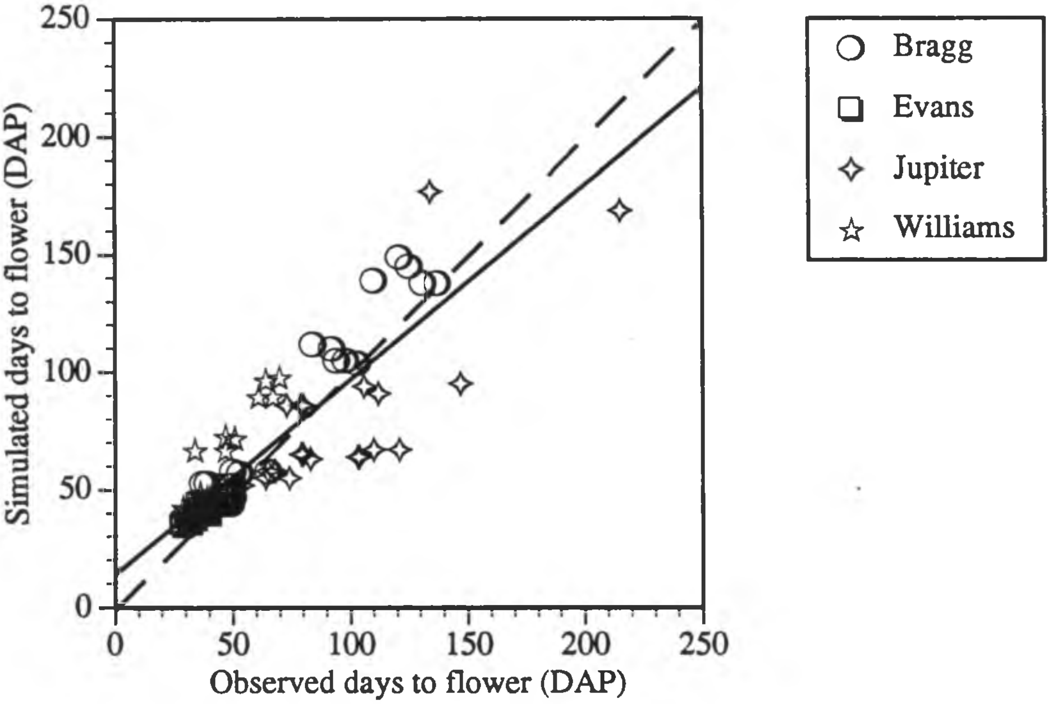

Figure 11. Comparison of observed and simulated days to flowering using original genetic coefficients for four soybean cultivars. The solid line is the linear regression where y = 0.83 x + 14.

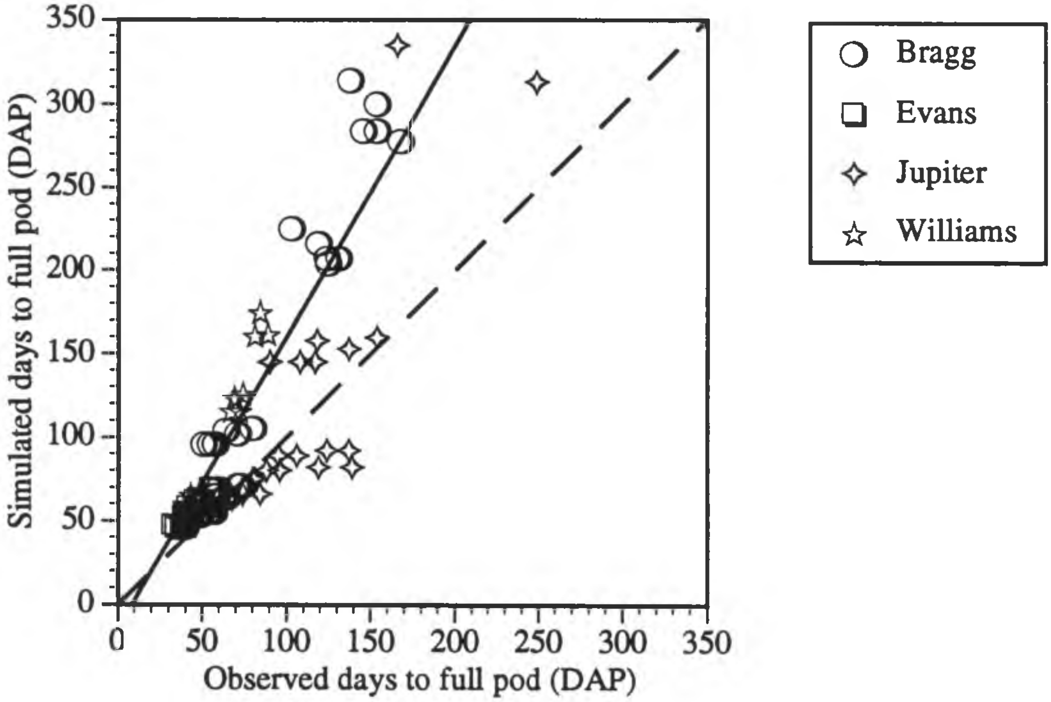

Figure 12. Comparison of observed and simulated days to full pod using original genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 1.6 x - 14.

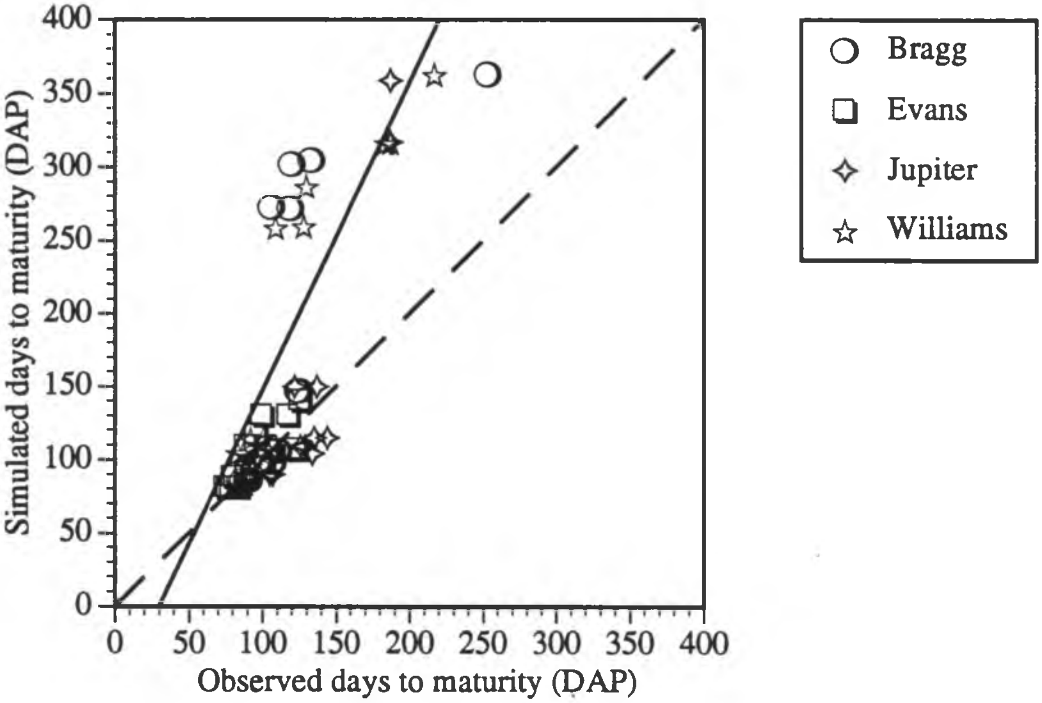

Figure 13. Comparison of observed and simulated days to physiological maturity using original genetic coefficients for four soybean cultivars. The solid line is the linear regression where y = 1.6 x -77.

Table 9. Simple regression and model performance statistics on observed vs. simulated growth data plots for combined soybean cvs. 'Bragg', 'Evans', 'Jupiter', and 'Williams' grown at two sites on Maui Island, Hawaii, under five photoperiod treatments.

Statistic	Yield [1]	Wt. · seed^{-1} [2]	Seed no. [3]	Biomass [4]	Stem [5]
d [6]	0.43	0.55	0.43	0.69	0.85
slope	0.078	0.81	0.065	0.41	0.61
y-intercept	2300	0.016	1700	4100	1200
MAE [7]	2200	0.063	1300	4700	2300
MSE(u)·MSE^{-1} [8]	0.19	0.49	0.40	0.52	0.64
MSE(s)·MSE^{-1} [8]	0.81	0.51	0.60	0.48	0.36
MSE(a)·MSE^{-1} [8]	0.48	0.045	1.1	0.29	0.082
MSE(p)·MSE^{-1} [8]	1.8	0.26	1.8	1.0	0.50
MSE(i)·MSE^{-1} [8]	-1.5	0.21	-2.3	-0.84	-0.23
Observed mean	3900	0.19	1900	9800	4100
Observed s.d.	3000	0.04	1400	8200	6100
Simulated mean	2600	0.14	1800	8000	3700
Simulated s.d.	1500	0.062	1000	6400	4900
r	0.11	0.35	0.04	0.52	0.75

[1] Dry grain yield, kg · ha^{-1}

[2] Dry weight per seed at maturity, g · seed^{-1}

[3] Seed number at maturity, seeds · m^{-2}

[4] Dry aboveground biomass at maturity, kg · ha^{-1}

[5] Dry stem and leaf weight at maturity, kg · ha^{-1}

[6] d index of agreement

[7] MAE mean absolute error

[8] MSE, MSE(u), MSE(s), MSE(a), MSE(p), MSE(i) are mean square error, and unsystematic, systematic, additive, proportional, and interdependence mean square error.

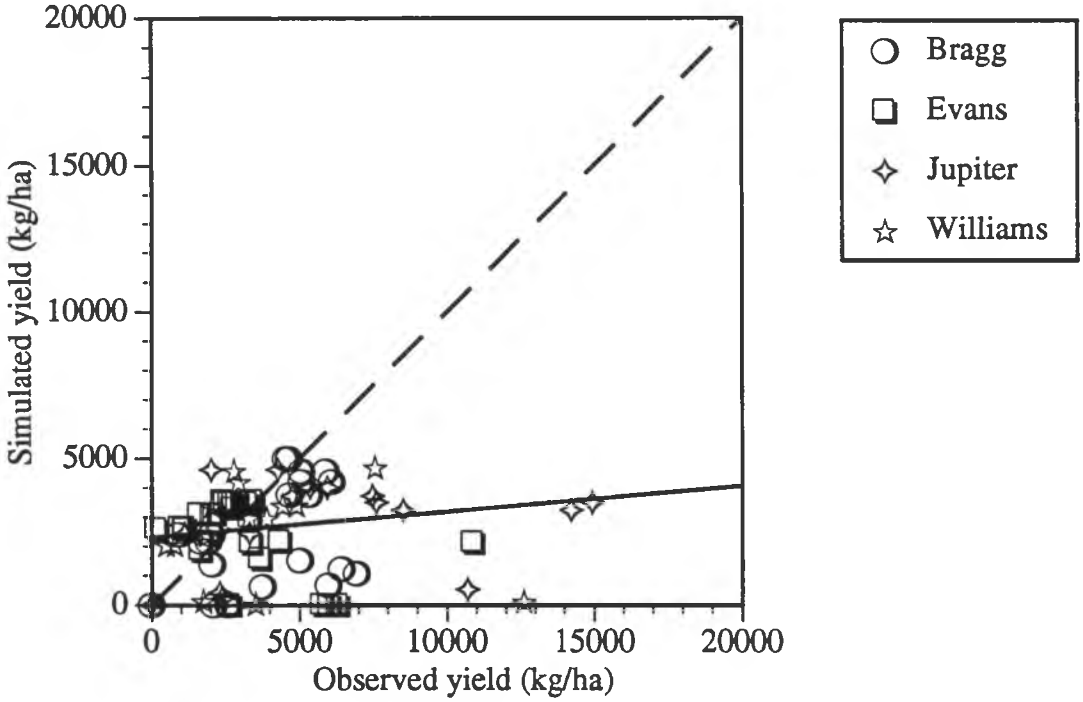

Figure 14. Comparison of observed and simulated yield using original genetic coefficients for four soybean cultivars. The solid line is linear regression where $y = 0.078\ x + 2300$.

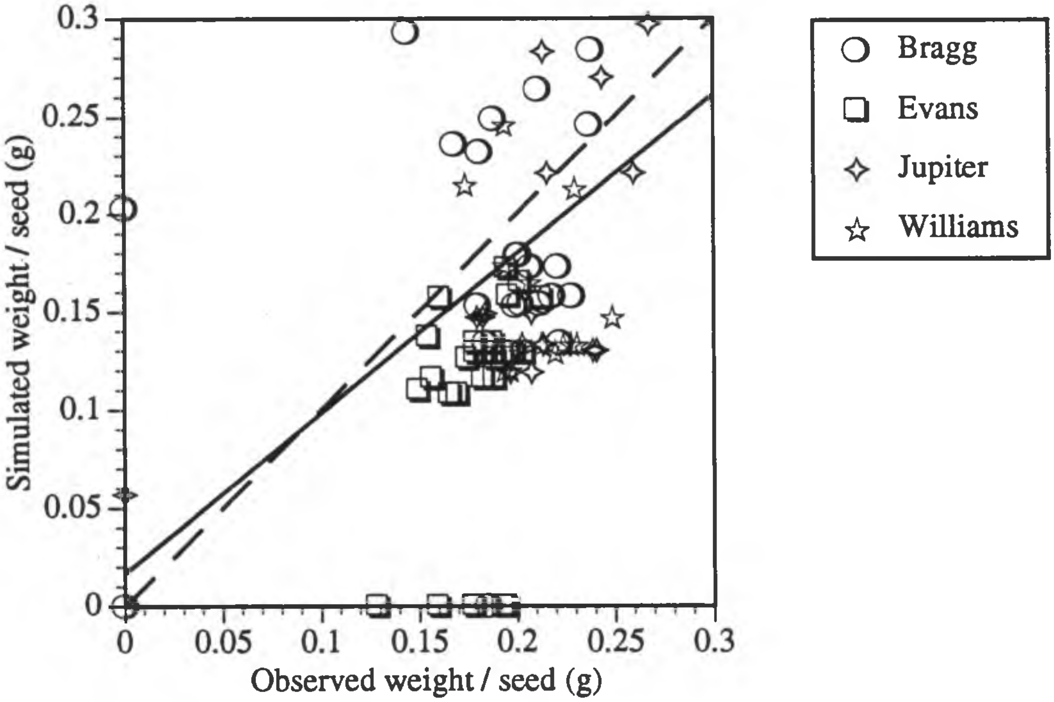

Figure 15. Comparison of observed and simulated weight per seed using original genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 0.81 x + 0.016.

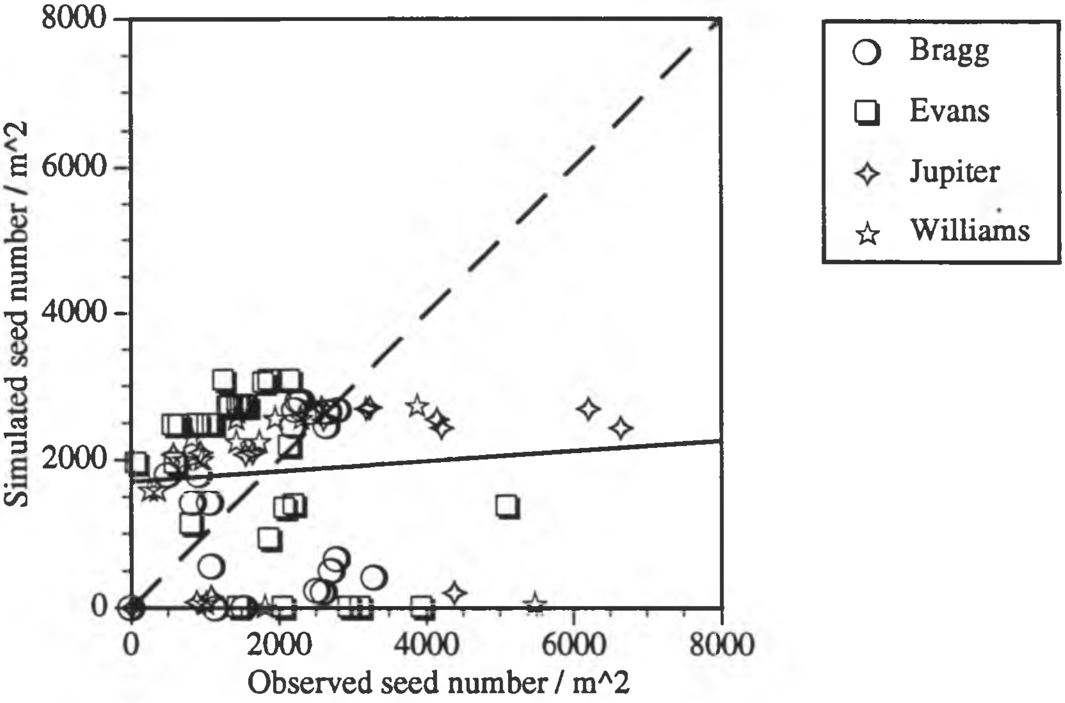

Figure 16. Comparison of observed and simulated seed number per m^2 using original genetic coefficients for four soybean cultivars. The solid line is linear regression where y = 0.065 x + 1700.

partitioned, but the partitioned error would be difficult to interpret because of the high interdependence error, MSE(i). Nevertheless, emphasis on correcting the model or input parameter bias should improve the simulation of seed number$\cdot$m^{-2}.

The index of agreement for aboveground biomass at maturity was fairly low, but higher for stem weight at maturity (Table 9) and was confirmed in the observed vs. simulated plots (Figures 17 and 18). Biomass had mean square error evenly split between systematic and unsystematic errors, but since the correlation coefficient was below 0.7 the precision of the partitioned mean square error may be questionable. The proportion of unsystematic mean square error was 64% for stem weight. So, reducing input parameter bias or model correction should improve biomass and stem weight simulation.

For CERES-Maize simulation of maize development, the low index of agreement (d) for days to tassel initiation and high d for days to silking and physiological maturity (Table 10) suggested that the simulations were inaccurate for tassel initiation (Figure 19), but fairly accurate for silking and maturity (Figures 20 and 21). Tassel initiation had 64% of its mean square error as systematic, but again the correlation coefficient was less than 0.7. Silking had high systematic error, and high interdependence error that made interpretation of the partitioned systematic error unreliable. Systematic and unsystematic errors were approximately equal for days to maturity. The maturity interdependence was also very high. So, correcting model

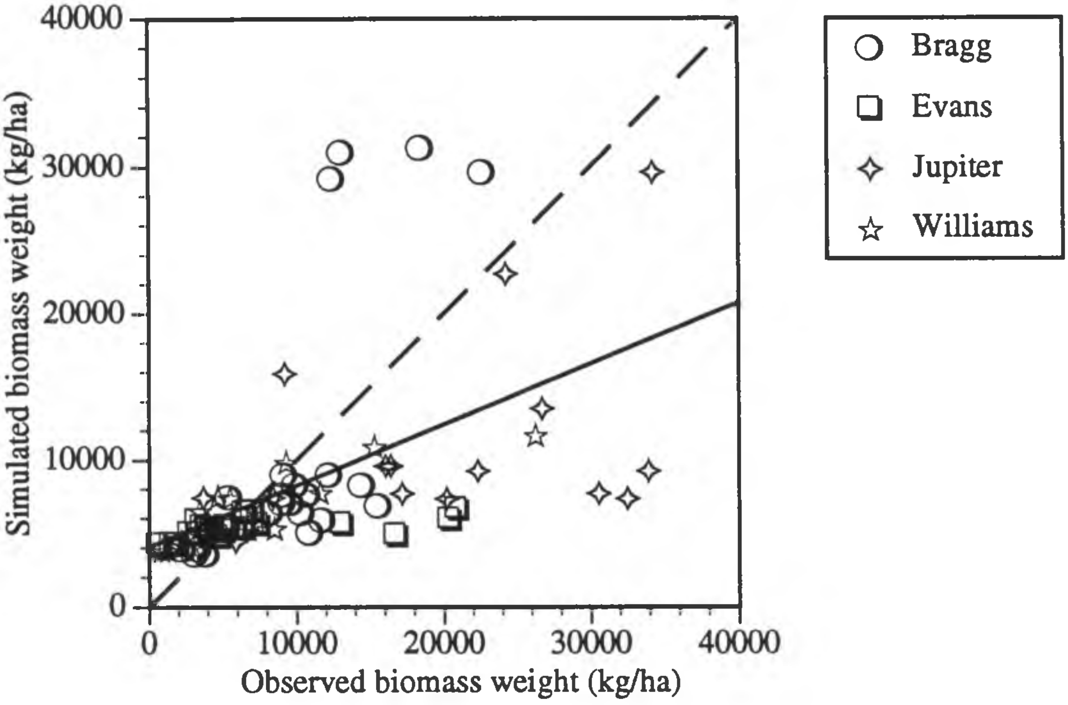

Figure 17. Comparison of observed and simulated aboveground biomass weight at harvest maturity using original genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 0.41 x + 4100.

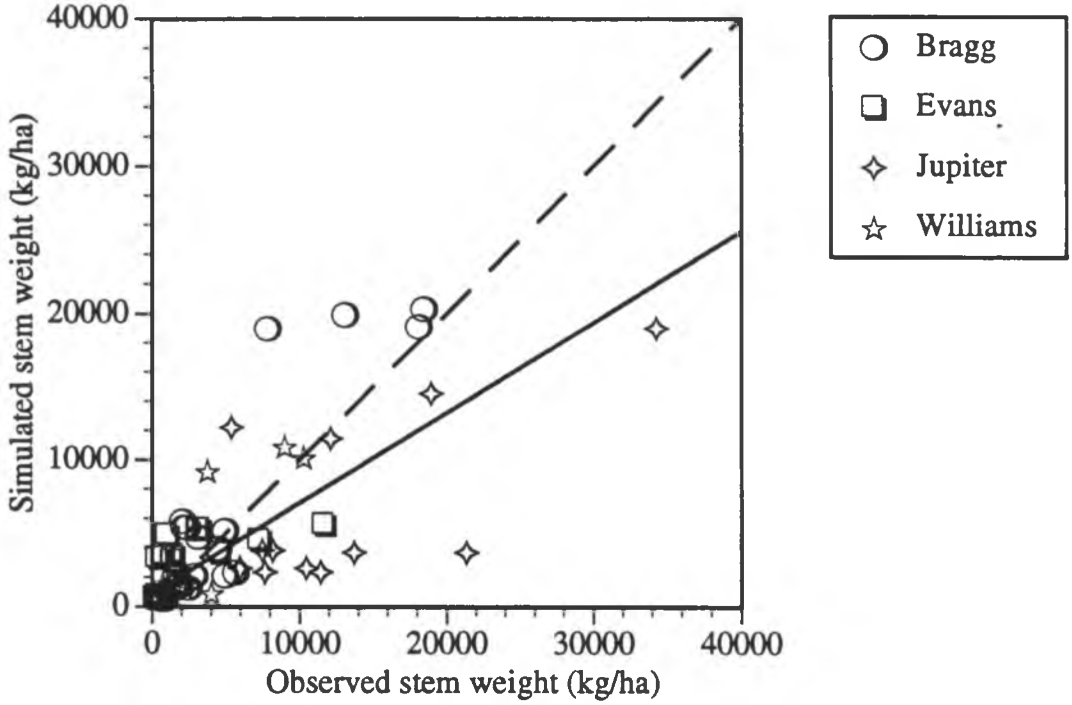

Figure 18. Comparison observed and simulated stem weight at harvest maturity using original genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 0.61 x + 1200.

Table 10. Simple regression and model performance statistics on observed vs. simulated phenology plots for combined maize Pioneer hybrids 3475 and X304C grown at two sites on Maui Island, Hawaii, under five photoperiod treatments.

Statistic	Tassel init.[1]	Silking[2]	Maturity[3]
d [4]	0.51	0.82	0.91
slope	0.47	0.46	0.68
y-intercept	19	40	42
MAE [5]	6.5	7.9	8.6
$MSE(u) \cdot MSE^{-1}$ [6]	0.36	0.29	0.55
$MSE(s) \cdot MSE^{-1}$ [6]	0.64	0.71	0.45
$MSE(a) \cdot MSE^{-1}$ [6]	6.6	13	11
$MSE(p) \cdot MSE^{-1}$ [6]	3.5	14	13
$MSE(i) \cdot MSE^{-1}$ [6]	-9.4	-26	-24
Observed mean	26	76	143
Observed s.d.	4.6	18	24
Simulated mean	31	74	139
Simulated s.d.	5	10	19
r	0.43	0.80	0.87

[1] Shoot apex elongated to 1 cm, days after planting

[2] Silk extrusion on 50% of plants, days after planting

[3] Black layer formed in mid-ear on 50% of plants, days after planting

[4] d index of agreement

[5] MAE mean absolute error

[6] MSE, MSE(u), MSE(s), MSE(a), MSE(p), MSE(i) are mean square error, and unsystematic, systematic, additive, proportional, and interdependence mean square error.

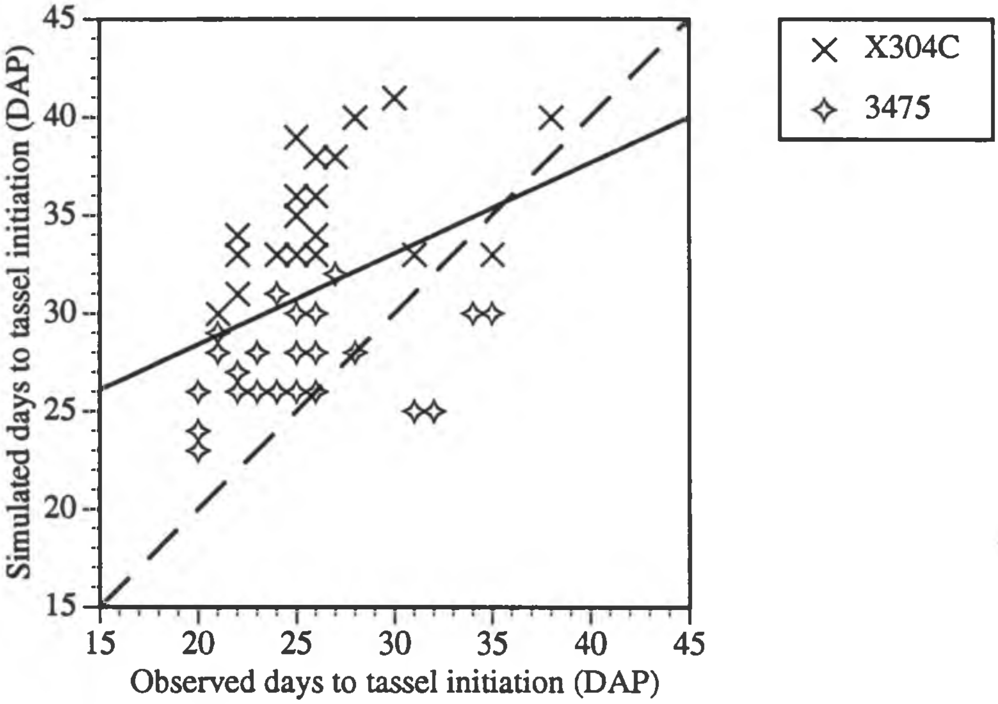

Figure 19. Comparison of observed and simulated days to tassel initiation using original genetic coefficients for two Pioneer hybrids. Solid line is linear regression where y = 0.47 x + 19.

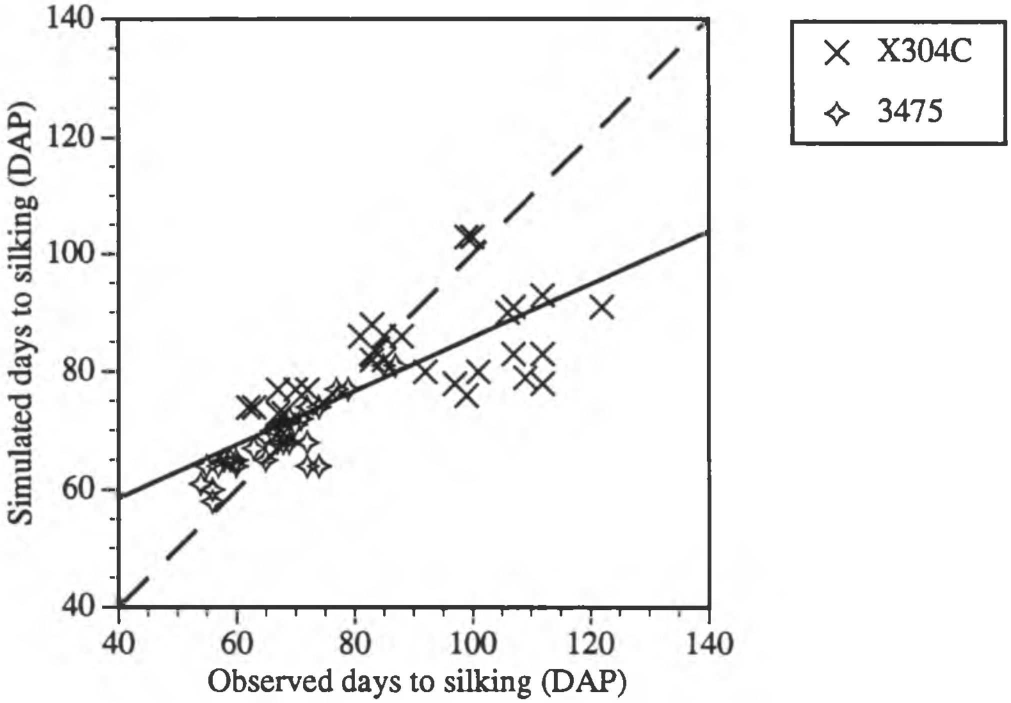

Figure 20. Comparison of observed and simulated days to silking using original genetic coefficients for two Pioneer hybrids. Solid line is linear regression where y = 0.46 x + 40.

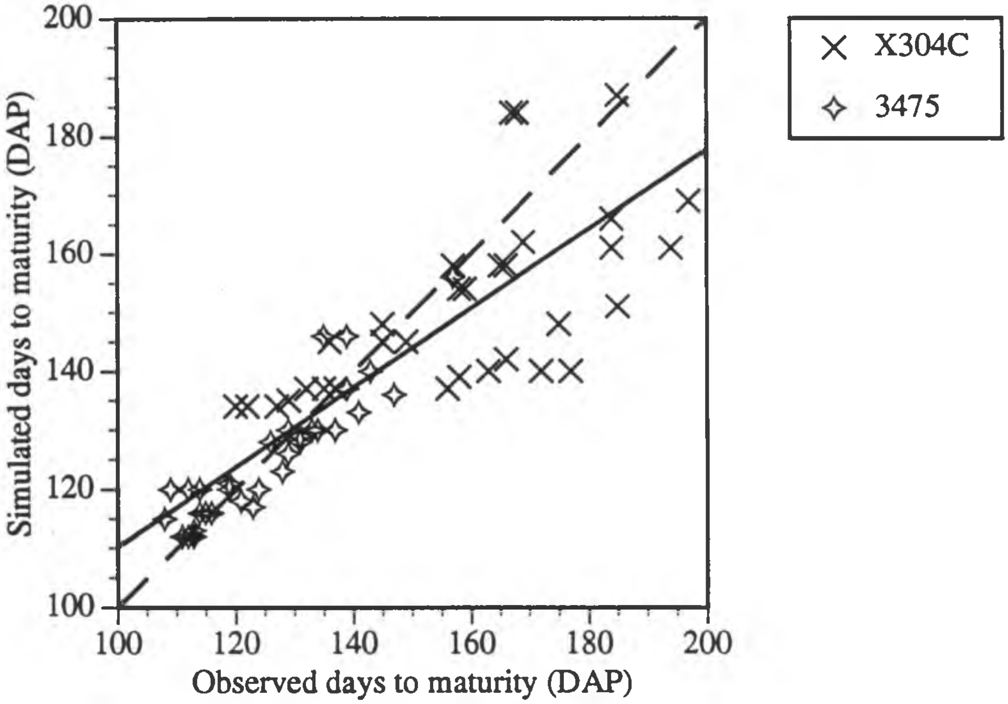

Figure 21. Comparison of observed and simulated days to physiological maturity using original genetic coefficients for two Pioneer hybrids. Solid line is linear regression where y = 0.68 x + 42.

flaws or bias in input parameters should increase accuracy for tassel initiation and silking.

The index of agreement was very low for yield, kernel weight, and kernels·m^{-2} (Table 11) and substantiated in the observed vs. simulated plots (Figures 22 to 24). Partitioned mean square error demonstrated that systematic error accounted for 70% to 82% of the error in yield, kernel weight and kernels·m^{-2}. However, the low correlation coefficient made the mean square error partitioning dubious, since low correlation meant the structural relationship between the observed and simulated data was imprecisely defined, and high interdependence error made futile partitioning the systematic error.

Aboveground biomass and stover weights had low index of agreement (Table 11) that was confirmed in the observed vs. simulated plots (Figures 25 and 26). Systematic means square error was very high for biomass and stover weights, approximately 97%. Again, the high interdependence error made useless partitioning the systematic error. However, the high systematic error indicated that model flaws or input parameter bias existed.

Discussion

Long photoperiod delays soybean development and the length of delay varies with genotype. Many studies have shown that the days from planting to flowering were prolonged under long photoperiod (Constable and Rose, 1988; Huxley and

Table 11. Simple regression and model performance statistics on observed vs. simulated growth data plots for combined maize cvs. Pioneer hybrids 3475 and X304C grown two sites on Maui Island, Hawaii, under five photoperiod treatments.

Statistic	Yield [1]	wt.·kernel^{-1} [2]	kernels·m^{-2} [3]	Biomass [4]	Stover [5]
d [6]	0.51	0.11	0.54	0.51	0.53
slope	0.16	-0.54	0.2	0.15	0.2
y-intercept	10500	0.49	2700	20000	10000
MAE [7]	3500	0.054	730	7100	5600
MSE(u)·MSE^{-1} [8]	0.26	0.18	0.3	0.032	0.026
MSE(s)·MSE^{-1} [8]	0.74	0.82	0.7	0.97	0.97
MSE(a)·MSE^{-1} [8]	6.1	51	7.7	5	1.6
MSE(p)·MSE^{-1} [8]	6.5	51	7.9	7.3	3.5
MSE(i)·MSE^{-1} [8]	-12	-102	-15	-11	-4.2
Observed mean	12300	0.32	3300	27000	17000
Observed s.d.	4400	0.04	1000	10000	9400
Simulated mean	12600	0.32	3300	24000	14000
Simulated s.d.	2300	0.037	570	2200	2300
r	0.32	0.60	0.36	0.69	0.81

[1] Grain yield at 15.5% moisture, kg · ha^{-1}

[2] Dry weight per kernel, g · kernel^{-1}

[3] Number of kernels · m^{-2}

[4] Dry aboveground biomass weight at maturity, kg · ha^{-1}

[5] Dry stover weight at maturity, kg · ha^{-1}

[6] d index of agreement

[7] MAE mean absolute error

[8] MSE, MSE(u), MSE(s), MSE(a), MSE(p), MSE(i) are mean square error, and unsystematic, sytematic, additive, proportional, and interdependence mean square error.

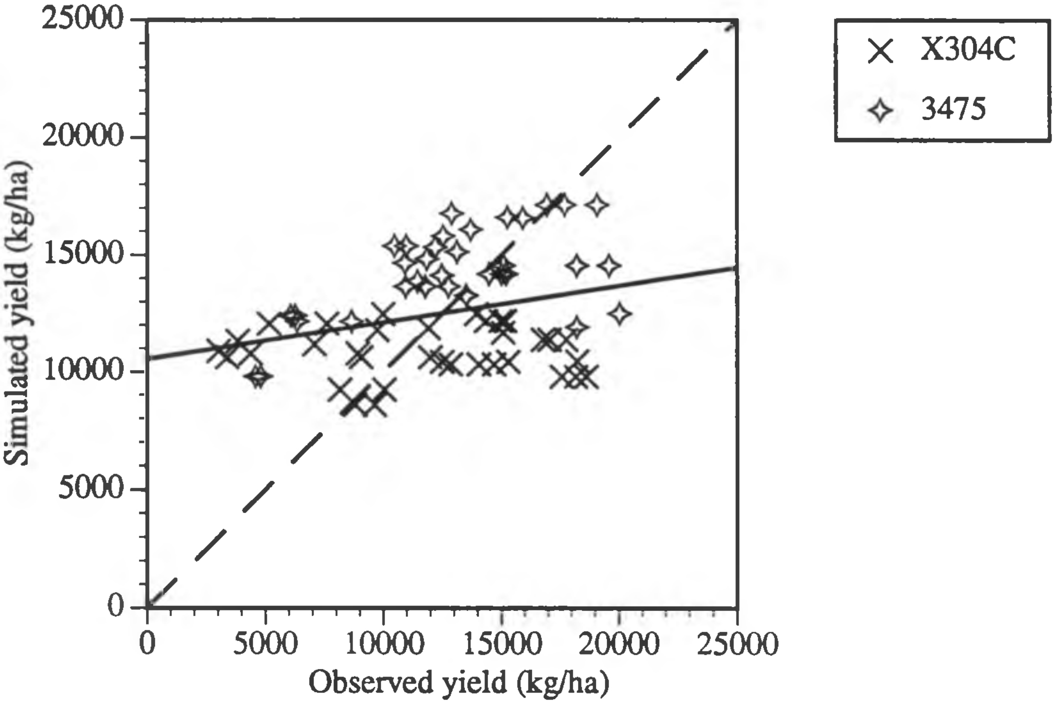

Figure 22. Comparison of observed and simulated yield at 15.5% moisture using original genetic coefficients for two Pioneer hybrids. Solid line is linear regression where y = 0.16 x + 10500.

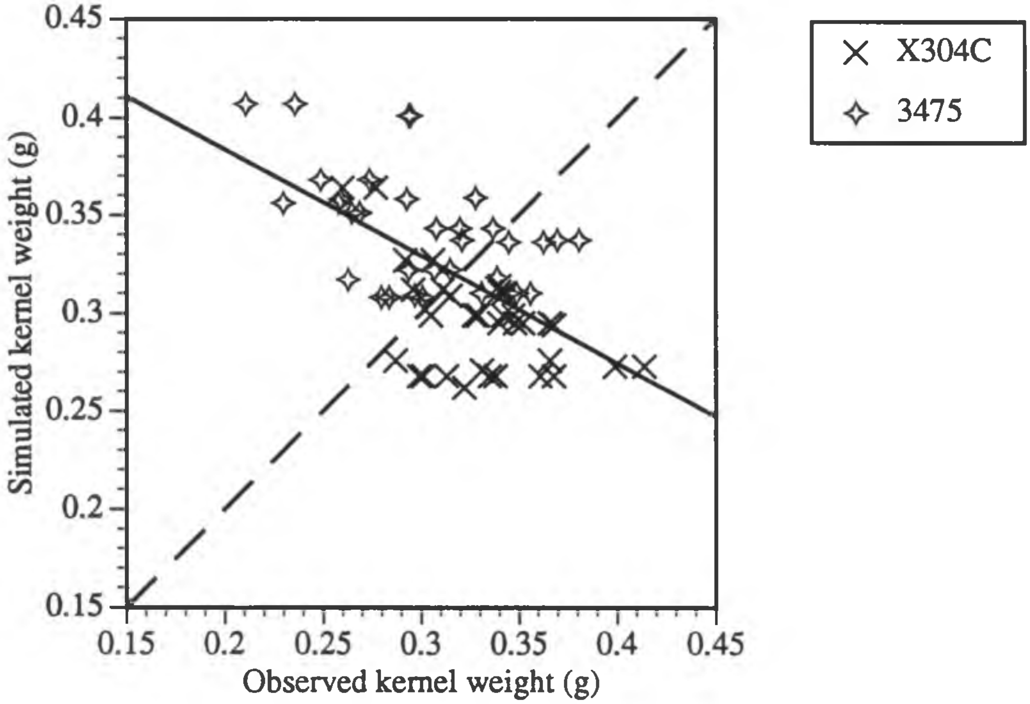

Figure 23. Comparison of observed and simulated kernel weight using original genetic coefficients for two Pioneer hybrids. Solid line is linear regression where $y = -0.54 x + 0.49$.

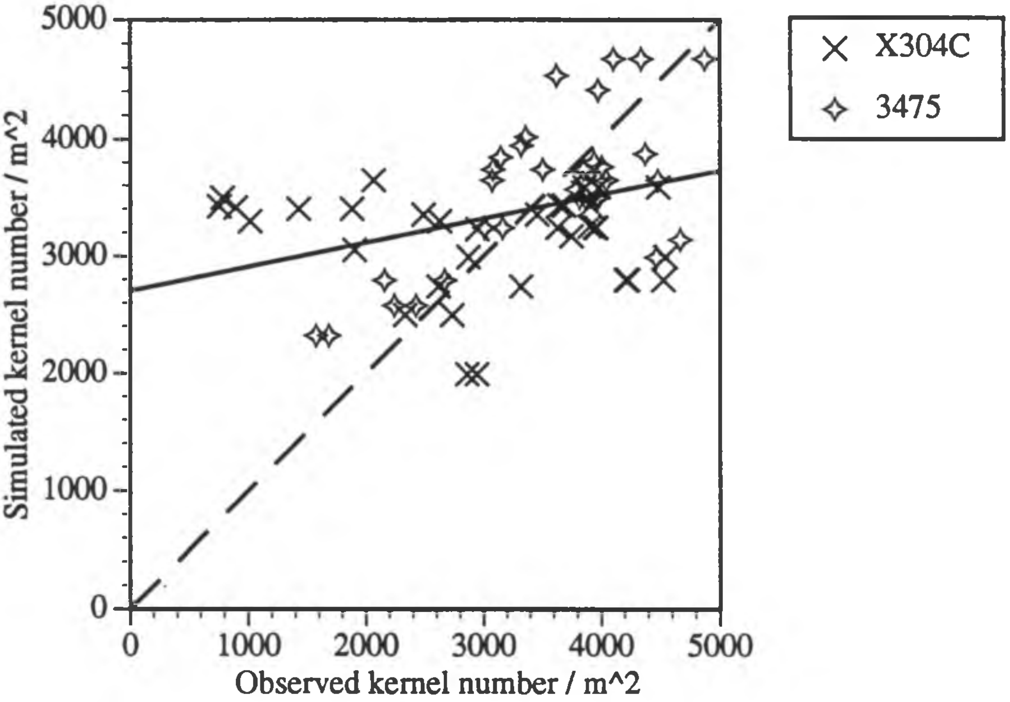

Figure 24. Comparison of observed and simulated kernel number per m^2 using original genetic coefficients for two Pioneer hybrids. Solid line is linear regression where y = 0.20 x + 2700.

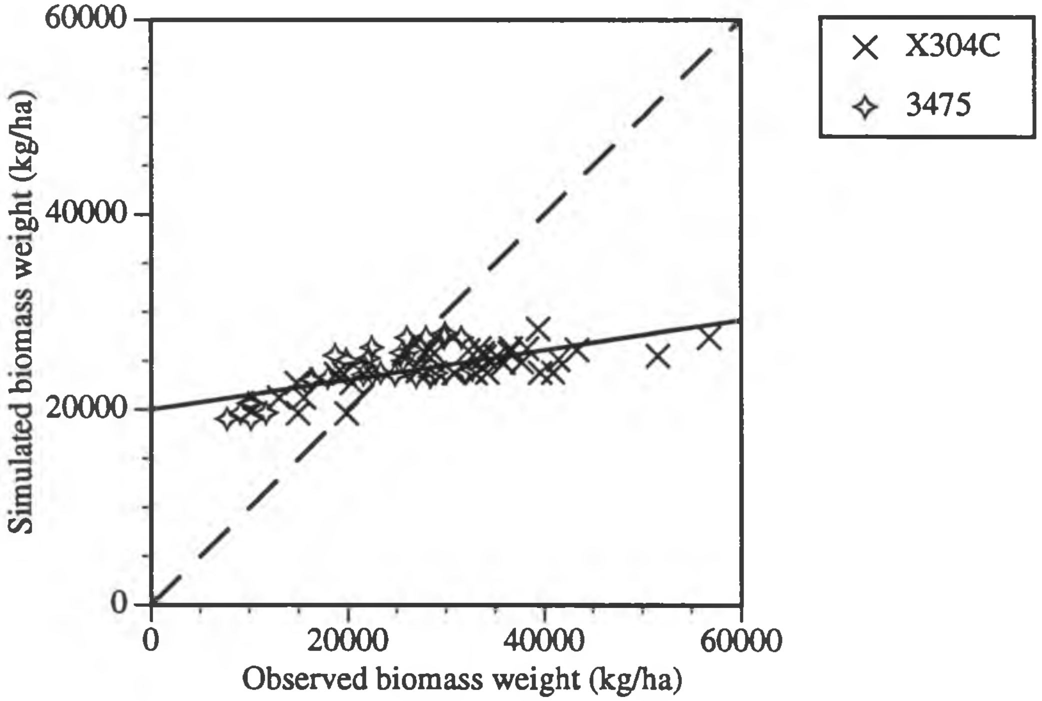

Figure 25. Comparison of observed and simulated aboveground biomass weight at harvest maturity using original genetic coefficients for two Pioneer hybrids. Solid line is linear regression where y = 0.15 x + 20000.

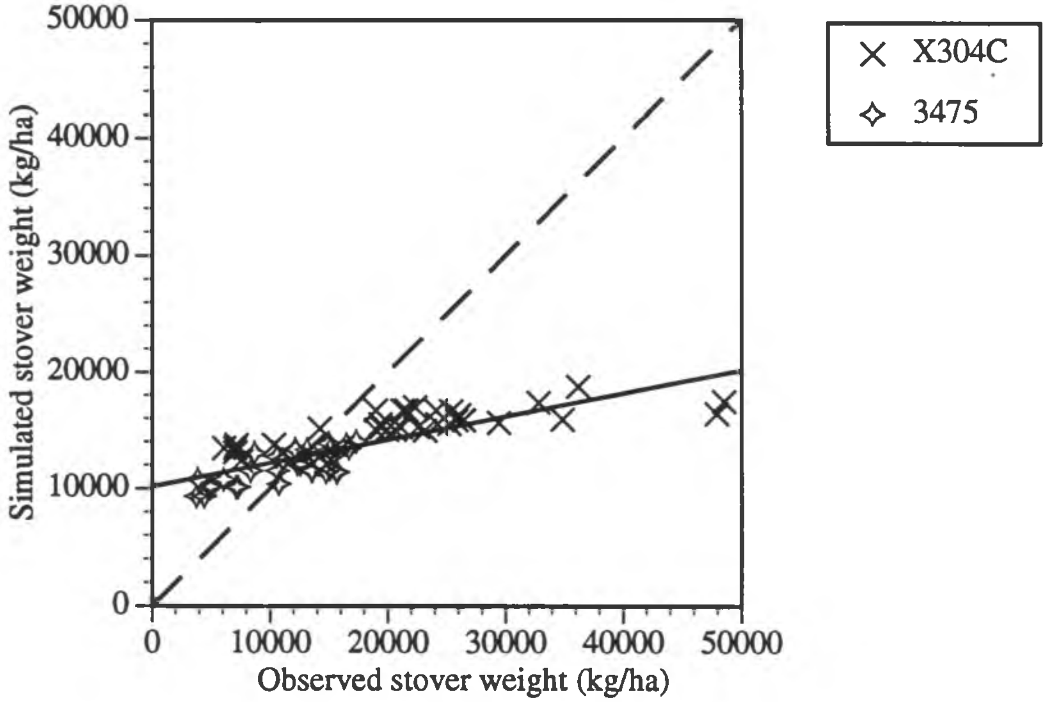

Figure 26. Comparison of observed and simulated stover weight at harvest maturity using original genetic coefficients for two Pioneer hybrids. Solid line is linear regression where y = 0.20 x + 10000.

Summerfield, 1974; Summerfield et al., 1993). The magnitude of the delay to flowering was generally greater for cultivars adapted to low latitude than cultivars adapted to high latitude (Cregan and Hartwig, 1984; Major et al., 1975). The high latitude adapted cultivars were presumed to be photoperiod insensitive, or had a very high photoperiod threshold that prevented any delaying effect (Cregan and Hartwig, 1984). Hence, soybean development delay was greater for low latitude adapted cultivars under long photoperiod (Parvez and Gardner, 1987).

Soybean cultivar differences in yield and yield components showed adaptation to latitude or photoperiod. Soybean cultivars 'Clark' and 'Midwest', grown in Indiana, had greater number of pods plant^{-1} when grown under 16 h photoperiod than 12 or 20 h (van Schaik and Probst, 1958). Presumably, the two cultivars produced the most pods in the photoperiod that was usual for Indiana. Similarly, soybean cultivars adapted to lower latitude, maturity group VIII, produced the greatest number of pods when grown at normal planting date in Florida (Parvez and Gardner, 1987). However, pod number decreased 34 to 95% when photoperiod was shortened to 10 h by covering plants with opaque plastic sheets or lengthened by planting at a later date. Yield among cultivars from maturity groups II to IV grown in Illinois showed that the early maturing cultivars do not tolerate short photoperiod (Schweitzer and Harper, 1985). Photoperiod was shortened to 10 h by covering plants with opaque plastic sheets. The shortened photoperiod significantly reduced the yield for cultivars in maturity group II, but did not significantly affect yield among the later maturing cultivars. Furthermore, the soybean cultivar 'Ransom', maturity group VII, had significantly reduced yield, pods plant^{-1}, and single seed weight when grown in long than short photoperiod (Raper and Thomas, 1978). So, similar to the results from the field experiments with artificial photoperiod extension, soybean seems to produce greater yield under photoperiod normally encountered at the latitude of adaptation.

Long photoperiod prolongs maize development. The time from planting to tassel initiation was lengthened, with concomitant increase in total leaf number, when maize was grown under long versus short photoperiod (Coligado and Brown, 1975; Hunter et al., 1974; Warrington and Kanemasu, 1983c). Generally, tropical adapted genotypes were more photoperiod sensitive than the temperate adapted in total leaf number and time to tassel initiation (Warrington and Kanemasu, 1983c; Francis et al., 1970). Photoperiod had no direct effect on the period from tassel initiation to silking (Breuer et al., 1976; Warrington and Kanemasu, 1983a). Photoperiod affected the phase from silking to physiological maturity, but the effect depended on temperature (Breuer et al., 1976; Hunter et al., 1977). At 30 °C, silking to physiological maturity duration decreased from 42 to 36 days when photoperiod was increased from 10 to 20 h. However, at 20 °C, silking to physiological maturity increased from 51 to 64 days when photoperiod increased from 10 to 20 h (Breuer et al., 1976). So, the photoperiod effect on prolonging maize development is mainly during the pre-tassel initiation phase and, depending on temperature, the silking to physiological maturity phase.

Photoperiod affects yield and yield components in temperate and tropical hybrids. Twenty h versus 10 h photoperiod increased grain yield when a temperate maize hybrid adapted to Ontario was grown at 20 °C in a growth chamber, but had no effect at 30 °C (Hunter et al., 1977). At 20 °C, both single kernel weight and kernel number plant^{-1} increased under long photoperiod. Conversely, in a field trial, photoperiod extended to over 18 h decreased yield of a temperate hybrid adapted to Kentucky (Ragland et al., 1966). The yield decline was mainly attributed to decreased single kernel weight in an April planting and decreased kernel number plant^{-1} in a June planting. Photoperiod extension of 15 h in the field reduced the yield of a tropical maize hybrid (McClelland, 1928). The low yield was assumed to be a result of decreased kernel number plant^{-1} caused by desychronization of tasseling and silking (Ragland et al., 1966). For temperate and tropical maize hybrids, non-optimal photoperiod reduced yield through decreased kernel number plant^{-1} or single kernel weight. Thus, these studies indicate that maize hybrid yield is greatest at its photoperiod of adaptation.

SOYGRO generally simulated soybean development well, but improvements in simulating days to maturity are possible. The error analysis statistics suggest that errors in full pod and maturity simulation are due to model or input parameter error. So, work is needed to correct the model or reduce the bias in input parameters that affect days to maturity. Input parameters that affect days to maturity include the genetic coefficients for photoperiod sensitivity and the post-flowering phase durations. Bias in the genetic coefficients can be reduced by re-determining the values through experiment or a calibration-type process.

The error in simulated soybean grain yield and aboveground biomass seems to be related to the error in seed number$\cdot$m^{-2}. The simulated yield is dependent on the yield components weight$\cdot$seed^{-1} and seed number$\cdot$m^{-2}. Any error in the yield components will be reflected in the yield unless the errors are offsetting. Furthermore, any error in yield or stem weight will be reflected in aboveground biomass because the aboveground biomass is the sum of grain yield and stem weight. The dependence of yield on seed number and the dependence of biomass on yield implies that improving the accuracy of seed number would improve the accuracy of yield and biomass. The error analysis in the present experiment showed that seed number deviation was attributed mainly to model or input parameter bias. So, concentrating effort primarily on correcting the model or input parameter bias in seed number should ameliorate simulation of yield and biomass.

CERES-Maize was able to simulate maize development well for days to silking and maturity, but not for tassel initiation. Error in simulated tassel initiation was mostly systematic. So, to improve the simulated corn development, model or input parameter correction is needed. Input parameters that may be corrected include the genetic coefficients that control photoperiod sensitivity and the juvenile phase duration.

Changes in CERES-Maize may be needed to correct the simulated growth attributes yield and aboveground biomass. The yield components kernel weight and kernels$\cdot$m^{-2} had very high systematic errors that require model or input parameter change to correct. Then with the yield components corrected, improvement in yield simulations would result. Stover weight also had large systematic error indicating the necessity to change the model or input parameters. Changes in the model or input parameters to correct the stover weight, with concomitant changes to correct yield, would improve simulated aboveground biomass because aboveground biomass is the sum of grain yield and stover weight.

The problem that caused the inaccurate simulation of stover weight in CERES-Maize may be related to leaf area. One possibility to account for the incorrect stover simulation may be the total carbohydrate production. Carbohydrate production in CERES-Maize is a function of leaf area, solar radiation, water stress, temperature, and soil nitrogen (Jones and Kiniry, 1986). In the simulations, no water stress was assumed across photoperiod treatments, locations, and years. While solar radiation, temperature, and soil nitrogen changed over time and space, the effects were not likely to be large enough to account for the large differences between the observed and simulated stover weights. CERES-Maize calculates leaf area as a function of leaf number$\cdot$plant^{-1} and area$\cdot$leaf^{-1} (Jones and Kiniry, 1986). In turn, leaf number is a function of leaf initiation rate, assumed constant, and thermal time from sowing to tassel initiation. Hence, any bias in simulating time to tassel initiation will result in bias in leaf area and, ultimately, stover weight. Also, area·leaf^{-1} may increase with increasing photoperiod (Manrique and Hodges, 1991), but this is not simulated in CERES-Maize. So, the inaccurate stover weight may be a result of the imprecision in days to tassel initiation and area·leaf^{-1}.

SOYGRO and CERES-Maize, with the present set of genetic coefficients and for the varieties tested, were able to simulate development, but not growth. The problems with simulating growth may not be in the genetic coefficients, but in the model itself.

Modification to SOYGRO may be required to correct growth. The growth attributes, especially weight·seed^{-1} and seed number·m^{-2}, require both change in input parameters and the model to improve the simulation of yield and biomass. The possible inputs to change include the genetic coefficients, soil properties, soil initial conditions, weather variables, and crop parameters. The changes in the input parameters should be tried first to determine whether change in the model is absolutely necessary to improve the growth simulation.

CERES-Maize simulated maize development fairly well, but growth was not. Days to silking and maturity were fairly well simulated across the various photoperiods, years, sites, and cultivars. However, tassel initiation was not well simulated and the model may need changing to correct the problem. The growth attribute kernel weight obviously needs change because the observed vs. simulated plot has negative slope. Kernels·m^{-2} was not well simulated because the model over-estimated the number of kernels for Pioneer hybrid X304C. Manrique and Hodges (1991) noted that in very long photoperiod, Pioneer hybrid X304C had fewer kernels per ear due to de-synchronization of pollen-shed and silking. The model does not have the ability to simulate kernel number in very long photoperiod for the tropically adapted variety Pioneer hybrid X304C. With the poor simulation of kernel weight and kernels$\cdot$m^{-2}, yield was not accurately simulated. Further work may be needed to improve the total carbohydrate production for better stover and biomass simulation. The improvements may include changes in the calculation of leaf number and area$\cdot$leaf^{-1}.

CHAPTER 3

EVALUATING METHODS TO ESTIMATE GENETIC COEFFICIENTS IN SOYGRO AND CERES-MAIZE

Introduction

Crop models contain genetic coefficients that quantify the genotype effects on development and growth. Genetic coefficients describe either the development rate response to environmental factors such as temperature and photoperiod, or potential growth rates and quantities. The development and growth genetic coefficients for SOYGRO and CERES-Maize are listed in tables 12 and 13 (Jones et al., 1986; Jones and Kiniry, 1986). The crop models assume temperature and photoperiod are the major environmental factors that affect development. Hence, the duration from stage to stage is based on thermal time concept and photoperiod sensitivity. The growth genetic coefficients define the genetic potential for characteristics such as yield components, growth rates, and leaf area. These genetic potentials are modified within the model through estimated water, temperature, nitrogen, or reduced photosynthate stresses. Therefore, the genetic coefficients are critical in simulating crop response to its environment.

There are two approaches to estimating genetic coefficients. One approach is to incrementally change the genetic coefficients until the simulation and observed crop characteristics match (Jones et al., 1989; Ritchie et al., 1992). This fitting

Table 12. Developmental and growth genetic coefficients in SOYGRO.

Genetic coefficient name	Description
VARN1	A threshold for night length that sets the night time accumulator at the minimum rate when night length is less than this value, in h.
VARN0	A threshold for night length that sets the night time accumulator at the maximum rate when night length is greater than this value, in h.
VARTH	Number of nights needed to accrue one unit of night time accumulator when night length is less than VARN1, the minimum development rate.
VARDH	Number of nights needed to accrue one unit of night time accumulator when night length is greater than VARN0, the maximum development rate set at 1.
PHTHRS (1)	Physiological days from planting to emergence.
PHTHRS (2)	Physiological days from emergence to unifoliolate stage.
PHTHRS (3)	Physiological days from unifoliolate to end of juvenile stage.
PHTHRS (4)	Units of night time accumulator from end of juvenile stage to floral induction.
PHTHRS (5)	Number of physiological days from floral induction to flowering.
PHTHRS (6)	Units of night time accumulator from flowering to beginning pod stage.
PHTHRS (7)	Units of night time accumulator from flowering to full pod stage.
PHTHRS (8)	Units of night time accumulator from flowering to expanded last leaf.
PHTHRS (9)	Night time accumulator units from flowering to last flower.
PHTHRS (10)	Night time accumulator units from flowering to physiological maturity.

Table 12. (Continued) Developmental and growth genetic coefficients in SOYGRO.

PHTHRS (11)	Number of physiological days from physiological maturity to harvest maturity.
SHVAR	Maximum individual shell growth rate, mg d^{-1}
SDVAR	Maximum individual seed growth rate, mg d^{-1}
SDPDVR	Number of seeds per pod
PODVAR	Maximum number of pods initiated per day during podding.
FLWVAR	Maximum number of flowers opening per day during flowering.
TRIFOL	Number of trifoliolates per physiological day.
SIZELF	Area of a normal leaf on nodes 8 to 10.
SLAVAR	Specific leaf area of newly expanded leaf.

Table 13. Developmental and growth genetic coefficients in CERES-Maize

Genetic coefficient name	Description
P1	Growing degree days, base temperature 8 °C, from emergence to end of juvenility.
P2	Photoperiod sensitivity, days delay per hour beyond 12.5 h photoperiod.
P5	Growing degree days, base temperature 8 °C, from silking to physiological maturity.
G2	Potential number of kernels per plant
G3	Potential kernel growth rate, mg $kernel^{-1}$ d^{-1}

method has been used to successfully simulate maize production in diverse climates as South Africa, Mid-west U.S., and Brazil (du Pisani, 1987; Hodges et al., 1987; Liu et al., 1989). The other approach requires detailed measurements of crop development and growth in growth chamber or field experiments (Ritchie et al., 1986).

The objective of this experiment is to determine the suitability of the two methods for calculating genetic coefficients in SOYGRO and CERES-Maize. If the models truly simulate the response of plant processes to the environment, the fitting or experimental method to estimate genetic coefficients should be stable when estimated across different environments. Stability of genetic coefficients estimated across environments implies that the coefficients established in one environment can be used to simulate crop growth and development in another environment.

Methods and Materials

The field experiments were described in the previous chapter, but the procedures are briefly explained here. Identical experiments were conducted at two sites on Maui Island, Hawaii. The site elevations were 640 m at Haleakala Experiment Station (clayey, oxidic, isothermic Humoxic Tropohumult) and 282 m at Kuiaha (clayey, ferritic, isohyperthermic Humoxic Tropohumult). The experimental design was a split-plot where photoperiod was the main-plot and cultivar was the sub-plot. The natural photoperiod was extended with quartz lamps (minimum 4 W m^{-2} at soil surface) to produce 20-, 17-, 14-, and natural + 0.5 h treatments. Natural photoperiod was used as a control treatment. Four soybean cultivars ('Bragg', 'Evans', 'Jupiter', and 'Williams') and five maize hybrids (Pioneer hybrids X304C, 3165, 3324, 3475, and 3790) were planted in 1.5 by 3.0 m sub-plots. The plots were fertilized, well irrigated, and pests were chemically controlled. These experiments were planted four times over three years.

Data on weather, date of development stages, and growth characters were observed. Daily maximum and minimum air temperature, rainfall, and solar radiation were recorded on automatic weather stations (LI-1200S, LI-COR, Inc., Lincoln, NE). Dates were observed when 50% of soybean plants within a plot reached the development stages planting, emergence, unifoliolate, first flower, first 0.5 cm pod, first 2 cm pod (full pod), last flower opened, last leaf fully expanded, and physiological maturity. The area of a single leaf on the upper 5 nodes from 10 plants and its dry weight was obtained between first flower and 2 cm pod growth stages. At harvest maturity, the pod number, seed number, shell dry weight, seed dry weight, stem dry weight, and number of nodes on the mainstem from 20 plants were determined. Dates were recorded when corn development stages were observed. These stages were planting, emergence, apex elongated 1 cm (tassel initiation), silking, and physiological maturity. Leaves 5 and 10 were marked with indelible ink on 10 plants to obtain total leaf number. At harvest maturity, the grain and stover dry weights, and kernel number were recorded. For each cultivar, each measurement was made on two plots that were randomized within a photoperiod treatment. The mean measurement for each cultivar within a photoperiod plot was used to generate genetic coefficients.

Two methods were used to estimate the genetic coefficients for SOYGRO and CERES-Maize. The first method was to calculate genetic coefficients that describe the rates of development and growth based on field observations of growth stages, weights, and sizes. This method was considered as an explicit method. The second method involved manipulating the genetic coefficient values until crop development and growth from the simulations matched those from the field experiments. This method was called fitting.

An explicit method to determine the SOYGRO v.5.42 genetic coefficients was not possible because the proper data were not collected. In the model, shell and seed growth are dependent on the number of shells. Shell number, in turn, is dependent on the number of flowers and pods produced per day during reproductive development. The actual number of flowers and pods produced per day during the flowering to podding phase was not recorded. So, most of the growth genetic coefficients could not be calculated. Most of the development genetic coefficients were related to photoperiod or photothermal time. Estimating the photoperiod genetic coefficients would be very similar to the fitting procedure and so was not done.

SOYGRO genetic coefficients were determined with a fitting method. Before the fitting procedure was done, the model was modified. The night length variable

DURNIT was set to mimic the photoperiod treatments in the field. The genetic coefficient PHTHRS(5), which was normally set to 12.86 (Jones et al., 1986), was changed to 6.20 as derived from the data of Thomas and Raper (1983). The array sizes for seed number, seed weight, shell number, shell weight, and flower number were increased from 200 to 365. These changes were necessary to match simulation results to the observations in the field experiments.

SOYGRO genetic coefficients were manipulated until simulated target data were within 1% of the observed. PHTHRS(1) and PHTHRS(2) were changed until simulated emergence and unifoliolate dates matched the observed dates. The juvenile phase genetic coefficient PHTHRS(3) was set to 0.0 for cultivars 'Bragg', 'Evans', and 'Williams' and assumed 5.0 for 'Jupiter'. While VARDH was assumed to be 1.0, the following was done to fit the photoperiod sensitivity genetic coefficients VARN0, VARN1, and VARTH. Using only the control and natural photoperiod treatments that had night length greater than 12 h (Jones et al., 1989), PHTHRS(4) was changed until simulated flowering date matched the observed. The fitted PHTHRS(4) value was used to simulate flowering date in the 14-, 17-, and 20-h photoperiod treatments. VARN0 and VARTH were modified until the simulated and observed flowering dates for the 14- and 20-h treatments agreed. To fit the 17-h photoperiod treatment, VARNO and VARN1 were concurrently changed until simulated and observed flowering dates matched. This fitting procedure was inadequate for 'Evans' because VARN1 was less than 4 h. So, VARN1 was set to 0.0. After photoperiod sensitivity was determined, PHTHRS(6), PHTHRS(7), PHTHRS(8), PHTHRS(9), and PHTHRS(10) were incrementally altered until the dates for first 0.5 cm pod, first 2 cm pod, last flower opened, last fully expanded leaf, and physiological maturity from the simulation coincided with the observed. The growth genetic coefficient TRIFOL was adjusted until the simulated number of nodes on the mainstem at harvest maturity agreed with the observed. SIZELF and SLAVAR were calculated from the observed leaf area and weight, and temperature (TPHFAC) and solar radiation (PARSLA) correction in SOYGRO. The growth genetic coefficients for maximum pod addition rate (PODVAR), maximum flower addition rate (FLWVAR), seeds per pod (SDPDVR), maximum shell growth rate (SHVAR), maximum seed growth rate (SDVAR), and photosynthetic correction (PHFAC3) were concurrently determined. PODVAR was adjusted until simulated pod number plant^{-1} at harvest maturity matched the observed data. As PODVAR was adjusted, FLWVAR was simultaneously adjusted to 2 times PODVAR (Jones et al., 1989). SDPDVR was set equal to the observed seeds per pod at harvest maturity. Seed growth rate and shell growth rate were changed to match simulated and observed single seed weight and total pod weight at harvest maturity. PHFAC3 was modified to match simulated and observed above ground biomass and stem weights at harvest maturity. Because the photosynthetic rate was changed, the fitting process for PODVAR, FLWVAR, SDVAR, and SHVAR was repeated until all simulated target data were within 1% of observed. The genetic coefficients derived from this procedure were called fitted.

Genetic coefficients for CERES-Maize v2.10 were calculated for each maize hybrid according to the assumptions in the model. P1 was the sum of growing degree days from emergence to four days before tassel initiation when photoperiod was less than 12.5 h. Therefore, P1 was estimated from the winter planting, the only period when photoperiod was less than 12.5 h. If photoperiod was greater than 12.5 h, then the phase from emergence to tassel initiation was assumed to be partly prolonged by photoperiod sensitivity and the juvenile phase would be confounded with photoperiod sensitivity. The equation for growing degree days (GDD) was,

$$GDD = [(Tmax + Tmin) / 2] - 8$$

where Tmax and Tmin were the daily maximum and minimum air temperature and 8 was the base temperature. The genetic coefficient P2 controls the duration of the phase from the end of juvenile phase to tassel initiation based on photoperiod. P2 was the slope of the regression of days from planting to tassel initiation on photoperiod (h) using data within a site from the Maui experiments. P5 was the cumulative GDD from silking to physiological maturity. The potential number of kernels per plant, G2, was determined as the number of kernels per plant at harvest maturity. The kernel growth rate, G3, was calculated as the ratio kernel weight at harvest maturity: days from 170 GDD after silk to 95% physiological maturity. The genetic coefficients estimated in this manner were called explicit genetic coefficients.

The fitting method was used to determine genetic coefficients for CERES-Maize. Before the fitting procedure was attempted, the model was modified by changing the simulated photoperiod to accommodate the different photoperiod treatments. Further, the variables that define the GDD from germination to emergence, the GDD to produce a leaf primordia, and the GDD for the expansion of one leaf were put into a model input file to allow easy access for modifications. These variables are crop coefficients that normally do not vary among varieties. This modification prevented the deviation in time to emergence to be incorporated into the P1 value, accounted more accurately for the number of leaves and ultimately leaf area, and allowed better fitting for silking date and growth. The inclusion of these variables allowed more flexibility to better fit observations and will be analyzed with the other genetic coefficients.

The fitting strategy for CERES-Maize was to change the genetic coefficients until a target characteristic was within 1% of the observed. P9 was incrementally changed until the simulated emergence date matched the observed. When photoperiod was approximately 12.5 h or less (i.e., the winter planting), P1 was changed until the simulated tassel initiation date matched the observed. This P1 value was used for subsequent fittings of P2 to tassel initiation in control and natural photoperiod treatments for the summer plantings and all 14 h, 17 h, and 20 h photoperiod treatments. P2 was changed until the simulated and observed tassel initiation dates matched. Further, because P1 seemed to be associated with season, the P1 value developed during the summer was only used for summer plantings. Once the tassel initiation was fitted, the total leaf number was matched by modification of GDD to produce a leaf primordia. Likewise, GDD to expand one leaf and P5 were changed to match silking and physiological maturity dates. G2 and G3 were altered to fit observed kernel number per plant and kernel weight. No attempt was made to fit above ground biomass and stover weight through modification of the carbohydrate production equation because increasing the carbohydrate production would depress G2. Further, increasing the carbohydrate production was not adequate to match the biomass and stover to the 1% criteria. The genetic coefficients derived from this procedure were called fitted.

Simulations that used the fitted and explicit genetic coefficients were compared to the same data set from which the coefficients were derived. Genetic coefficient means for each cultivar were calculated for explicit and fitted sets. The results from the simulations were compared to the observed values from the photoperiod experiment. To compare the genetic coefficient derivation methods' effect on simulations, the error statistics from Willmott (1981) were calculated.

Crop growth and development was compared between the control and natural photoperiod treatments to detect any effects of light quality. The natural photoperiod treatment had 15 minutes of artificial light added before sunrise and after sunset, approximately equivalent to civil twilight. Error statistics (Willmott, 1981) were calculated for observed growth and development data between the paired control and natural treatments.

Analysis of variance was performed on the explicit and fitted genetic coefficients. The experiment was analyzed as a modified split-plot with photoperiod as the main-plots and cultivar as the sub-plots and sites as replications. F-tests for photoperiod treatments were not examined for statistical significance because these treatments were not randomized in the field, but interactions with photoperiod were tested (LeClerg et al., 1962). Because of the unbalanced nature of the data, certain planting years and cultivars were eliminated to create a balanced data set. Then, one of the four experimental designs was used for analysis of variance: 1) randomized complete block with site as block and photoperiod as treatment when data from only one year and one cultivar were available, 2) combined year randomized complete block (McIntosh, 1983) with site as block and photoperiod as treatment when data from two years and one cultivar were available, 3) split-plot with site as replicate, photoperiod treatment as main plot, and cultivar as sub plot when data from one year and more than one cultivar was available, and 4) combined year split plot (McIntosh, 1983) with photoperiod treatment as main plot and cultivar as sub plot when data from two years and more than one cultivar were available.

Interaction sums of squares were partitioned into orthogonal trend comparisons over photoperiod. Coefficients for linear and quadratic orthogonal polynomials were calculated for unequally spaced independent variables, i.e., photoperiod (Gomez and Gomez, 1976). The sample variance was calculated according to Gomez and Gomez (1976). From the sample variance, the standard error of the mean was calculated from the two subsamples within a cultivar.

Results

The fitted SOYGRO development genetic coefficients were different from the original (Tables 14 and 15). The night length sensitivity and development genetic coefficients VARN1, VARN0, VARTH, and PHTHRS 4 to 9 were usually lower for fitted than the original. This was most likely a result of assuming that PHTHRS(5) was 6.2 rather than the original 12.86. This assumption would increase PHTHRS(4) to compensate for the reduced PHTHRS(5) since both genetic coefficients are addends for the phase from end of juvenility to flowering. The increased PHTHRS(4) forced a reduction in VARTH, the genetic coefficient that determined the night length sensitivity. When VARTH was reduced, PHTHRS 6 to 10 were expected to increase to accommodate the faster development rate that a small VARTH caused. So, the fitted PHTHRS 6 to 9 were larger than the originals indicating that post-flowering development was less sensitive to nightlength than pre-flowering.

Differences between original and fitted growth genetic coefficients for SOYGRO were also apparent (Tables 14 and 15). The fitted pod and flower addition rate genetic coefficients, PODVAR and FLWVAR, were much higher than the

Table 14. Original and fitted SOYGRO genetic coefficients for cvs. 'Bragg' and 'Evans'. Values with stars were assumed, not fitted

Genetic Coefficient	Bragg		Evans	
	Original	Fitted	Original	Fitted
VARN1	5.000	5.380	5.000	0.000
VARN0	11.800	10.560	9.500	8.930
VARTH	13.500	5.190	2.000	3.010
VARDH	1.000	1.000	1.000	1.000
PHTHRS(1)	5.000	3.400	5.000	3.530
PHTHRS(2)	9.000	10.380	9.000	10.460
PHTHRS(3)	0.000	0.000*	0.000	0.000*
PHTHRS(4)	4.000	14.850	3.500	6.070
PHTHRS(5)	12.860	6.200*	12.860	6.200*
PHTHRS(6)	6.500	5.230	7.000	3.070
PHTHRS(7)	9.740	7.700	10.670	5.490
PHTHRS(8)	9.000	11.040	25.500	15.980
PHTHRS(9)	34.000	10.310	34.000	8.640
PHTHRS(10)	47.500	49.880	44.000	43.910
SHVAR	11.600	12.460	9.500	11.900
SDVAR	6.000	4.660	6.000	4.440
SDPDVR	2.050	1.610	2.200	1.810
PODVAR	200.000	589.100	160.000	2707.100
FLWVAR	450.000	1178.200	320.000	5414.100
TRIFOL	0.330	0.330	0.380	0.356
SIZELF	171.400	171.200	173.470	125.490
SLAVAR	350.000	287.100	360.000	265.300
PHFAC3	1.000	1.830	1.000	2.170

Table 15. Original and fitted SOYGRO genetic coefficients for cvs.'Jupiter' and 'Williams'. Values with stars were assumed, not fitted.

Genetic Coefficient	Jupiter		Williams	
	Original	Fitted	Original	Fitted
VARN1	5.000	5.000*	5.000	2.200
VARN0	12.000	10.450	10.430	9.480
VARTH	18.620	1.380	6.000	5.290
VARDH	1.000	1.000	1.000	1.000
PHTHRS(1)	5.000	3.540	5.000	3.010
PHTHRS(2)	9.000	9.980	9.000	9.350
PHTHRS(3)	5.000	5.000*	0.000	0.000*
PHTHRS(4)	5.500	39.780	7.400	7.080
PHTHRS(5)	12.860	6.200*	12.860	6.200*
PHTHRS(6)	8.500	10.830	6.000	5.210
PHTHRS(7)	9.500	14.590	11.437	7.480
PHTHRS(8)	9.500	7.430	17.000	15.910
PHTHRS(9)	34.000	14.160	34.000	10.310
PHTHRS(10)	42.000	57.630	43.000	44.080
SHVAR	13.000	11.770	11.000	14.150
SDVAR	6.000	4.460	6.000	4.930
SDPDVR	2.100	1.440	2.200	1.980
PODVAR	200.000	481.100	120.000	2131.800
FLWVAR	400.000	962.200	240.000	4263.600
TRIFOL	0.338	0.328	0.350	0.418
SIZELF	173.700	266.500	188.370	195.000
SLAVAR	350.000	252.400	350.000	289.000
PHFAC3	1.000	2.560	1.000	1.610

originals. The difference may be attributable to a very severe pod and flower abortion rate with the short night length defined in the model. So, in fitting the pod number, PODVAR and FLWVAR were necessarily high to compensate for the severe abortion rate especially in the long photoperiod treatments. The fitted seed growth rate and seed per pod genetic coefficients SDVAR and SDPDVR were consistently less than the originals. Specific leaf area genetic coefficient SLAVAR was also consistently lower than the original. This may indicate that leaf samples were taken too late in the season when leaf thickening had already occurred. The trifoliolate production (TRIFOL), individual leaf area (SIZELF), and shell growth rate (SHVAR) differences between the fitted and original were variable across cultivars. The differences between the original and fitted SOYGRO genetic coefficients may be attributed to changing assumed values, empirical response of plant to the environment, or mis-specified field data.

The CERES-Maize genetic coefficients also differed from the original, and those that were explicitly determined, and fitted (Tables 16, 17, and 18). The growing degree days (GDD) from emergence to end of juvenile phase, P1, were similar for the explicit and fitted methods. The similarity was expected since the beginning and ending of the phases and the equation to calculate GDD were identical. The original P1 for Pioneer hybrid 3475 was similar to the values from explicit and fitted, but the original P1 for Pioneer hybrid X304C was much greater than that derived from the other methods. Curiously, the explicit and fitted P1 value from the

Table 16. Original, mean explicit, and mean fitted CERES-Maize genetic coefficients for Pioneer hybrids X304C and 3165. Values with stars were assumed.

Genetic Coefficient	Pioneer hybrid X304C			Pioneer hybrid 3165		
	Original	Explicit	Fitted	Original	Explicit	Fitted
P1	320.00	230.00	235.00	na	238.00	241.00
P2	0.52	0.25	0.35	na	0.29	1.52
P5	940.00	960.00	965.00	na	942.00	943.00
G2	625.00	450.00	646.00	na	545.00	711.00
G3	6.00	4.92	6.20	na	5.09	6.33
P9	39.00	39.0*	52.63	39.00	39.0*	50.00
XLPGDD	21.00	21.0*	18.59	21.00	21.0*	22.03
PCHRON	38.90	38.9*	49.18	38.90	38.9*	49.23

Table 17. Original, mean explicit, and mean fitted CERES-Maize genetic coefficients for Pioneer hybrids 3324 and 3475. Values with stars were assumed.

Genetic Coefficient	Pioneer hybrid 3324			Pioneer hybrid 3475		
	Original	Explicit	Fitted	Original	Explicit	Fitted
P1	320.00	208.00	209.00	200.00	211.00	210.00
P2	0.52	0.07	0.61	0.70	0.11	0.22
P5	940.00	837.00	859.00	800.00	827.00	832.00
G2	625.00	470.00	721.00	725.00	531.00	760.00
G3	6.00	5.50	7.25	8.60	5.31	6.78
P9	39.00	39.0*	47.50	39.00	39.0*	51.32
XLPGDD	21.00	21.0*	22.84	21.00	21.0*	25.74
PCHRON	38.90	38.9*	48.80	38.90	38.9*	48.75

Table 18. Original, mean explicit, and mean fitted CERES-Maize genetic coefficients for Pioneer hybrid 3790. Values with stars were assumed.

Genetic coefficient	Pioneer hybrid 3790		
	Original	Explicit	Fitted
P1	na	209.00	209.00
P2	na	0.11	0.28
P5	na	801.00	804.00
G2	na	421.00	657.00
G3	na	5.38	7.05
P9	39.00	39.0*	49.74
XLPGDD	21.00	21.0*	30.14
PCHRON	38.90	38.9*	51.50

winter planting was very similar to the original P1 for Pioneer hybrid X304C (data not shown). The photoperiod sensitivity genetic coefficient, P2, was highly variable among the three types of genetic coefficients. Generally, the original P2 had the highest value, followed by the fitted, then explicit. The explicit may have been lowest because the regression line was not forced through an intercept, whereas the fitted method effectively forced a line through the point at 12.5 h. The GDD from silking to physiological maturity, P5, was similar among those that were explicit and fitted. The similarity may be that the beginning and ending stages, and the GDD calculation for both methods were the same. The potential number of kernels per plant and the kernel growth rate, G2 and G3, were lower for the explicit than the fitted. The lower explicit G2 and G3 may indicate that there were non-ideal conditions for kernel development in the field, at least in some cases. A possible non-ideal condition may be temperature. Linear regression of G3 on mean daily temperature during kernel growth was described as $y = 0.45x - 4.51$, $r^2 = 0.55$ ($n=158$), where y was G3 and x was temperature. This indicates G3 varies as a function of temperature and is not an environment independent constant. The GDD from germination to emergence and to fully expand one leaf, P9 and PCHRON, was greater for fitted than the original values. GDD to produce a leaf primordia during the phase from germination to tassel initiation, XLPGDD, varied from 18.59 to 30.14 among the hybrids while the original value was a constant 21.

The factors that affected the SOYGRO and CERES-Maize genetic coefficients derived from the fitting and explicit method were identified with analysis of variance. If the genetic coefficients and the model well simulated the soybean growth and development and the genetic coefficient derivation method was sound, then the only significant source of variation would be the difference among cultivars. Any other significant source of variation would indicate shortcomings of the field data, genetic coefficient estimation method, or the model.

The SOYGRO development genetic coefficients PHTHRS 1 and PHTHRS 2, the thermal time from planting to emergence and planting to unifoliolate, had site and cultivar as significant sources of variation (Table 19). The PHTHRS 1 value was higher at the warmer site, Kuiaha, than the cooler site, Haleakala, 3.33 compared to 2.65. The opposite effect of site was observed in PHTHRS 2 values: 9.5 at the warm site and 10.1 at the cool site. The paradoxical results may be an artifact of where temperature was measured versus the temperature that was more related to development. From planting to emergence, development rate should be related to soil temperature, but air temperature was used to calculate thermal time. The mean soil and air temperature was 24.26 and 20.24 °C at the cool site, and 23.50 and 21.73 °C at the warm site. The difference in soil and air temperature suggested that the plant was developing quickly at the cool site, but the thermal time was accumulating relatively slowly due to the much lower air temperature. Hence, the thermal time from planting to emergence was greater at the cool than at the warm site. However,

Table 19. Mean squares from analysis of variance on fitted SOYGRO genetic coefficients PHTHRS(1), PHTHRS(2),and PHTHRS(4) for soybean cultivars. The fitted genetic coefficients were estimated from a field experiment conducted at two sites on Maui Island, Hawaii, with five photoperiod treatments planted in 1990. PHTHRS(1) and PHTHRS(2) data collected from cultivars 'Bragg', 'Evans', 'Jupiter', and 'Williams'. PHTHRS(4) data collected from cultivars 'Bragg', 'Evans', and 'Williams'.

Source	df	PHTHRS(1)[1]	df	PHTHRS(2)[2]	df	PHTHRS(4)[3]
Site	1	4.556 **	1	3.691 **	1	0.327 *
Photoperiod	4	0.209	4	0.269	4	0.260
Error a	4	0.228	4	0.214	4	0.177
Cultivar	3	0.673 **	3	0.556 **	2	211.458 **
Photo x Cult	12	0.084	12	0.097 ns	8	0.260 ns
Error b	15	0.060 ns	15	0.078	10	4.362

ns not significant at the 0.05 probability level.

* significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Physiological days from planting to emergence.

[2] Physiological days from emergence to unifoliolate.

[3] Night units from end of juvenile phase to floral induction.

once the plant emerged and the apical meristem exposed, development should be closely related to air temperature.

Although PHTHRS 2 did not have a significant cultivar-by-photoperiod interaction, orthogonal trend comparison revealed a significant ($p>0.05$) quadratic difference between cultivars 'Evans' and 'Jupiter' (Figure 27). This indicated photoperiod may have an effect on development earlier than assumed in the model.

Photoperiod sensitivity genetic coefficients were not affected by the site where the coefficients were derived. As expected, the photoperiod threshold genetic coefficients VARN1 and VARN0 had only cultivar as a significant source of variation (Table 20). The genetic coefficient that assigns the number of nights necessary to accrue one night unit at a given photoperiod, VARTH, had no significant source of variation (Table 20).

The photothermal time from unifoliolate to floral induction, PHTHRS 4, only displayed cultivar as a significant source of variation (Table 19). Since no other source of variation was found significant, PHTHRS 4 was considered a true genetic coefficient as previously discussed.

Post-flowering growth stages exhibited less photoperiod sensitivity than pre-flowering stage for low latitude adapted cultivars and greater photoperiod sensitivity for higher latitude adapted cultivars. The photothermal time from flowering to beginning pod, full pod, expanded last leaf, and last flower, corresponding to PHTHRS 6 to 9, had significant cultivar and cultivar-by-photoperiod interaction

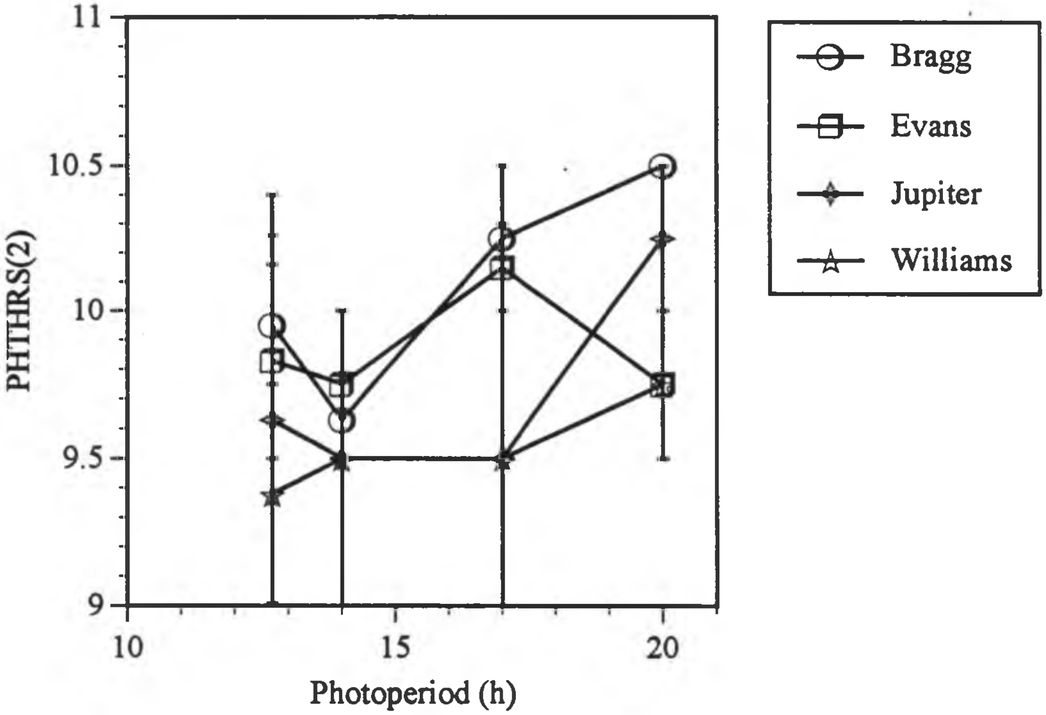

Figure 27. Photoperiod extension effect on estimating PHTHRS(2) genetic coefficient of SOYGRO for soybean cultivars 'Bragg', 'Evans', 'Jupiter', and 'Williams' using field data from 1990. Vertical bars are standard errors of the mean.

Table 20. Mean squares from analysis of variance on fitted SOYGRO genetic coefficients VARTH, VARN1, VARN0 for soybean cultivars 'Bragg', 'Evans', and 'Williams' estimated from two sites on Maui Island, Hawaii, under five photoperiod treatments in 1990.

Source	df	VARTH [1]	df	VARN1 [2]	df	VARN0 [3]
Site	1	0.928 ns	1	0.180 ns	1	0.470 ns
Cultivar	2	2.060 ns	2	14.618 *	2	7.007 **
Error	2	0.461 ns	2	0.802	2	0.077

ns not significant at the 0.05 probability level.

* significant at the 0.05 probability level.

[1] Maximum night units threshold, night accumulator units.

[2] Lower nightlength threshold, h.

[3] Upper nightlength threshold, h.

sources of variation (Tables 21 and 22). Orthogonal trend comparisons showed that cultivar 'Bragg', 'Evans', and 'Williams' had significantly ($p>0.05$) different linear trends one from another. The general trend was the low latitude adapted cultivar 'Bragg' had decreased photothermal time value as photoperiod increased, while the high latitude adapted cultivar 'Evans' had increased photothermal time value (figures 28 to 31). The mid-latitude adapted cultivar 'Williams' had intermediate linear trend. The decreased photothermal time value as photoperiod increased indicated the photoperiod sensitivity in the model was too great for the particular phase, so a decreased photothermal value was needed to correctly estimate the stage occurrence in the field. Similarly, the increased photothermal time value indicated photoperiod sensitivity was too small in the model.

Photothermal time from flowering to physiological maturity, PHTHRS(10), was related to photoperiod. The cultivar-by-photoperiod interaction was a significant source of variation for PHTHRS(10) (Table 22). The interaction resulted from a highly significant ($p>0.01$) difference in quadratic trends between soybean cultivars 'Evans' and 'Williams' (Figure 32). The trend with photoperiod indicated the pre-flowering photoperiod sensitivity did not adequately describe sensitivity in the present phase.

Site had an effect on the number of trifoliolates produced in one physiological day, TRIFOL, for soybean cultivar 'Bragg', but no effect for cultivar 'Evans' (Table 23). The TRIFOL value for the cool site was greater than at the warm site for cultivar

Table 21. Mean squares from analysis of variance on fitted SOYGRO genetic coefficients PHTHRS(6), PHTHRS(7), and PHTHRS(8) for soybean cultivars 'Bragg', 'Evans', and 'Williams' grown at two sites on Maui Island, Hawaii, under five photoperiod treatments in 1990.

Source	df	PHTHRS(6)[1]	df	PHTHRS(7)[2]	df	PHTHRS(8)[3]
Site	1	0.0301 ns	1	0.0001 ns	1	1.50 ns
Photoperiod	4	2.2037	4	5.22	4	37.69
Error a	4	1.3988	4	1.63	4	2.09
Cultivar	2	33.4701 **	2	28.70 **	2	191.79 **
Photo x Cult	8	16.0647 **	8	26.65 **	8	89.50 **
Error b	10	0.9791	10	2.35	10	13.97

ns not significant at the 0.05 probability level.
* significant at the 0.05 probability level.
** significant at the 0.01 probability level.

[1] Night units from flowering to beginning pod.

[2] Night units from flowering to full pod.

[3] Night units from flowering to last leaf.

Table 22. Mean squares from analysis of variance on fitted SOYGRO genetic coefficients PHTHRS(9) and PHTHRS(10) for soybean cultivars grown at two sites on Maui Island, Hawaii, under five photoperiod treatments in 1990. PHTHRS(9) data was collected from cultivars 'Bragg', 'Evans', and 'Williams'. PHTHRS(10) data was collected from cultivars 'Evans' and 'Williams'.

Source	df	PHTHRS(9) [1]	df	PHTHRS(10) [2]
Site	1	0.00408 ns	1	189.1 ns
Photoperiod	4	25.36	4	152.8
Error a	4	5.85	4	44.6
Cultivar	2	19.87 *	1	112.3 ns
Photo x Cult	8	27.52 **	4	305.5 **
Error b	10	3.66	5	21.3

ns not significant at the 0.05 probability level.

* significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Night units from flowering to last flower.

[2] Night units from flowering to physiological maturity.

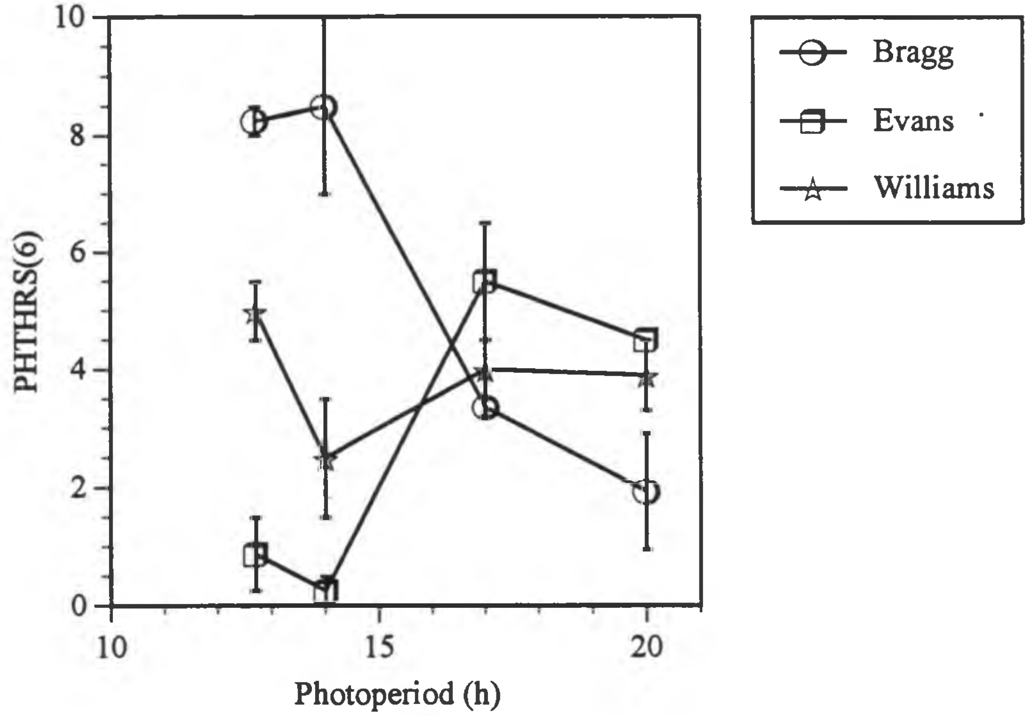

Figure 28. Photoperiod effect on estimating PHTHRS(6) genetic coefficient of SOYGRO for soybean cultivars 'Bragg', 'Evans', and 'Williams' using field data from 1990.

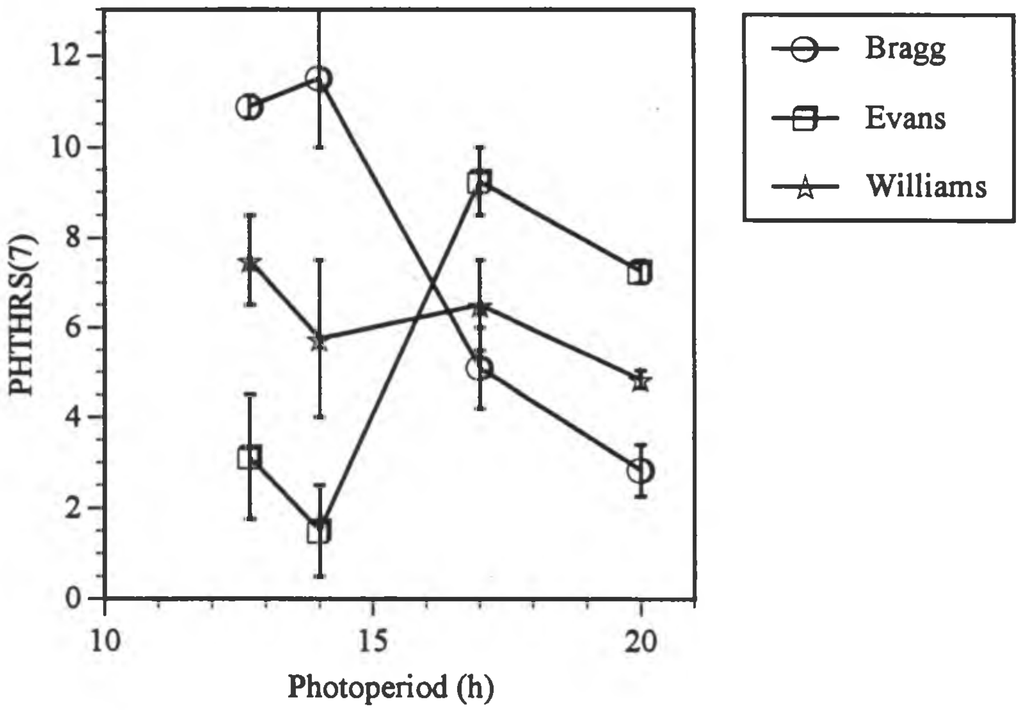

Figure 29. Photoperiod effect on estimating PHTHRS(7) genetic coefficient of SOYGRO for soybean cultivars 'Bragg', 'Evans', and 'Williams' using field data from 1990. Vertical bars are standard errors of the mean.

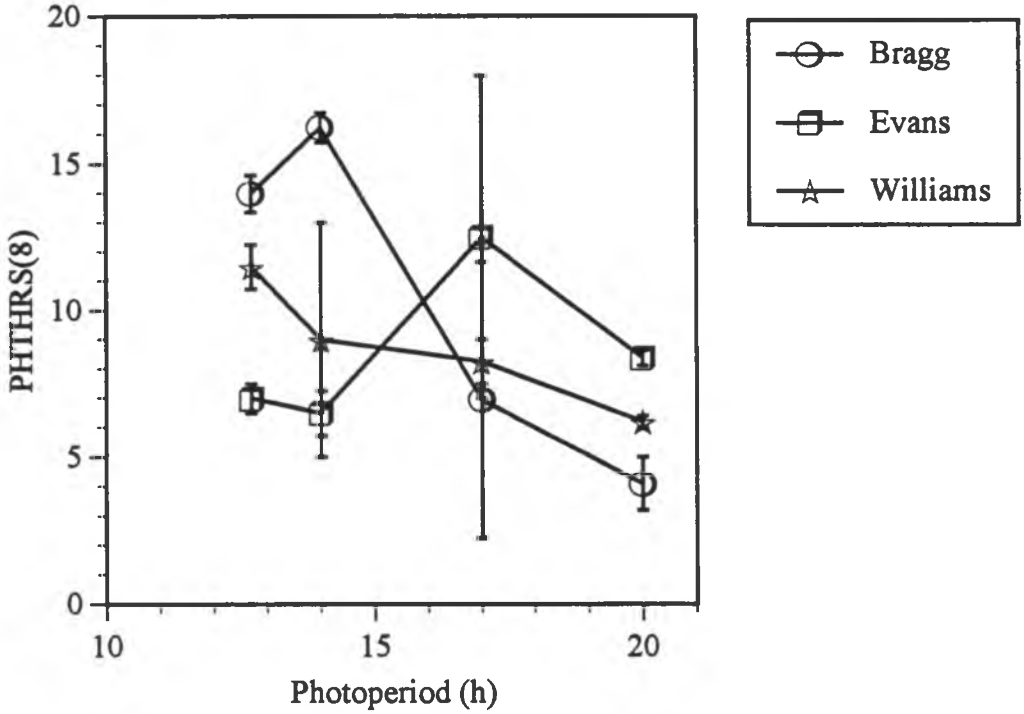

Figure 30. Photoperiod effect on estimating PHTHRS(8) genetic coefficient of SOYGRO for soybean cultivars 'Bragg', 'Evans', and 'Williams' using field data from 1990. Vertical bars are standard errors of the mean.

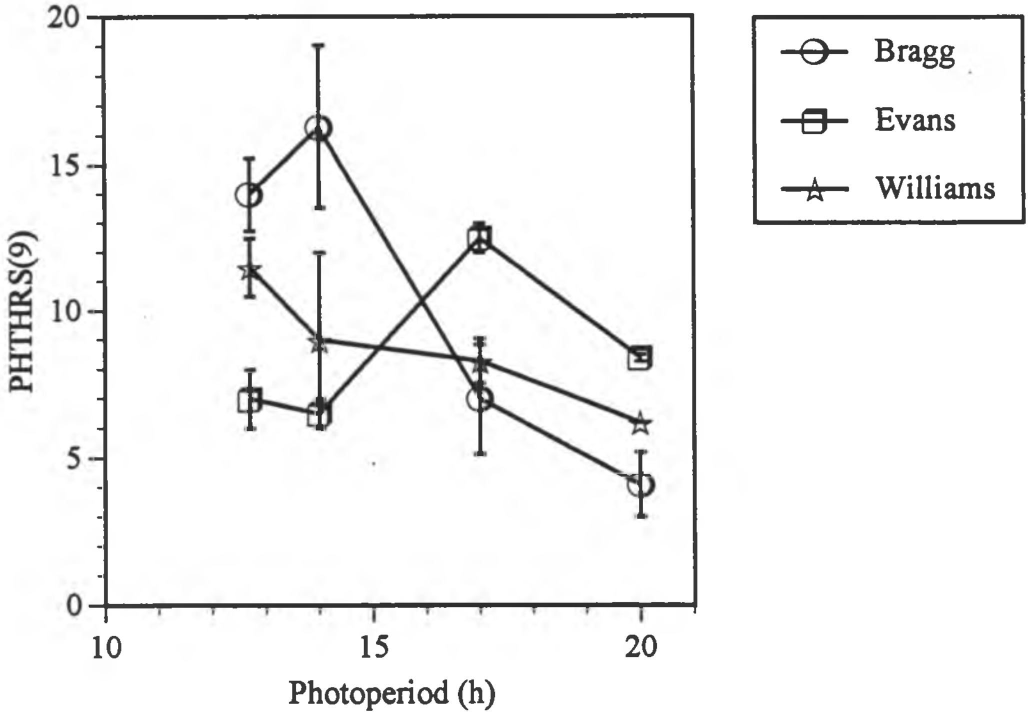

Figure 31. Photoperiod effect on estimating PHTHRS(9) genetic coefficient of SOYGRO for soybean cultivars 'Bragg', 'Evans', and 'Williams' using field data from 1990. Vertical bars are the standard errors of the mean.

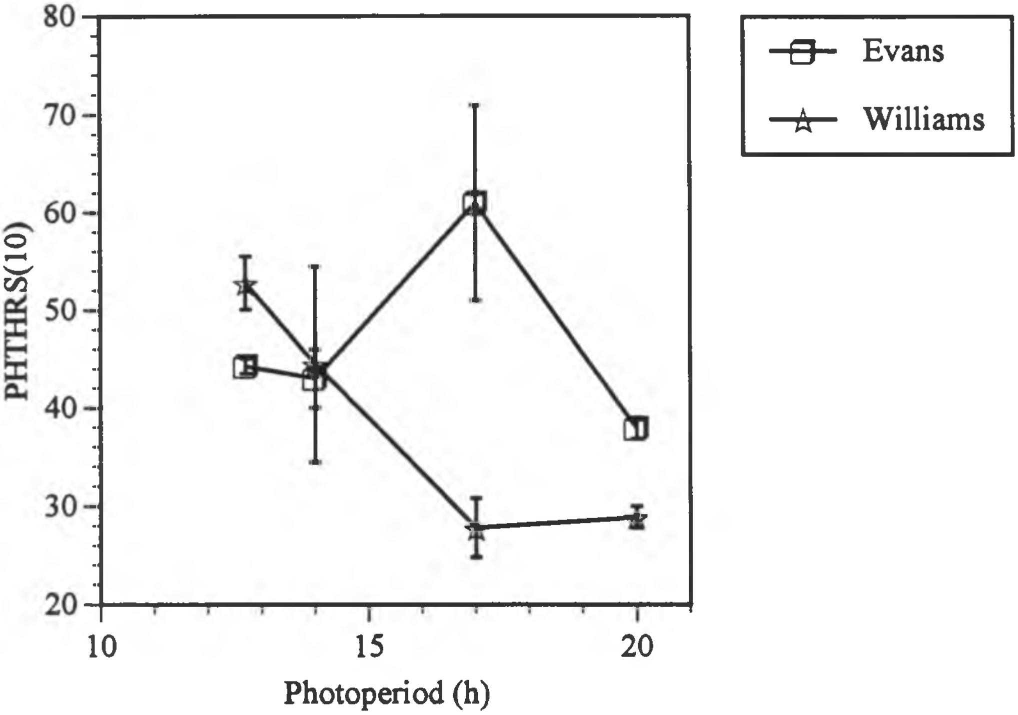

Figure 32. Photoperiod effect on estimating PHTHRS(10) genetic coefficient of SOYGRO for soybean cultivars 'Evans' and 'Williams' using field data from 1990. Vertical bars are standard errors of the mean.

Table 23. Mean squares from analysis of variance on fitted SOYGRO genetic coefficient TRIFOL, number of trifoliolates produced in one physiological day, for soybean cultivars grown at two sites on Maui Island, Hawaii, under five photoperiod treatments. Data for 'Bragg' are from 1988 and for 'Evans' from 1990.

Source	df	Bragg	Evans
Site	1	0.00829 *	0.000029 ns
Photoperiod	4	0.00347	0.019454
Error	4	0.00093	0.001274

ns not significant at the 0.05 probability level.
* significant at the 0.05 probability level.

'Bragg': 0.271 versus 0.214. However, no significant difference between sites was found in cultivar 'Evans'.

Area of a single leaf genetic coefficient, SIZELF, changed with photoperiod. The only significant source of variation was cultivar (Table 24). However, orthogonal linear trend comparison over photoperiod indicated that cultivars 'Bragg' and 'Evans' were significantly ($p>0.05$) different (Figure 33). 'Williams' had linear trend that was not different from 'Bragg' or 'Evans'. Generally, soybean produced larger leaf as photoperiod increased, and the leaf size increase was greater for the high latitude adapted cultivar 'Evans'. The seed per pod and shell growth rate genetic coefficients, SDPDVR and SHVAR, were typical. SDPDVR and SHVAR only had cultivar as a significant source of variation (Tables 25 and 26). This indicated that site and photoperiod did not affect the estimation of these genetic coefficients.

Table 24. Mean squares from analysis of variance on fitted SOYGRO genetic coefficients SIZELF and SLAVAR for soybean cultivars grown at two sites on Maui Island, Hawaii, under five photoperiod treatments in 1990. SIZELF data was collected from cultivars 'Bragg', 'Evans', and 'Williams'. SLAVAR data was collected from cultivars 'Evans' and 'Williams'.

Source	df	SIZELF[1]	df	SLAVAR[1]
Site	1	7121. ns	1	84.9 ns
Photoperiod	4	5873.	4	13420.9
Error a	4	1619.	4	801.0
Cultivar	2	7326. **	1	1711.3 ns
Photo x Cult	8	656. ns	4	473.2 ns
Error b	10	356.	5	1781.8

ns not significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Area of a normal leaf, cm^2.

[2] Specific leaf area of a new leaf.

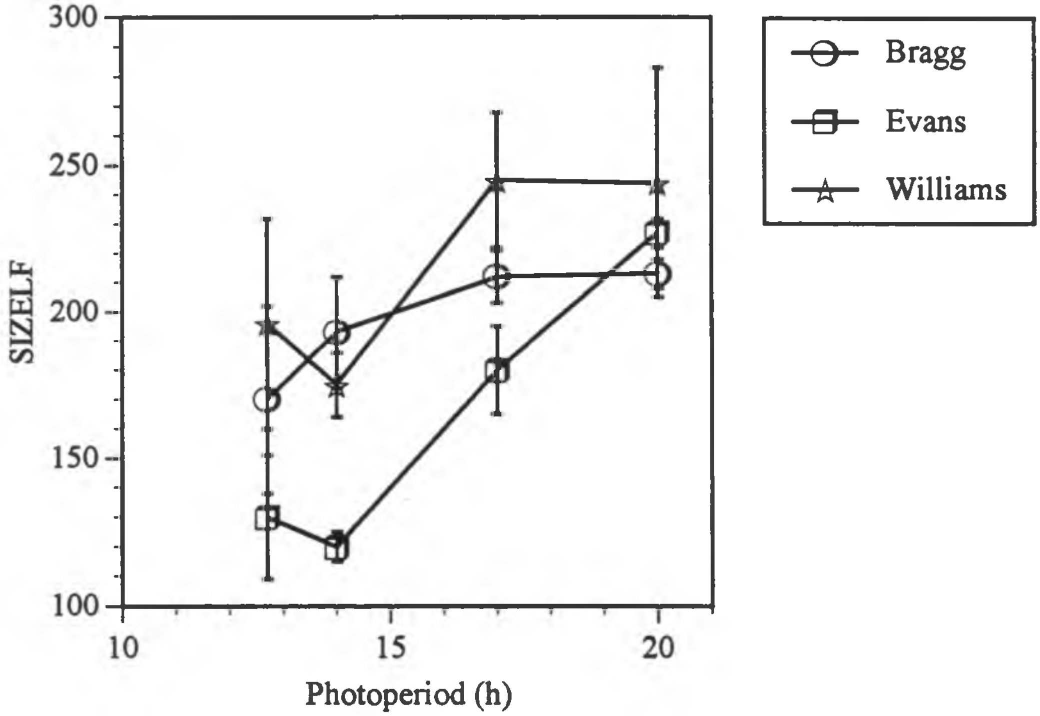

Figure 33. Photoperiod effect on estimating SIZELF genetic coefficient of SOYGRO for soybean cultivars 'Bragg', 'Evans', and 'Williams' using field data from 1990. Vertical bars are standard errors of the mean.

Table 25. Mean squares from analysis of variance on fitted SOYGRO genetic coefficients SDPDVR, FLWMAX, and PODVAR for soybean cultivars 'Bragg', 'Evans', and 'Williams' grown at two sites on Maui Island, Hawaii, under photoperiod treatments control, natural, and 14 h.

Source	df	SDPDVR[1]	df	FLWMAX[2] x 10^{-4}	df	PODVAR[3] x 10^{-3}
Site	1	0.2640 ns	1	4.34 ns	1	10.85 ns
Photoperiod	2	0.0234	2	4.13	2	10.32
Error a	2	0.0698	2	9.24	2	23.10
Cultivar	2	0.3296 **	2	13.53 ns	2	33.81 ns
Photo x Cult	4	0.0128 ns	4	2.81 ns	4	7.02 ns
Error b	6	0.0268	6	5.77	6	14.43

ns not significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Number of seeds pod^{-1}.

[2] Maximum number of flowering opening d^{-1} during flowering.

[3] Maximum number of pods initiated d^{-1} during podding.

Table 26. Mean squares from analysis of variance on fitted SOYGRO genetic coefficients SHVAR and SDVAR and the apparent photosynthetic factor PHFAC3 for soybean cultivars 'Bragg', 'Evans', and 'Williams' grown at two sites on Maui Island, Hawaii, under photoperiod treatments control, natural, and 14 h.

Source	df	SHVAR[1]	df	SDVAR[2]	df	PHFAC3[3]
Site	1	0.007 ns	1	0.0038 ns	1	0.186 ns
Photoperiod	2	0.170	2	0.0518	2	0.331
Error a	2	0.626	2	0.0478	2	0.215
Cultivar	2	23.627 **	2	0.1471 ns	2	0.147 ns
Photo x Cult	4	0.554 ns	4	0.1263 ns	4	0.166
Error b	6	1.110	6	0.1793	6	0.391 ns

ns not significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Maximum individual shell growth rate, mg d^{-1}.

[2] Maximum individual seed growth rate, mg d^{-1}.

[3] Photosynthetic rate correction factor.

Site, photoperiod, and cultivar did not affect the estimation of the genetic coefficients that determine specific leaf area (SLAVAR), maximum number of flowers per day (FLWVAR), maximum number of pods per day (PODVAR), and seed growth rate (SDVAR), and the photosynthetic rate factor (PHFAC3). In the analysis of variance, SLAVAR, FLWVAR, PODVAR, SDVAR, and PHFAC3 were not significantly different among sites, cultivars, and interaction between cultivar and photoperiod (Tables 24, 25, 26). The lack of significance may be due to independence of these coefficients from environmental and genotype factors, or imprecision in the experimental results.

Explicitly estimated genetic coefficients for CERES-Maize displayed some dependence on environment. The genetic coefficient that determined the thermal time from emergence to end of juvenile phase, P1, had significant year, cultivar, and cultivar-by-year interaction sources of variation (Table 27). The significant effect of year resulted from P1 values of 168 and 270 in 1989 and 1991, respectively. The difference in P1 values may be attributed to where temperature was measured. Air temperature was used to calculate thermal time for development from emergence to end of juvenile phase. However, soil temperature may be more closely related to development rate during this phase. Then, using the current calculation for P1, the difference in soil and air temperature can cause variation in P1 because thermal time will accumulate according to air temperature while soil temperature determines development rate. The soil temperature at 10 cm depth and air temperature was 23.4

Table 27. Mean squares from analysis of variance on explicit CERES-Maize genetic coefficients P1 and P5 for maize hybrids grown at two sites on Maui Island, Hawaii. P1 data were collected from control and natural photoperiod treatments for five maize hybrids in 1989 and 1991. P5 data were collected from five photoperiod treatments for Pioneer hybrids X304C, 3165, 3475, and 3790 in 1988 and 1990.

Source	df	P1 [1]	df	P5 [1]
Year	1	104684. *	1	20053. ns
Site(Year)	2	3232.	2	6346.
Photoperiod	1	1123.	4	2320.
Year x Photo	1	383. ns	4	1946. ns
Error	2	78.	8	4385.
Cultivar	4	1612. **	3	143787. **
Year x Cult	4	682. **	3	6516. ns
Photo x Cult	4	131. ns	12	4814. ns
Year x Photo x Cult	4	214. ns	12	1652. ns
Error	16	126.	30	4681.

ns not significant at the 0.05 probability level.

* significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Growing degree days from emergence to end of juvenile phase.

[2] Growing degree days from silking to physiological maturity.

°C and 21.3 °C in 1989 and 19.7 °C and 18.5 °C in 1991 during the first month after planting. The larger difference between soil and air temperatures indicated that less thermal time was accumulating while development was proceeding at a high rate in 1989. Therefore, the P1 value was less in 1989 than in 1991. There was a cultivar-by-year interaction that seemed to result from Pioneer hybrid 3165 accumulating more thermal time in 1991 than the other hybrids (figure 34).

The explicitly estimated photoperiod sensitivity genetic coefficient for CERES-Maize, P2, did not display any significant source of variation (Table 28). The lack of any significant factor to affect P2 may have been due to imprecision in the experimental design.

Explicitly calculated genetic coefficient that determined thermal time from silking to physiological maturity, P5, showed dependence on genotype. The significantly different P5 values among hybrids indicated that the time from silking to physiological maturity was only dependent on genotype (Table 27). However, orthogonal linear trend comparisons over photoperiod indicated that Pioneer hybrid X304C was different from Pioneer hybrids 3165 and 3475 (Figure 35). Yet, Pioneer hybrids 3165, 3475, and 3790 did not have significantly different linear trends over photoperiods.

The explicitly estimated number of kernels per plant genetic coefficient, G2, for the tropically adapted hybrid was highly sensitive to photoperiod. The significant sources of variation for G2 were cultivar and photoperiod-by-cultivar interaction

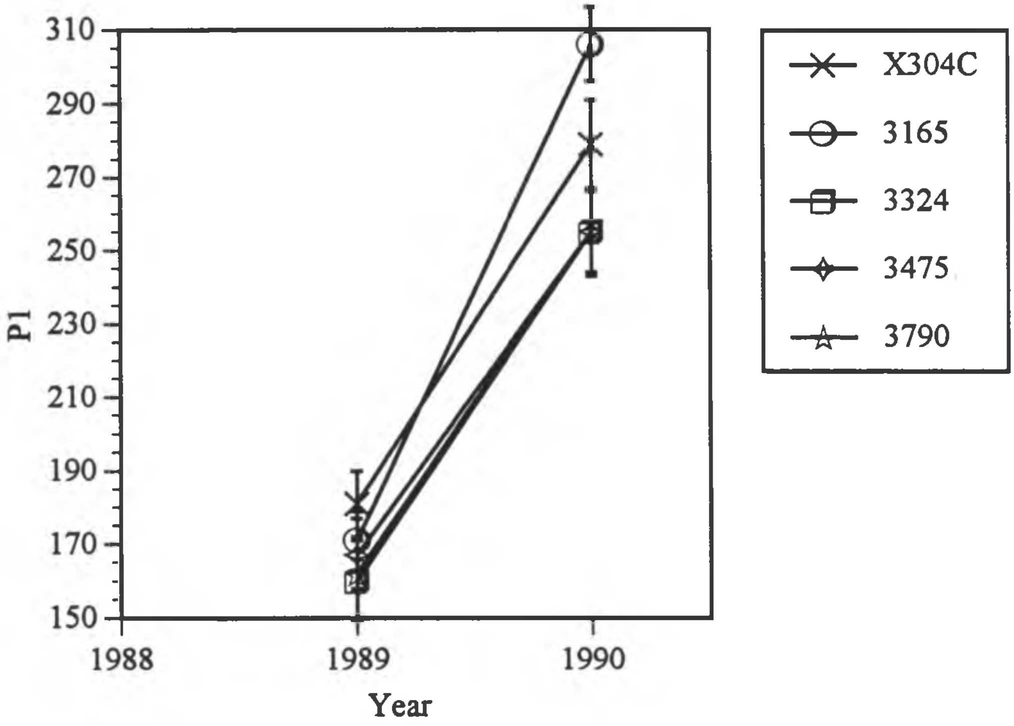

Figure 34. Year effect on estimating explicit P1 genetic coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 using field data from 1989 and 1990. Vertical bars are standard errors of the mean.

Table 28. Mean squares from analysis of variance on explicit CERES-Maize genetic coefficient P2 for five maize hybrids grown at two sites on Maui Island, Hawaii, under five photoperiod treatments in 1989 and 1990.

Source	df	P2[1]
Year	1	0.1217 ns
Error a	2	0.0482
Cultivar	4	0.0369 ns
Year x Cult	4	0.0218 ns
Error b	8	0.0317

ns not significant at the 0.05 probability level.

[1] Photoperiod sensitivity, days tassel initiation delays h^{-1}.

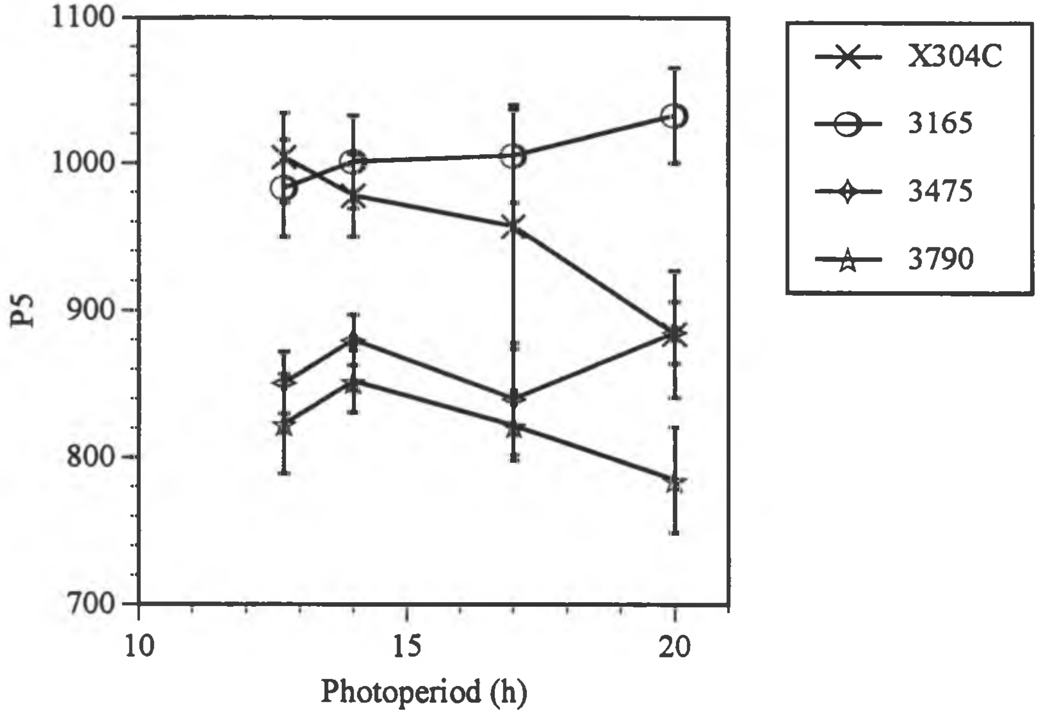

Figure 35. Photoperiod effect on estimating explicit P5 genetic coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3475, and 3790 using field data from 1988 and 1990. Vertical bars are standard errors of the mean.

(Table 29). Orthogonal linear trends over photoperiod indicated that the negative slope for Pioneer hybrid X304C was highly significantly different (p>0.01) from the other three hybrids that were fairly constant (Figure 36). The decreasing number of kernels was attributable to the increasing silking-tasseling interval with longer photoperiod that disrupted pollination for Pioneer hybrid X304C (Manrique and Hodges, 1991).

The kernel number response to photoperiod affected the explicitly estimated kernel growth rate genetic coefficient, G3. Although no significant sources of variation were found for G3 (Table 29), orthogonal linear trend over photoperiod revealed that only Pioneer hybrid X304C was different (p>0.01, p>0.05) compared to Pioneer hybrid 3165 and 3475 (Figure 37). While Pioneer hybrids 3165, 3475, and 3790 had reduced G3 as photoperiod increased, Pioneer hybrid X304C had increased G3. The increase in kernel growth rate for Pioneer hybrid can be due to the decrease in kernel number that allowed more available photosynthate to increase the size of the fewer pollinated kernels (Schoper et al., 1982) in a shorter filling period (Figure 35). Then, the effect photoperiod on kernel growth rate would be related to the photoperiod effect on kernel number.

The fitted CERES-Maize genetic coefficients that determine the thermal time from planting to emergence, P1, and from silking to physiological maturity, P5, showed similar dependence on environment as the explicitly calculated ones. Fitted P1 had significant year, cultivar, and year-by-cultivar interaction sources of variation

Table 29. Mean squares from analysis of variance on explicit CERES-Maize genetic coefficients G2 and G3 for Pioneer hybrids X304C, 3165, 3475, and 3790 grown at two sites on Maui Island, Hawaii, under five photoperiod treatments.

Source	df	G2[1]	df	G3[2]
Year	1	111169. ns	1	16.317 ns
Site(Year)	2	19982.	2	7.069
Photoperiod	4	35294.	4	0.126
Year x Photo	4	3207. ns	4	0.060 ns
Error	8	6942.	8	0.504
Cultivar	3	125588. **	3	0.821 ns
Year x Cult	3	4306. ns	3	0.243 ns
Photo x Cult	12	32072. **	12	0.434 ns
Year x Photo x Cult	12	3932. ns	12	0.129 ns
Error	30	3658.	30	0.410

ns not significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Potential number of kernels plant^{-1}.

[2] Potential kernel growth rate, mg kernel^{-1} d^{-1}.

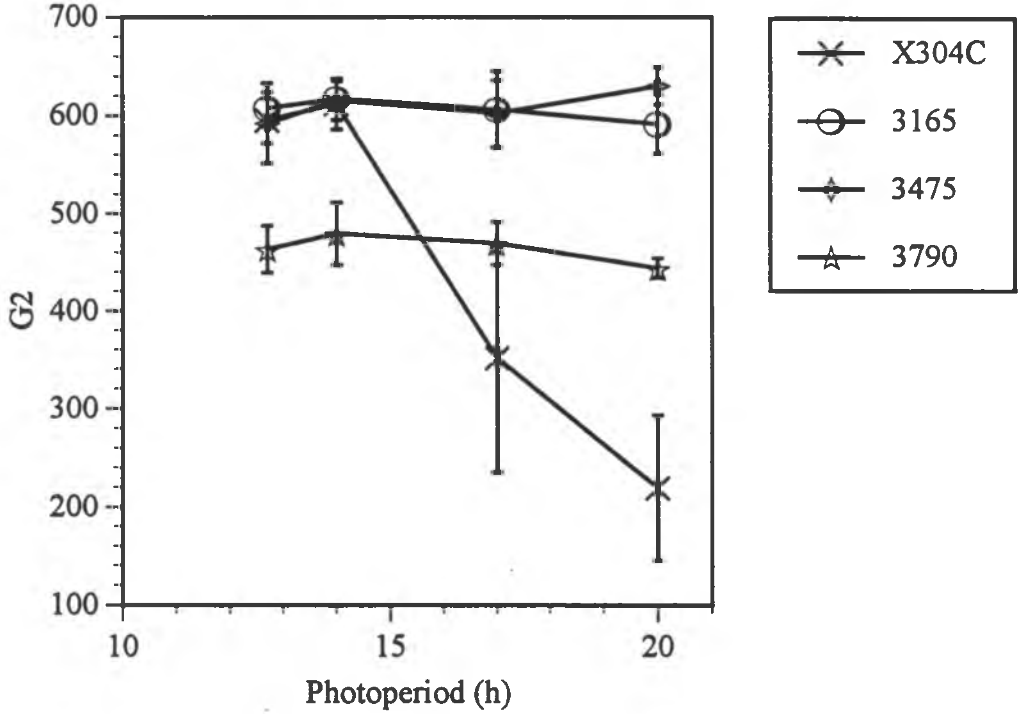

Figure 36. Photoperiod effect on estimating explicit G2 genetic coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3475, and 3790 using field data from 1988 and 1990. Vertical bars are standard errors of the mean.

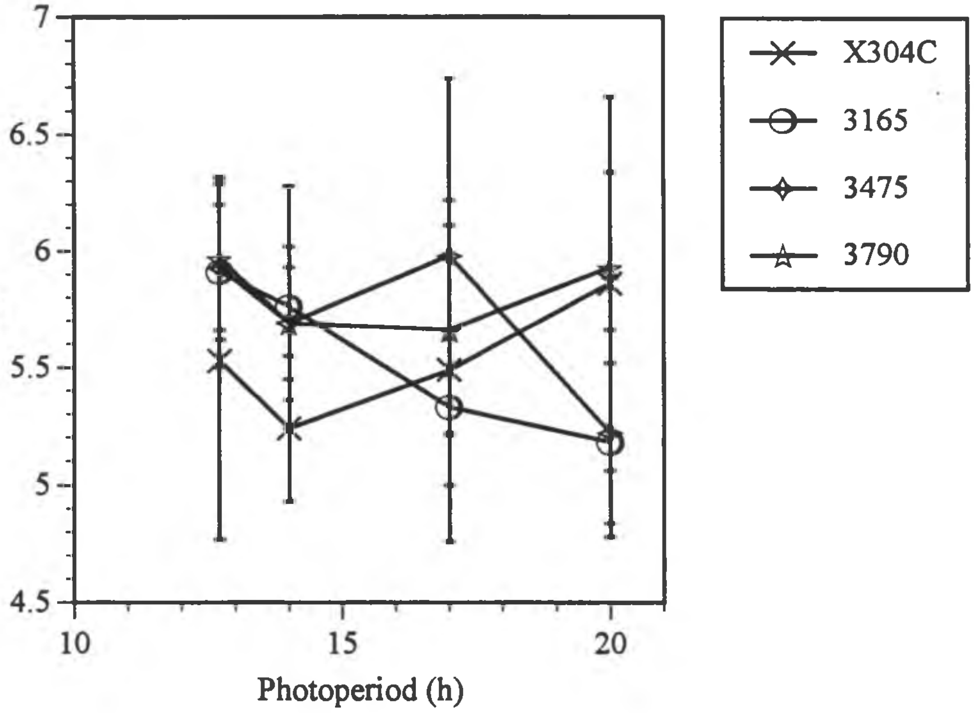

Figure 37. Photoperiod effect on estimating explicit G3 genetic coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3475, and 3790 using field data from 1988 and 1990. Vertical bars are standard errors of the mean.

(Table 30). The year-by-cultivar interaction resulted from Pioneer hybrid 3165 responding differently to year from the other hybrids (figure 38). Fitted P5 had cultivar as a significant source of variation (Table 30). While there was no significant photoperiod-by-cultivar interaction, orthogonal linear trend comparison over photoperiod revealed that Pioneer hybrid X304C was highly significantly ($p>0.01$) different from Pioneer hybrids 3165 and 3475 (figure 39). These results for the fitted P1 and P5 are almost identical to the explicitly calculated genetic coefficients. The similar results between the two methods were a consequence of using the same thermal time equation, temperature data, and dates to calculate the genetic coefficients.

Values for the fitted photoperiod sensitivity genetic coefficient, P2, were dependent on photoperiod. P2 had a highly significant ($p>0.01$) cultivar effect (Table 31). There was no significant photoperiod-by-cultivar interaction effect, but orthogonal linear trend over photoperiod comparisons showed significant differences between Pioneer hybrids X304C and 3165, 3165 and 3475, and 3165 and 3790 (figure 40). The P2 trend over photoperiod may be caused by the model assumption that the threshold photoperiod for delaying tassel initiation is 12.5 h. If the true threshold photoperiod were less than 12.5 h, then fitting the P2 value to match tassel initiation would be very large to correct for the delay already imposed by photoperiod below 12.5 h (figure 41). Furthermore, photoperiods close to 12.5 h would have large P2 values and decrease as photoperiod increased. This relationship of decreasing P2

Table 30. Mean squares from analysis of variance on fitted CERES-Maize genetic coefficients P1 and P5 for maize hybrids grown at two site on Maui Island, Hawaii. Data for P1 were collected from photoperiod treatments control and natural for five hybrids in 1989 and 1991. Data for P5 were collected from five photoperiod treatments for Pioneer hybrids X304C, 3165, 3475, and 3790 in 1988 and 1990.

Source	df	P1 [1]	df	P5 [2]
Year	1	121000. *	1	3380. ns
Site(Year)	2	5996.	2	6483.
Photoperiod	1	1103.	4	1922.
Year x Photo	1	490.	4	1373. ns
Error	2	36.	8	4194.
Cultivar	4	1974. **	3	157535. **
Year x Cult	4	1255. ns	3	7370. ns
Photo x Cult	4	57. ns	12	5371. ns
Year x Photo x Cult	4	154. ns	12	1742. ns
Error	16	148.	30	4590.

ns not significant at the 0.05 probability level.

* significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Growing degree days from emergence to end of juvenile phase.

[2] Growing degree days from silking to physiological maturity.

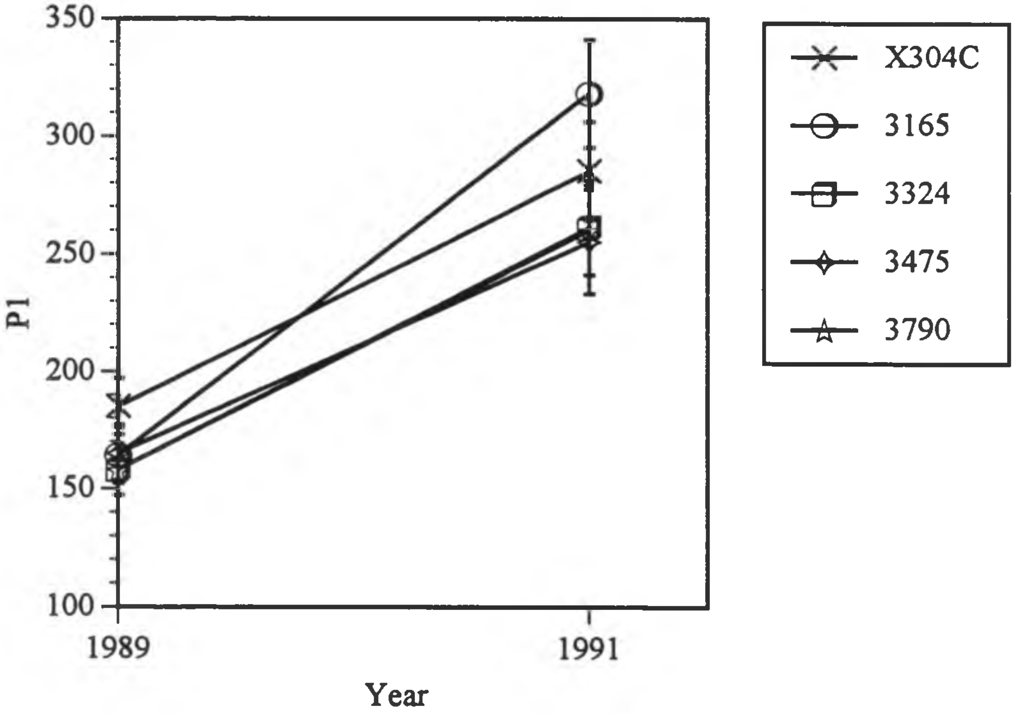

Figure 38. Year effect on estimating fitted P1 genetic coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 using field data from 1989 and 1991. Vertical bars are standard errors of the mean.

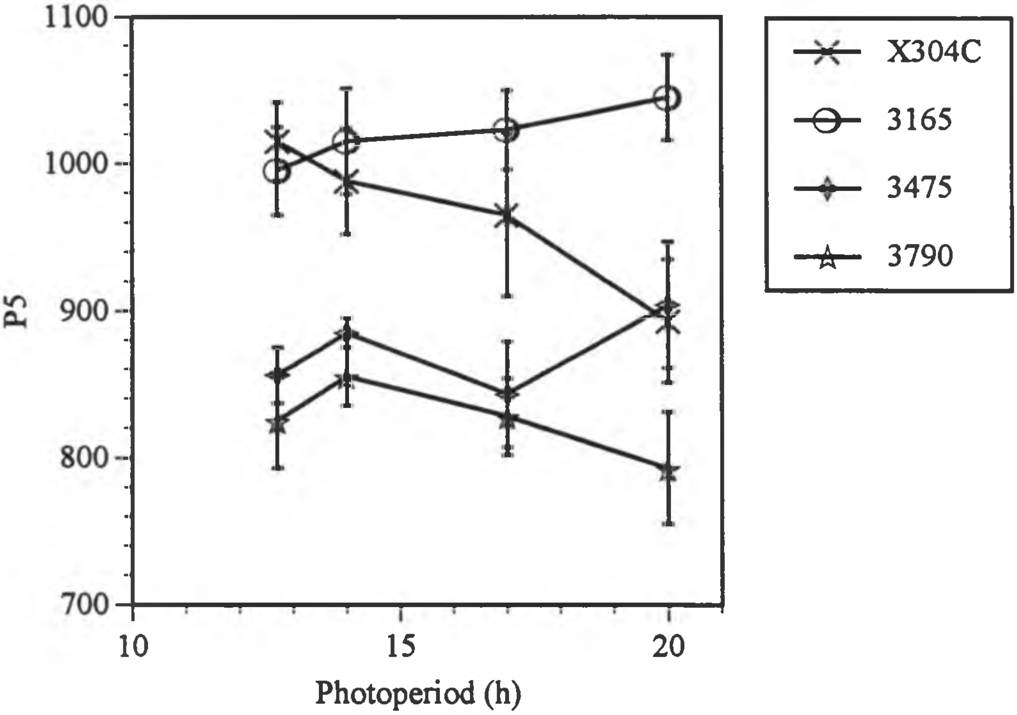

Figure 39. Photoperiod effect on estimating fitted P5 genetic coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3475, and 3790 using field data from 1988 and 1990. Vertical bars are standard errors of the mean.

Table 31. Mean square from analysis of variance on fitted CERES-Maize genetic coefficient P2 for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 grown at two sites on Maui, Hawaii, under five photoperiod treatments in 1990.

Source	df	P1 [1]
Site	1	3.001 ns
Photoperiod	4	3.214
Error a	4	0.795
Cultivar	4	4.480 **
Photo x Cult	16	0.271 ns
Error b	20	0.239

ns not significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] growing degree days from emergence to end of juvenile phase.

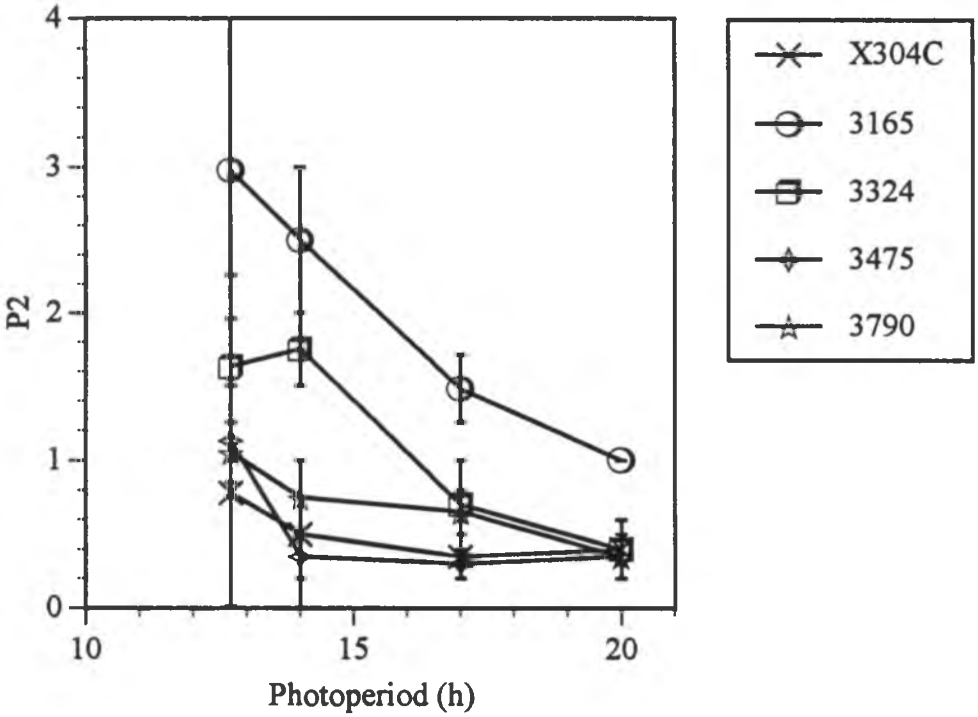

Figure 40. Photoperiod effect on estimating fitted P2 genetic coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 using field data from 1990. Vertical bars are standard errors of the mean.

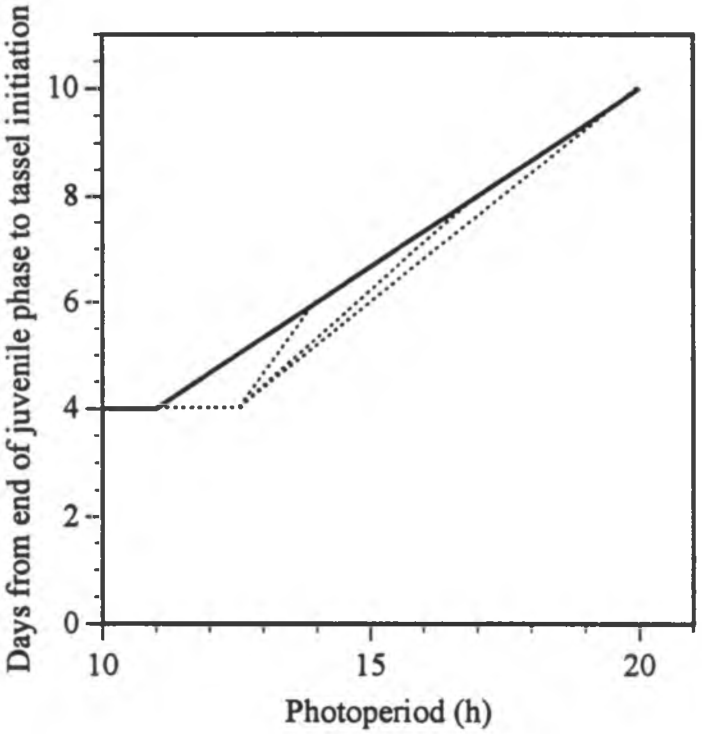

Figure 41. Effect of reducing threshold photoperiod from 12.5 to 10 h on fitted P2 values. Slope of dotted lines are hypothetical fitted P2 values. Solid line is hypothetical plant response to photoperiod.

value with increasing photoperiod was seen in the fitted P2 genetic coefficient (figure 40).

The fitted kernel number per plant and kernel growth rate genetic coefficients, G2 and G2, showed photoperiod dependence for some cultivars. G2 had highly significant cultivar and photoperiod-by-cultivar interaction sources of variation (Table 32). Linear trend over photoperiod comparisons revealed that Pioneer hybrid X304C was highly significantly ($p>0.01$) different from the other hybrids (figure 42). Pioneer hybrid X304C had decreased number of kernels per plant as photoperiod increased while the other hybrids had relatively stable kernel number as photoperiod increased. The decreased kernels per plant for Pioneer hybrid X304C were probably due to desynchronization of tassel and silk growth stages. G3 had significant cultivar effect. There was no significant photoperiod-by-cultivar effect, but linear trends over photoperiod indicated that Pioneer hybrid X304C was significantly different from the others and Pioneer hybrid 3475 was different from 3790 (Table 32). Pioneer hybrid X304C had increased G3 as photoperiod increased while G3 values for Pioneer hybrids 3165, 3324, and 3475 decreased (figure 43). Pioneer hybrid 3790 had G3 that remained relatively stable as photoperiod increased. The relationship between photoperiod and fitted G2 and G3 values were similar to the explicitly calculated G2 and G3 values. So, similar causes for these relationships can be assumed.

Curiously, year-by-cultivar interaction was significant for the crop coefficient that determines the thermal time from planting to emergence, P9. Analysis of

Table 32. Mean squares from analysis of variance on fitted CERES-Maize genetic coefficients G2 and G3 for five maize hybrids grown at two sites on Maui Island, Hawaii, under five photoperiod treatments.

Source	df	G2 [1]	df	G3 [2]
Site	1	5429. ns	1	2.469 ns
Photoperiod	4	62069.	4	0.693
Error a	4	3467.	4	0.482
Cultivar	4	132084. **	4	1.645 **
Photo x Cult	16	30640. **	16	0.617 ns
Error b	20	7198.	20	0.334

ns not significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Potential number of kernels plant^{-1}.

[2] Potential kernel growth rate, mg kernel^{-1} d^{-1}.

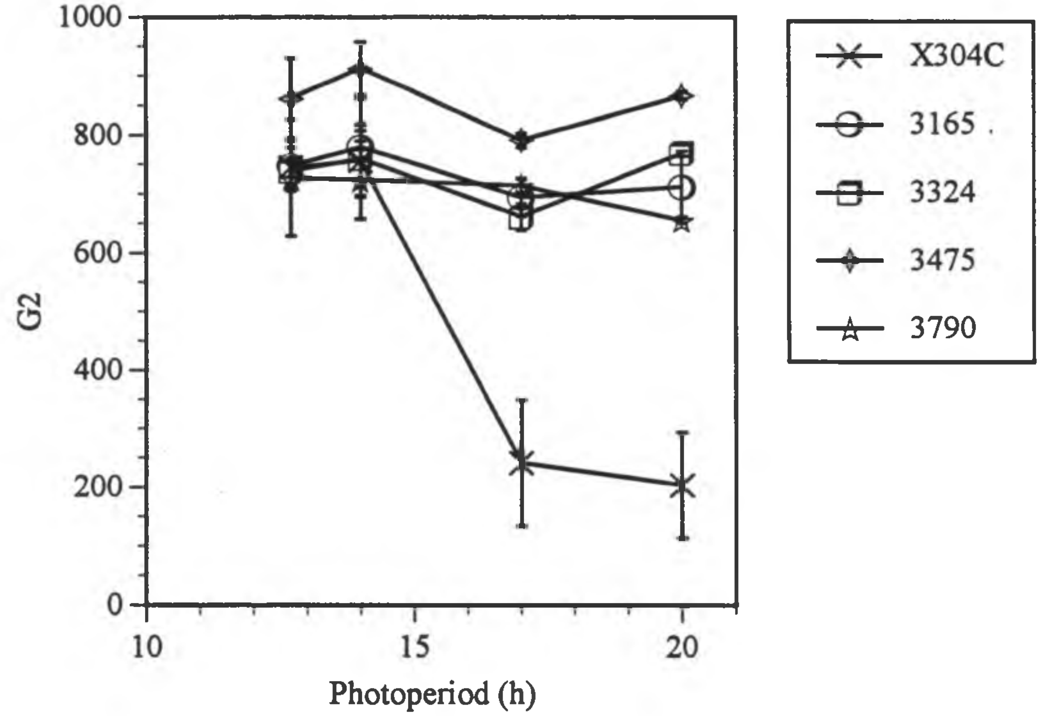

Figure 42. Photoperiod effect on estimating fitted G2 genetic coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 using field data from 1990. Vertical bars are standard errors of the mean.

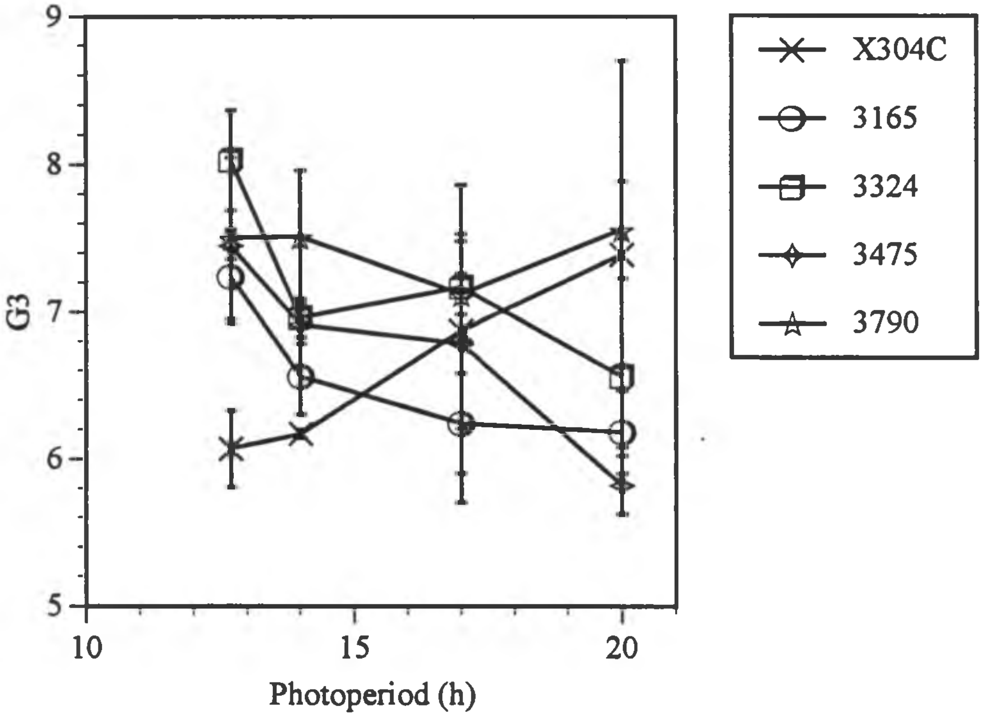

Figure 43. Photoperiod effect on estimating fitted G3 genetic coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 using field data from 1990. Vertical bars are standard errors of the mean.

variance showed no cultivar differences for P9, but a highly significant year-by-cultivar interaction effect was present (Table 33). Pioneer hybrid X304C had a constant P9 value across years while the other hybrids had lower P9 values in 1990 (figure 44). The soil-air temperature difference was almost identical for the maize plantings in 1988 and 1990. Soil temperature was 23.6 and 22.6 °C in 1988 and 1990 which would not cause differences in emergence due to differing cold tolerance. Hence, soil-air temperature difference and hybrid temperature tolerance cannot account for these results.

Photoperiod affected the fitted thermal time to add a leaf primordia, XLPGDD. XLPGDD was significantly different among cultivars (Table 34). There was no significant photoperiod-by-cultivar interaction, but orthogonal linear trend over photoperiods indicated that Pioneer hybrid X304C and 3324 were different ($p>0.05$). Pioneer hybrid X304C had XLPGDD that decreased as photoperiod increased while Pioneer hybrid 3324 showed a slighter decrease (figure 45). Generally, leaf primordia seemed to initiate faster under longer photoperiod that caused the significant linear trends.

The thermal time to fully expand one leaf, PCHRON, seemed related to photoperiod. PCHRON had no significant sources of variation (Table 34). However, orthogonal linear trend over photoperiods indicated that Pioneer hybrid X304C was significantly different from Pioneer hybrids 3165, 3475, and 3790. Pioneer hybrid X304C required more thermal time to expand a leaf as photoperiod increased, but

Table 33. Mean squares from analysis of variance on fitted CERES-Maize crop coefficient P9 for Pioneer hybrids X304C, 3165, 3475, and 3790 grown at two sites on Maui Island, Hawaii, under five photoperiod treatments.

Source	df	P9 [1]
Year	1	1805.00 ns
Site(Year)	2	342.50
Photoperiod	4	14.38
Year x Photo	4	14.38 ns
Error	8	14.38
Cultivar	3	6.67 ns
Year x Cult	3	165.00 **
Photo x Cult	12	3.54 ns
Year x Photo x Cult	12	3.54 ns
Error	30	13.33

ns not significant at the 0.05 probability level.
** significant at the 0.01 probability level.

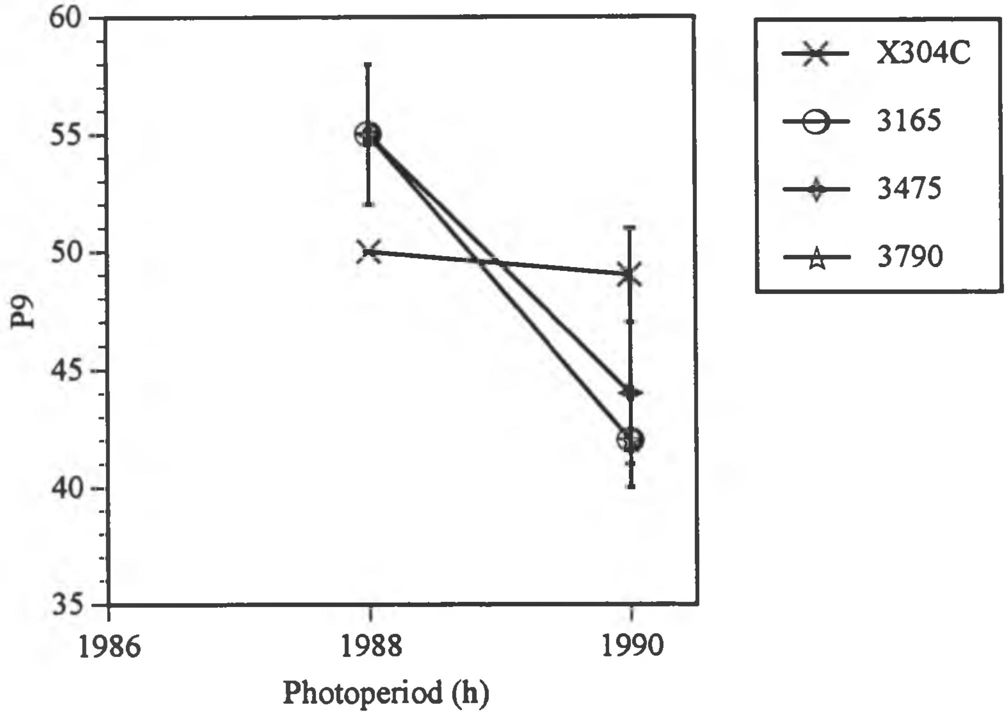

Figure 44. Year effect on estimating fitted P9 crop coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3475, and 3790 using field data from 1988 and 1990. Vertical bars are standard errors of the mean.

Table 34. Mean squares from analysis of variance on fitted CERES-Maize genetic coefficients XLPGDD and PCHRON for five maize hybrids grown at two sites on Maui Island, Hawaii, under five photoperiod treatments.

Source	df	XLPGDD [1]	df	PCHRON [2]
Site	1	12.80 ns	1	0.980 ns
Photoperiod	4	49.68	4	33.530
Error a	4	2.43	4	2.030
Cultivar	4	239.42 **	4	17.380 ns
Photo x Cult	16	5.21 ns	16	11.618 ns
Error b	20	3.67	20	7.220

ns not significant at the 0.05 probability level.

* significant at the 0.05 probability level.

** significant at the 0.01 probability level.

[1] Growing degree days to produce one leaf primordia.

[2] Growing degree days for one leaf tip to emerge.

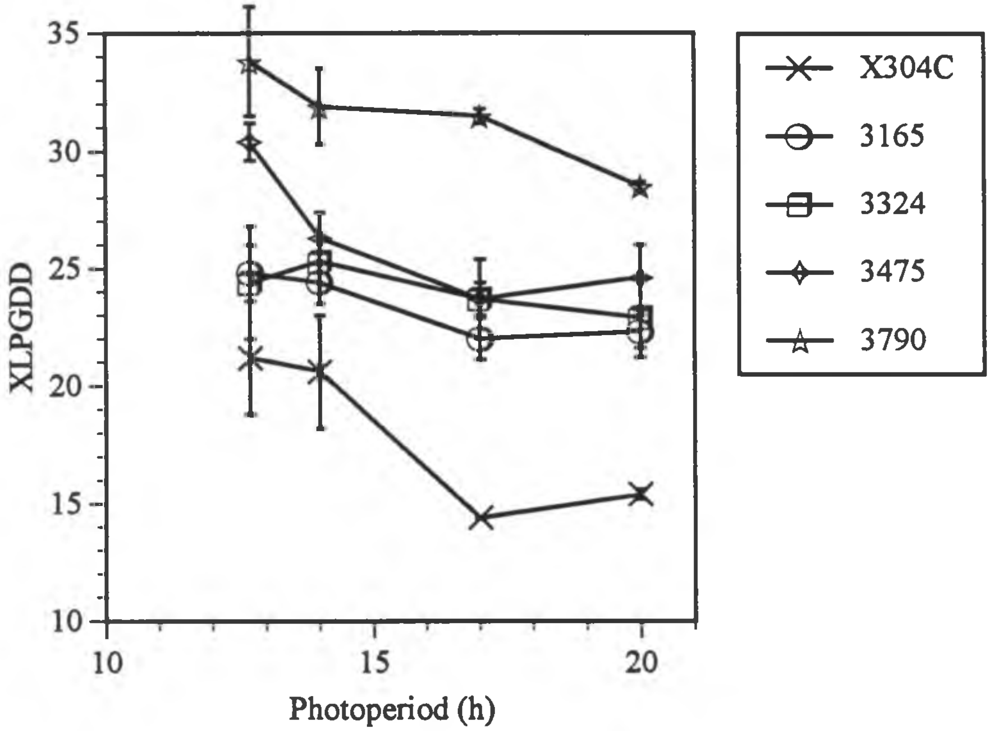

Figure 45. Photoperiod effect on estimating fitted XLPGDD crop coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 using field data from 1990. Vertical bars are standard errors of the mean.

Pioneer hybrids 3165, 3475, and 3790 did not (figure 46). The thermal time to expand a leaf was related to photoperiod, but the relation was cultivar dependent.

The significant environment-by-genotype interactions for the genetic coefficients may be attributable to errors in field data, genetic coefficient estimation method, or model assumptions. One cause of field data error may be that the light quality difference between artificial and sun light may have affected growth or development. The natural photoperiod treatment had the same photoperiod length as the control. In the natural photoperiod treatment, the artificial light extension before sunrise and after sunset was equivalent to the civil twilight, so differences between the natural and control may be due to different light quality not photoperiod.

The error analysis for soybean comparison between the control and natural photoperiod treatments showed little differences for development, but growth characteristics displayed some difference especially for weight seed^{-1} and seeds pod^{-1}. Because the light quality of the artificial light may have affected development and growth, a test comparing the control and natural photoperiod treatments was conducted with Willmott's (1981) error analysis statistics where model predictions were plotted against observed values. Soybean development did not seem to be affected by light quality. The time to growth stages emergence, flowering, and physiological maturity and the number of nodes on the mainstem were not greatly affected when exposed to artificial lights. The time to emergence, flowering, physiological maturity, and node number had indices of agreement of 0.94 or greater

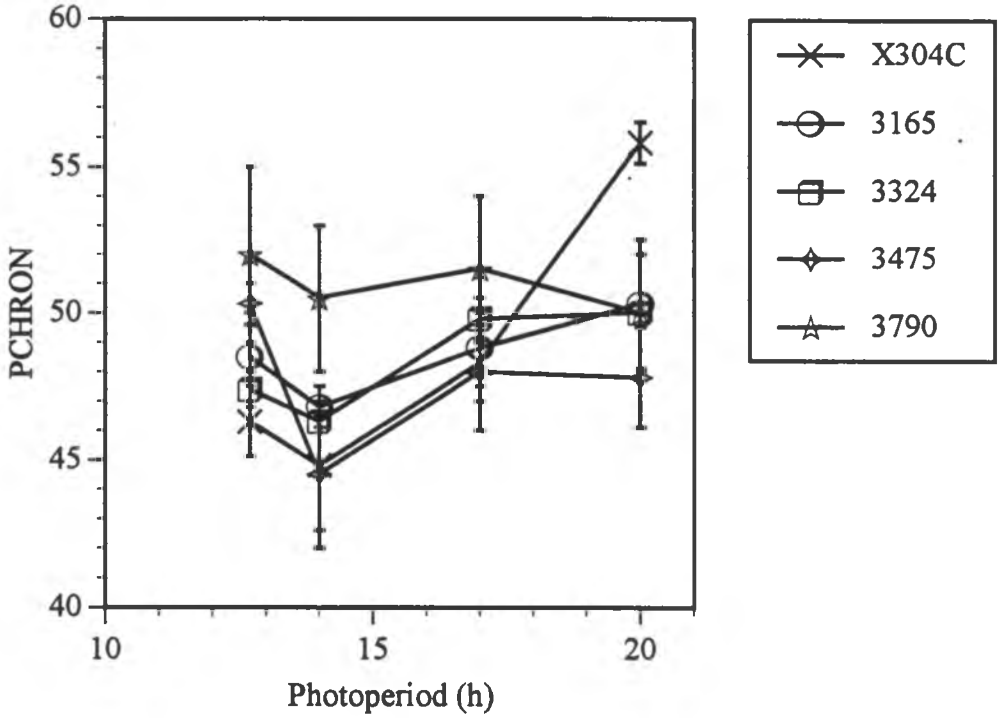

Figure 46. Photoperiod effect on estimating fitted PCHRON crop coefficient of CERES-Maize for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790 using field data from 1990. Vertical bars are standard errors of the mean.

(Table 35). Further, for the phase durations, a greater proportion of mean square error (MSE) was unsystematic that signified most of the variation between the two treatments was random. Aboveground biomass, seed yield, and pod number m^{-2} were strongly related despite artificial light exposure. The indices of agreement for the three characteristics were 0.86 to 0.91 despite a relatively high mean absolute error (Table 36). Aboveground biomass and pod number m^{-2} had high proportions of systematic MSE that was indicative of a multiplicative bias rather than additive. Seed yield had MSE equally partitioned between systematic and unsystematic (Table 36). The yield components weight $seed^{-1}$ and seeds pod^{-1} had relatively low indices of agreement, 0.79 and 0.76 (Table 36). Both yield components had very high proportions of unsystematic error compared to systematic. However, the relatively poor relation between the photoperiod treatments for weight $seed^{-1}$ and seeds pod^{-1} seemed to be caused by the data from the cultivar 'Bragg' at Kuiaha in 1989. When this data point was eliminated, the indices of agreement increased from 0.79 to 0.83 and 0.76 to 0.85 for weight $seed^{-1}$ and seeds pod^{-1}. So, while not firmly substantiated, light quality in the artificially extended photoperiod treatments may have affected the growth characteristics weight $seed^{-1}$ and seeds pod^{-1}, but not biomass, seed yield, pod number m^{-2}, and development.

Light quality effects on maize development and growth seemed minimal. Error analysis between the control and natural photoperiod treatments for the development characteristics days to tassel initiation, silking, and physiological

Table 35. Regression and error analysis for control and natural photoperiod treatments on development of soybean cvs. 'Bragg', 'Evans', 'Jupiter', and 'Williams'.

Statistic	Emergence (DAP[1])	Flowering (DAP[1])	Physiological maturity (DAP[1])	Mainstem nodes
slope	0.88	1.07	1.02	1.09
y-intercept	0.99	-2.31	1.56	0.17
r^2	0.81	0.96	0.96	0.94
control mean	5.68	49.9	105.	10.7
natural mean	5.96	50.9	109.	11.9
mean absolute error	0.57	2.63	4.55	1.27
RMSE [2]	0.96	4.83	6.96	1.57
MSE(u)/MSE [3]	0.84	0.87	0.63	0.41
MSE(s)/MSE [3]	0.16	0.13	0.37	0.59
MSE(a)/MSE [3]	1.06	0.23	0.050	0.012
MSE(p)/MSE [3]	0.61	0.55	0.15	0.44
MSE(i)/MSE [3]	-1.51	-0.66	0.17	0.14
index of agreement	0.95	0.99	0.98	0.96

[1] Days after planting.

[2] Root mean square error

[3] MSE, MSE(u), MSE(s), MSE(a), MSE(p), MSE(i) are mean square error, and unsystematic, systematic, additive, proportional, and interdependence mean square error.

Table 36. Regression and error analysis for control and natural photoperiod treatments on growth of soybean cvs. 'Bragg', 'Evans', 'Jupiter', and 'Williams'.

Statistic	Yield (kg ha^{-1})	Weight seed^{-1} (g)	Seeds pod^{-1}	Pods m^{-2}	Biomass (kg ha^{-1})
slope	1.52	0.78	0.56	1.4	1.5
y-intercept	-643.	0.046	0.69	-33.	-883.
r^2	0.82	0.42	0.35	0.90	0.91
control mean	3367.	0.203	1.80	1018.	7307.
natural mean	4473.	0.204	1.70	1363.	10016.
MAE [1]	1298.	0.013	0.27	389.	3000.
RMSE [2]	2227.	0.017	0.34	584.	4992.
MSE(u)/MSE [3]	0.49	0.94	0.68	0.39	0.33
MSE(s)/MSE [3]	0.51	0.058	0.32	0.61	0.67
MSE(a)/MSE [3]	0.083	7.1	4.3	0.0031	0.031
MSE(p)/MSE [3]	0.88	6.9	5.8	0.68	0.89
MSE(i)/MSE [3]	-0.45	-14.	-9.8	-0.072	-0.25
d [4]	0.86	0.79	0.76	0.91	0.90

[1] Mean absolute error

[2] Root mean square error

[3] MSE, MSE(u), MSE(s), MSE(a), MSE(p), MSE(i) are mean square error, and unsystematic, systematic, additive, proportional, and interdependence mean square error.

[4] Index of agreement

maturity and total leaf number showed high agreement. The index of agreement was 0.97 to 0.99 for development attributes (Table 37). Further, the mean absolute errors were very low compared to the means, the regression lines had slopes were nearly one and the y-intercepts close to zero, and unsystematic mean square errors dominated systematic for most characteristics (Table 37). Similarly, high agreement between the two photoperiod treatments was present for maize growth attributes. The indices of agreement for yield, kernel weight, kernels m^{-2}, and aboveground biomass were 0.94 to 0.98 (Table 38). The regression line slope and y-intercept, mean absolute error, and unsystematic error were also indicated high agreement between the photoperiod treatments. So, light quality of incandescent lamps before sunrise and after sunset did not seem to affect maize development and growth.

Subsamples within photoperiod treatments indicated that measurement error and within plot heterogeneity in a photoperiod treatment was small. The subsample variance represents the accumulation of errors in measurement in the field and laboratory, and plot heterogeneity. The subsample variance was used to estimate the precision of the within plot cultivar means for development and growth characteristics, i.e., the standard error. The standard error was very low in relation to the overall range of values for days to development stages, yield, yield components, and aboveground biomass weight (Figures 47 to 70). The small measurement errors would not fully account for differences between observed and simulated characteristics.

Table 37. Regression and error analysis for corn development in control and natural photoperiod treatments of Pioneer hybrids X304C, 3165, 3324, 3475, and 3790.

Statistic	Tassel initiation (DAP[1])	Silking (DAP[1])	Physiological maturity (DAP[1])	Leaf number [2]
slope	0.94	1.0	0.98	0.89
y-intercept	0.54	-0.91	2.3	2.1
r^2	0.95	0.97	0.95	0.92
control mean	28.0	70.8	136.	16.8
natural mean	26.8	70.3	135.	17.1
MAE [3]	1.3	1.5	3.3	0.53
RMSE [4]	1.7	2.1	4.5	0.68
MSE(u)/MSE [5]	0.50	0.95	0.94	0.68
MSE(s)/MSE [5]	0.50	0.052	0.058	0.32
MSE(a)/MSE [5]	0.1	0.19	0.26	9.8
MSE(p)/MSE [5]	1.0	0.045	0.54	7.3
MSE(i)/MSE [5]	-0.64	-0.18	-0.75	-17.
d [6]	0.98	0.99	0.99	0.97

[1] Days after planting.

[2] Total leaf number plant^{-1}.

[3] Mean absolute error.

[4] Root mean square error.

[5] MSE, MSE(u), MSE(s), MSE(a), MSE(p), MSE(i) are mean square error, and unsystematic, systematic, additive, proportional, and interdependence mean square error.

[6] Index of agreement.

Table 38. Regression and error analysis for corn growth in control and natural photoperiod treatments of Pioneer hybrids X304C, 3165, 3324, 3475, and 3790.

Statistic	Yield ($kg\ ha^{-1}$)	Kernel weight (g)	Kernels m^{-2}	Biomass ($kg\ ha^{-1}$)
slope	1.0	1.0	0.96	1.1
y-intercept	104.	-0.0084	253.	-580.
r^2	0.89	0.84	0.80	0.94
control mean	11434.	0.308	3049.	20297.
natural mean	11898.	0.304	3175.	21480.
MAE [1]	1229.	0.018	319.	2182.
RMSE [2]	1620.	0.022	401.	2858.
MSE(u)/MSE [3]	0.91	0.96	0.89	0.76
MSE(s)/MSE [3]	0.089	0.040	0.11	0.24
MSE(a)/MSE [3]	0.0041	0.13	0.40	0.041
MSE(p)/MSE [3]	0.057	0.027	0.11	0.45
MSE(i)/MSE [3]	0.029	-0.12	-0.40	-0.25
d [4]	0.97	0.95	0.94	0.98

[1] Mean absolute error.

[2] Root mean square error.

[3] MSE, MSE(u), MSE(s), MSE(a), MSE(p), MSE(i) are mean square error, and unsystematic, systematic, additive, proportional, and interdependence mean square error.

[4] Index of agreement.

Error analysis for the soybean simulations with fitted genetic coefficients indicated that poor comparisons between simulated and observed characteristics resulted from poor quality input and model bias. The high indices of agreement between simulation and observation for the days to growth stages indicated that the model performed well for development. However, the relatively small deviation of the simulation from observation was mostly attributable to input. Time to flowering had evenly proportioned systematic and unsystematic error that indicated both variances in inputs and model bias caused the simulation to deviate from the observed (Table 39, Figure 47). Days to post-flowering stages had greater proportions of unsystematic error than systematic (Table 39, Figures 48 and 49). The greater unsystematic error indicated input variation was the major cause for simulation to deviate from observation. For growth characteristics, the deviation of simulation from observation was mostly due to input variation. Yield, weight seed^{-1}, seeds m^{-2}, and aboveground biomass and stem weights at harvest maturity were poorly simulated as seen in the low indices of agreement (Table 40, Figures 50 to 54). The systematic root mean square error (RMSE(s)) was higher than the unsystematic root means square error (RMSE(u)) in yield (Table 39). The high RMSE(s) suggested that bias in the model was the major cause of deviations for yield. However, the yield components weight seed^{-1} and seeds m^{-2} had higher RMSE(u) than RMSE(s) that demonstrated input variation was more important in producing the simulation deviations. Since yield is a function of weight seed^{-1} and seeds m^{-2}, the underlying

Table 39. Regression and error analysis of soybean simulated with fitted genetic coefficients vs. observed days to developmental stages for cultivars 'Bragg', 'Evans', 'Jupiter', and 'Williams'.

Statistic	First flower (DAP[1])	Full pod (DAP[1])	Physiological mature (DAP[1])
slope	0.64	0.73	1.3
y-intercept	19	18	-27
r^2	0.70	0.71	0.81
observed mean	59	72	112
observed sd	34	40	36
simulated mean	57	70	118
simulated sd	26	34	52
MAE [2]	8.8	11	16
RMSE[3]	19	21	26
RMSE(u)[4]	14	18	23
RMSE(s)[5]	12	11	12
d [6]	0.89	0.91	0.91

[1] Days after planting.

[2] Mean absolute error.

[3] Root mean square error.

[4] Root mean square error, unsystematic

[5] Root mean square error, systematic

[6] Index of agreement.

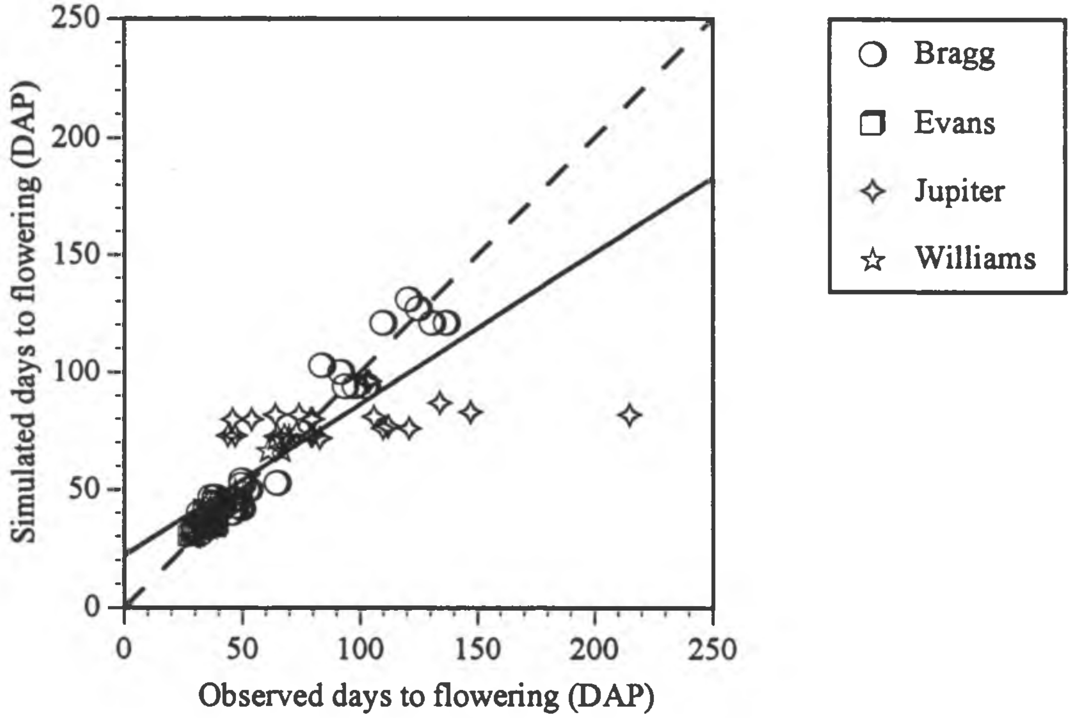

Figure 47. Comparison of observed and simulated days to flowering for four soybean cultivars. Solid line is linear regression where y = 0.64 x + 19. Standard error for observations is 2.57.

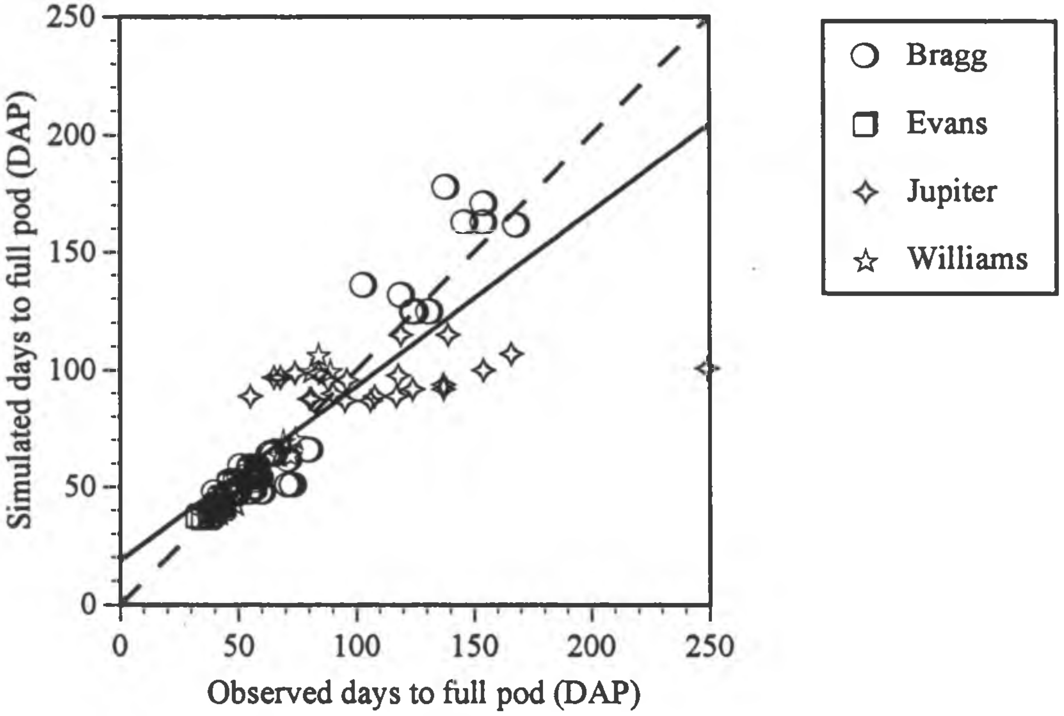

Figure 48. Comparison of observed and simulated days to full pod using fitted genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 0.73 x + 18. Standard error for obervations is 2.42.

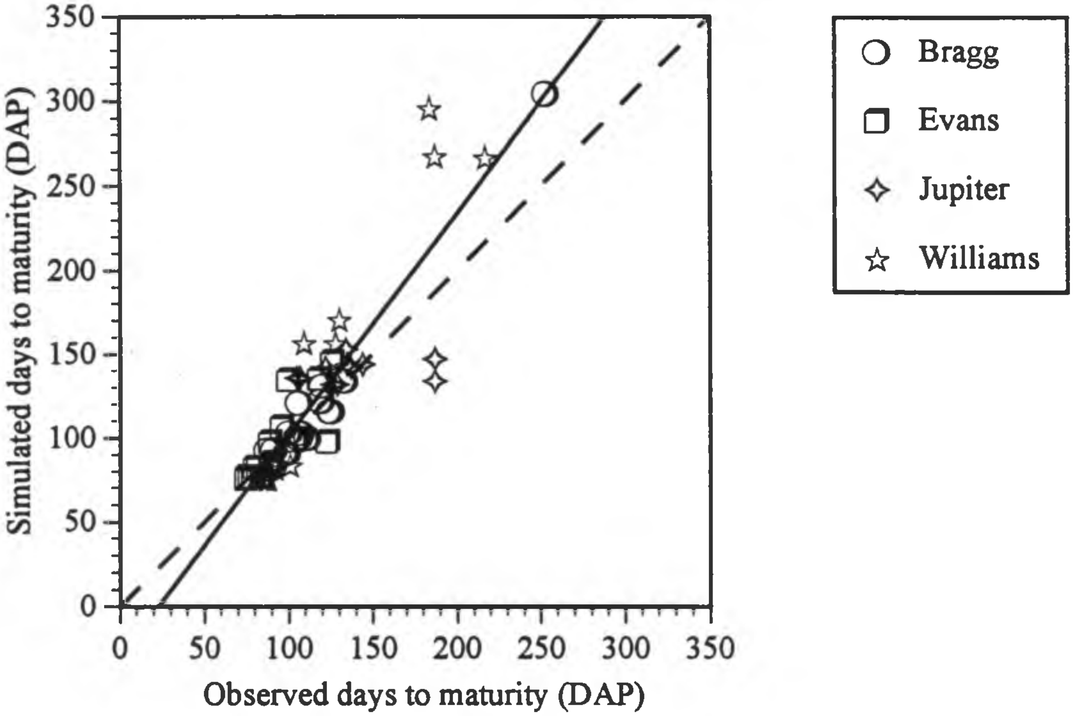

Figure 49. Comparison of observed and simulated days to physiological maturity using fitted genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 1.3 x - 27. Standard error for observation is 5.97.

Table 40. Regression and error analysis of soybean simulated with fitted genetic coefficients vs. observed growth characteristics for cultivars 'Bragg', 'Evans', 'Jupiter', and 'Williams'.

Statistic	Yield (kg ha^{-1})	Weight seed^{-1} (g)	Seeds m^{-2}	Biomass (kg ha^{-1})	Stem (kg ha^{-1})
slope	0.28	0.076	0.11	0.36	0.59
y-intercept	4013	0.165	2884	7950	1293
r^2	0.13	0.0028	0.0081	0.16	0.36
observed mean	3959	0.191	1961	10042	4210
observed sd	3009	0.0457	1361	8258	6019
simulated mean	5122	0.180	3108	11558	3765
simulated sd	2369	0.0660	1729	7464	5869
MAE [1]	2514	0.0602	1905	5838	2646
RMSE [2]	3290	0.0786	2383	8734	5289
RMSE(u) [3]	2200	0.0655	1711	6807	4656
RMSE(s) [4]	2447	0.0435	1658	5473	2509
d [5]	0.56	0.39	0.35	0.59	0.76

[1] Mean absolute error.

[2] Root mean square error.

[3] Root mean square error, unsystematic

[4] Root mean square error, systematic

[5] Index of agreement

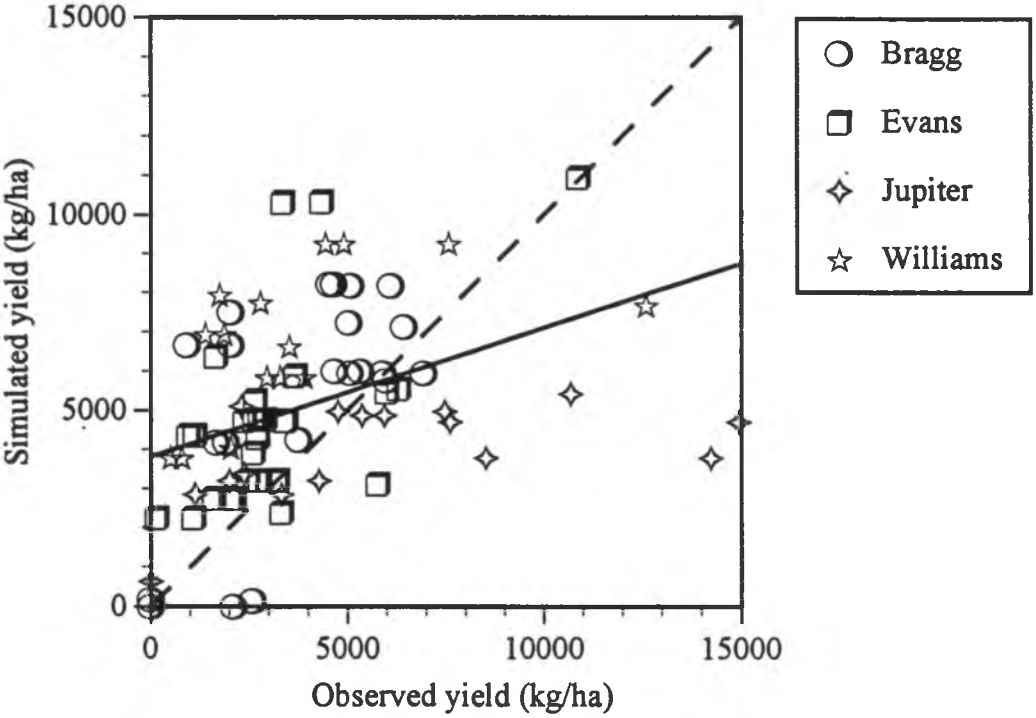

Figure 50. Comparison of observed and simulated grain yield using fitted genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 0.28 x + 4013. Standard error for observations is

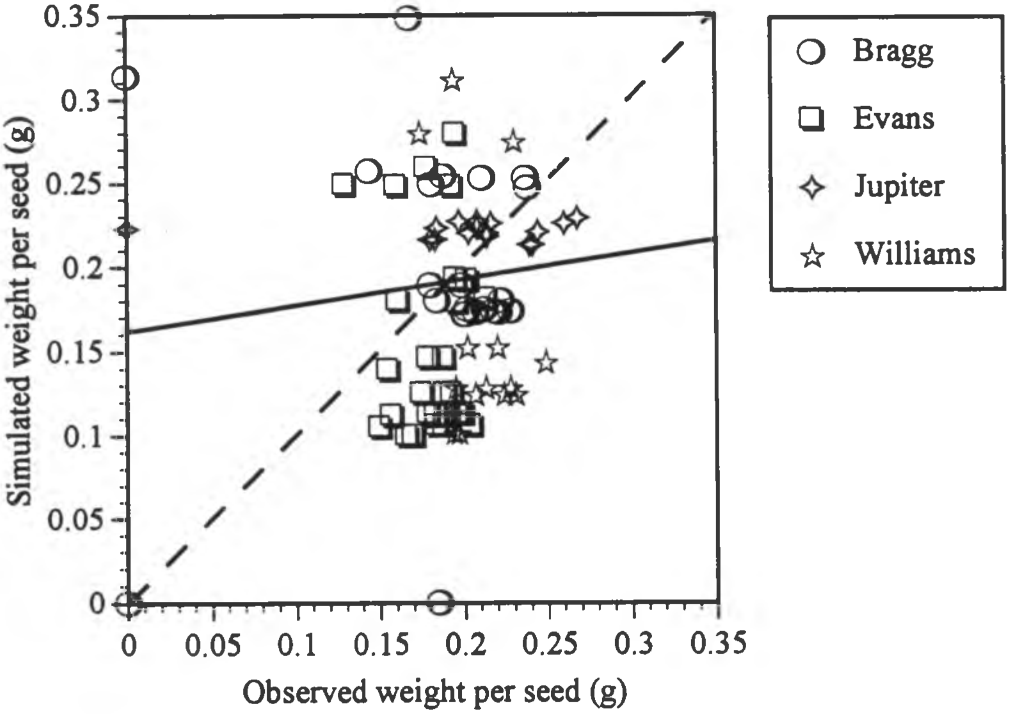

Figure 51. Comparison of observed and simulated weight per seed using fitted genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 0.076 x + 0.165. Standard error for observations is 0.0163.

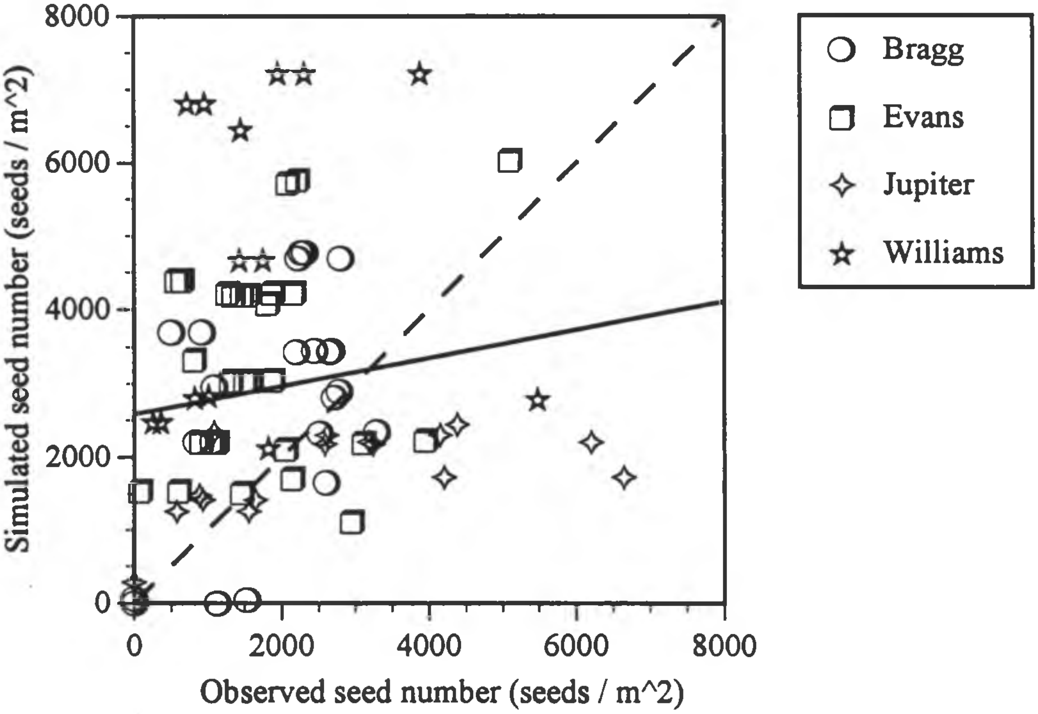

Figure 52. Comparison of observed and simulated seed number using fitted genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 0.11 x + 2884. Standard error for observations is 503.

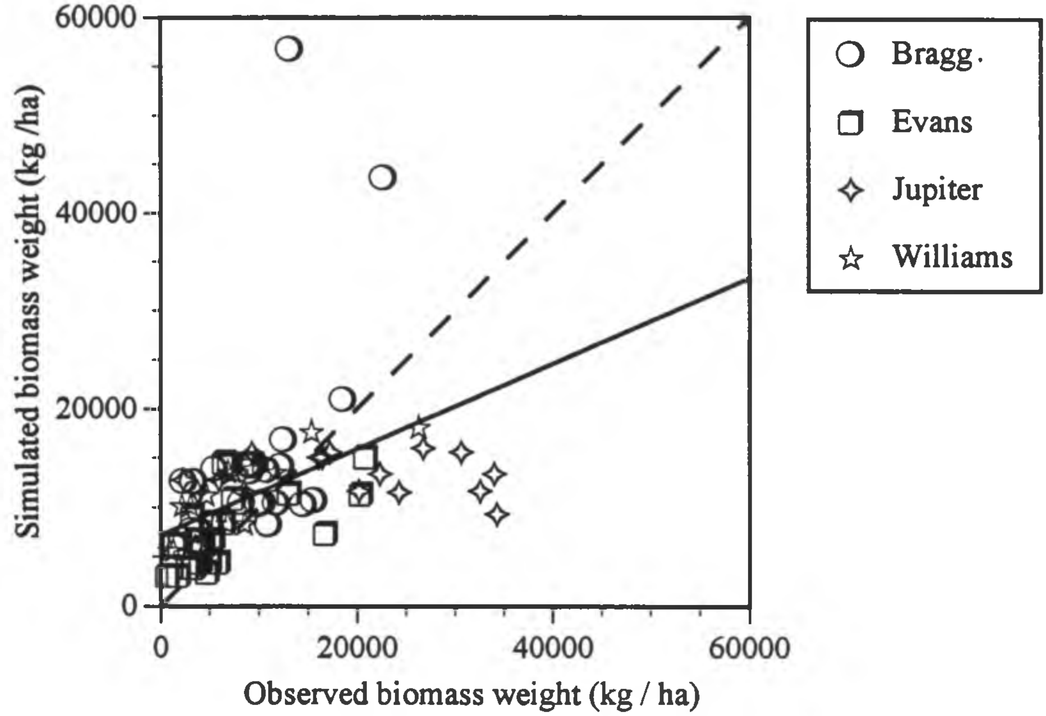

Figure 53. Comparison of observed and simulated aboveground biomass dry weight using fitted genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 0.36 x + 7950. Standard error for observations is 2655.

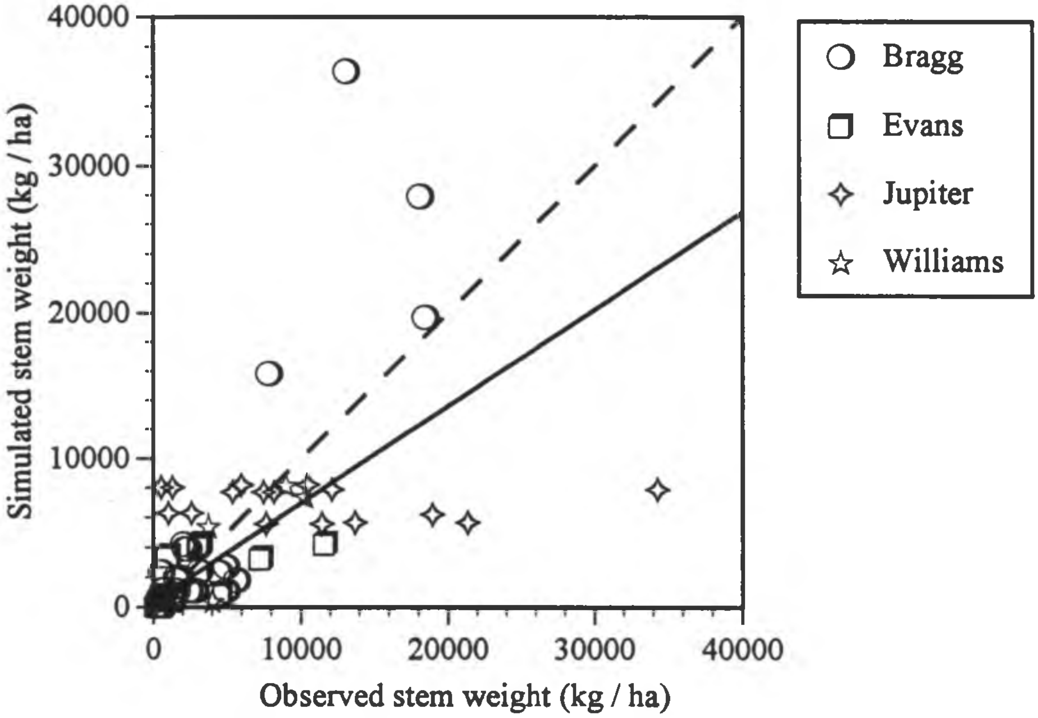

Figure 54. Comparison of observed and simulated stem dry weight at harvest maturity using fitted genetic coefficients for four soybean cultivars. Solid line is linear regression where y = 0.59 x + 1293. Standard error for observations is 1953.

error for yield may be considered unsystematic, too. Simulated aboveground biomass and stem weights deviated from observed weights and were more attributable to input variation. Input variation, more than model bias, may be responsible for deviations since RMSE(u) was greater than RMSE(s) (Table 40). While the deviation of simulated soybean development and growth from observations resulted from input variation and model bias, input variation was the greater cause.

Maize simulations showed that model bias produced deviations from observed development and growth more than input variations. Regardless of the genetic coefficient determination method, RMSE(s) was generally greater than or equal to RMSE(u) for days to development stages (Tables 41 and 42, Figures 55 to 57 and 58 to 60). The greater RMSE(s) suggested that model bias was the greater cause for simulation deviation from observation. Similarly, the growth characteristics yield, yield components, above ground biomass and stover weights at harvest maturity had higher RMSE(s) than RMSE(u) regardless of genetic coefficient determination method (Tables 43 and 44, Figures 61 to 65 and 66 to 70). The high RMSE(s) suggested that model bias was the major contributor to the growth simulation deviation from observation for maize. Hence, the error in simulated development and growth resulted mostly from model bias, but uncertainty in the input parameters also contributed to the error.

Error analysis for maize simulation vs. observation demonstrated that fitted genetic coefficients, including leaf number modifications, could correct some model

Table 41. Regression and error analysis of maize simulated with explicit genetic coefficients vs. observed days to developmental stages for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790.

Statistic	Tassel initiation (DAP[1])	Silking (DAP[1])	Physiological mature (DAP[1])
slope	0.36	0.30	0.58
y-intercept	18	46	53
r^2	0.47	0.47	0.61
observed mean	26	73	137
observed sd	4.9	15	21
simulated mean	27	68	133
simulated sd	2.6	6.4	16
mean absolute error	3.4	8.0	9.7
RMSE [2]	4.0	12	14
RMSE(u) [3]	1.9	4.7	9.8
RMSE(s) [4]	3.6	11	10
index of agreement	0.70	0.67	0.85

[1] Days after planting.

[2] Root mean square error

[3] Root mean square error, unsystematic

[4] Root mean square error, systematic

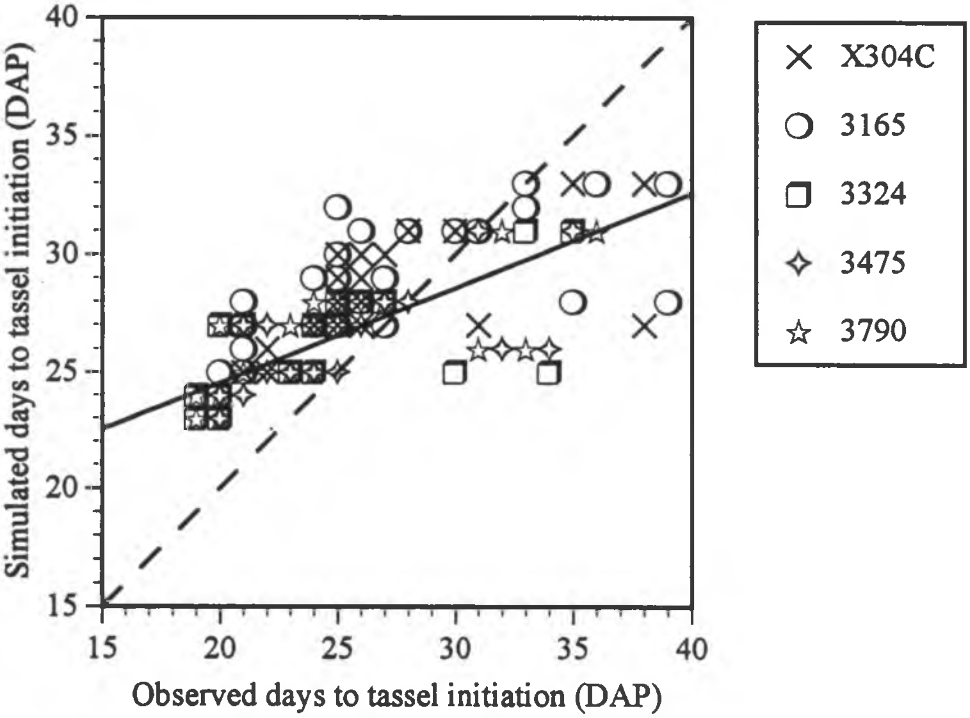

Figure 55. Comparison of observed and simulated days to tassel initiation using explicit genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.36 x +18. Standard error for observations is 1.07.

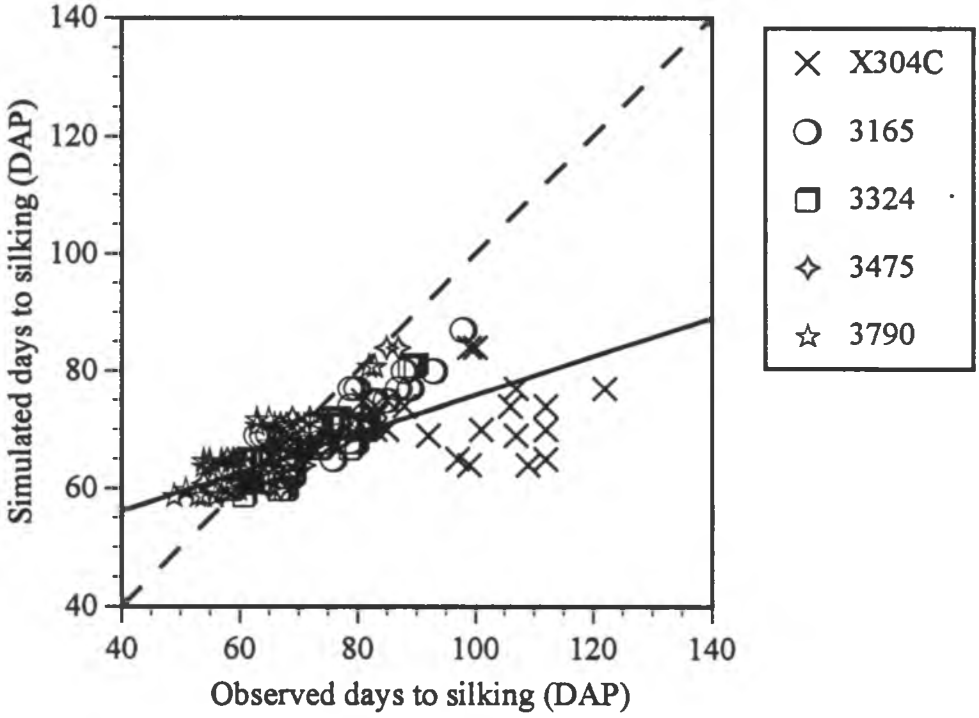

Figure 56. Comparison of observed and simulated days to silking using explicit genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.30 x + 46. Standard error for observations is 1.60.

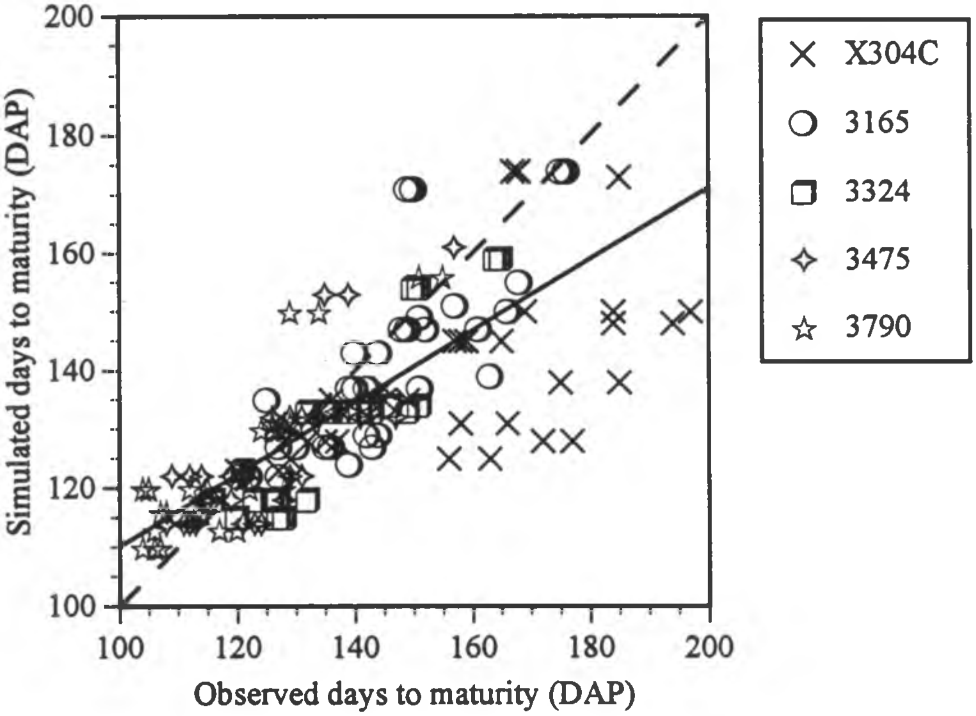

Figure 57. Comparison of observed and simulated days to physiological maturity using explicit genetic coefficients for five Pioneer hybrids. Solid line is regression where y = 0.58 x + 53. Standard error for observations is 3.14.

Table 42. Regression and error analysis of maize simulated with fitted genetic coefficients vs. observed days to developmental stages for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790.

Statistic	Tassel initiation (DAP[1])	Silking (DAP[1])	Physiological mature (DAP[1])
slope	0.37	0.77	0.96
y-intercept	20	27	16
r^2	0.25	0.64	0.77
observed mean	26	73	137
observed sd	4.9	15	21
simulated mean	29	83	149
simulated sd	3.6	14	23
mean absolute error	5.2	12	13
RMSE [2]	5.8	14	16
RMSE(u) [3]	3.1	8.3	11
RMSE(s) [4]	4.9	11	11
index of agreement	0.59	0.79	0.87

[1] Days after planting.

[2] Root mean square error

[3] Root mean square error, unsystematic

[4] Root mean square error, systematic

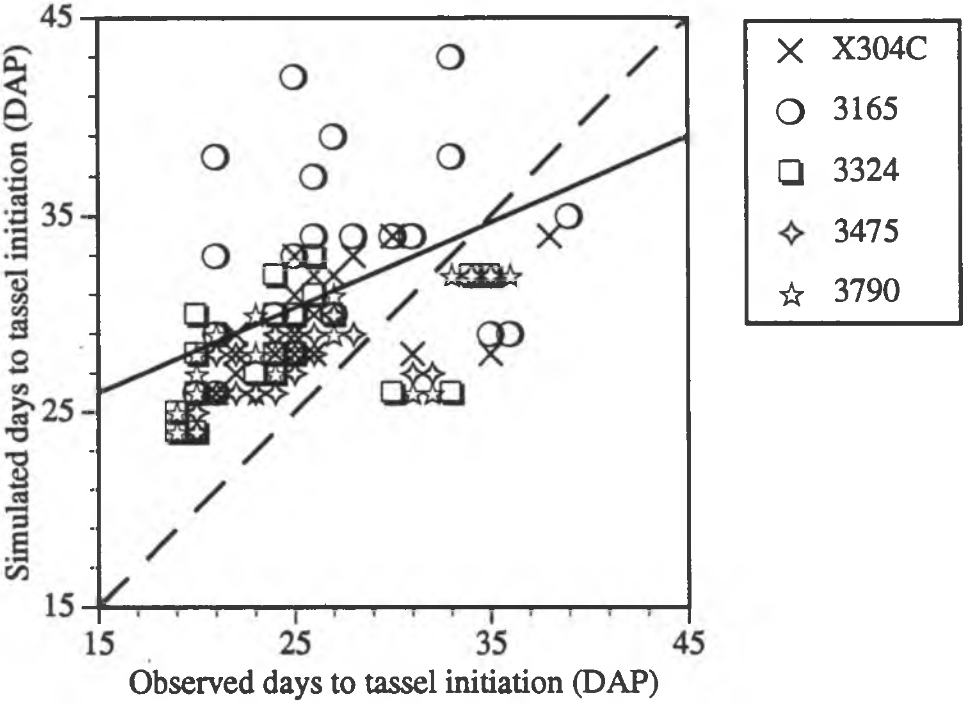

Figure 58. Comparison of observed and simulated days to tassel initiation using fitted genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.37 x + 20. Standard error for observations is 1.07.

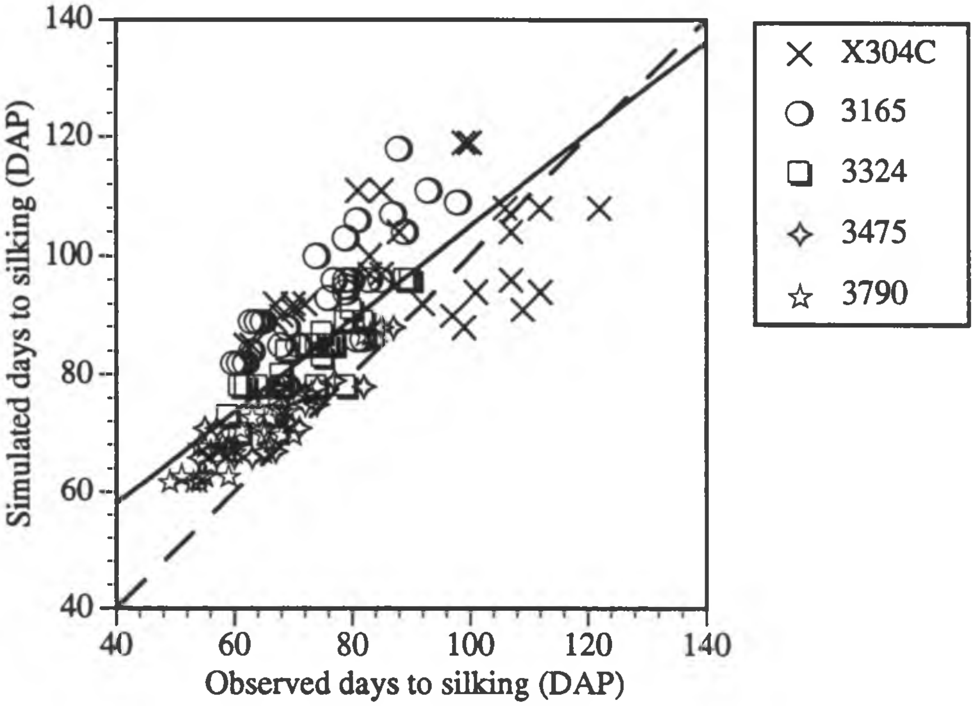

Figure 59. Comparison of observed and simulated days to silking using fitted genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.77 x + 27. Standard error for observations is 1.07.

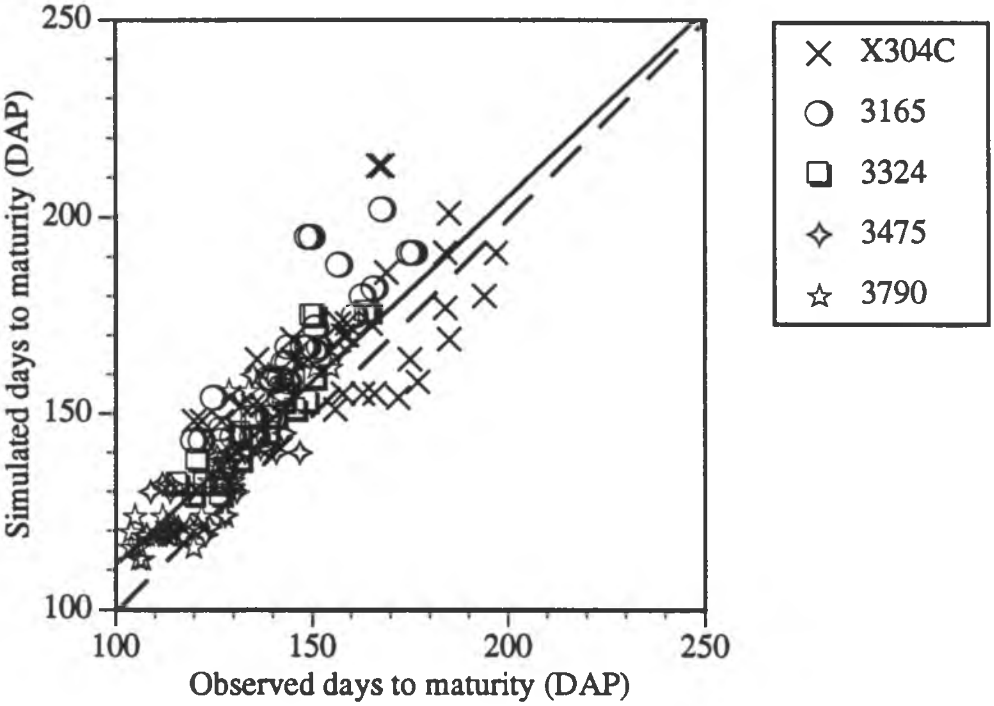

Figure 60. Comparison of observed and simulated days to physiological maturity using fitted genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.96 x +16. Standard error for observations is 3.14.

Table 43. Regression and error analysis of maize simulated with explicit genetic coefficients vs. observed growth characteristics for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790.

Statistic	Yield (kg ha^{-1})	Kernel weight (g)	Kernels m^{-2}	Biomass (kg ha^{-1})	Stover (kg ha^{-1})
slope	0.15	-0.15	0.30	0.13	0.088
y-intercept	4961	0.279	1531	14476	10684
r^2	0.30	0.0685	0.31	0.55	0.50
observed mean	12267	0.316	3226	24304	13869
observed sd	4303	0.0461	869	9315	7619
simulated mean	6820	0.324	2489	17676	11908
simulated sd	1183	0.0256	466	1648	947
MAE [1]	5786	0.0896	891	8416	4927
RMSE [2]	6624	0.101	1032	10496	7228
RMSE(u) [3]	984	0.0246	387	1097	665
RMSE(s) [4]	6551	0.0977	956	10438	7197
d [5]	0.49	0.32	0.60	0.53	0.38

[1] Mean absolute error.

[2] Root mean square error.

[3] Root mean square error, unsystematic.

[4] Root mean square error, systematic.

[5] Index of agreement.

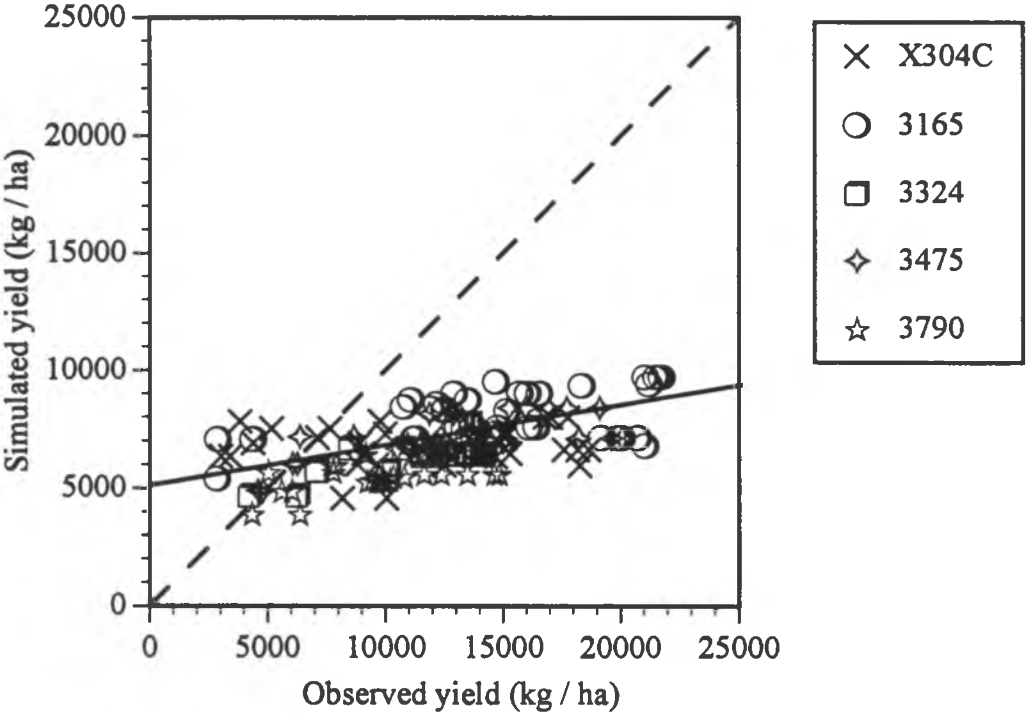

Figure 61. Comparison of observed and simulated grain yield at 15.5% moisture using explicit genetic coefficients for five Pioneer hybrids. Solid line is regression where y = 0.15 x + 4961. Standard error for observations is 1229.

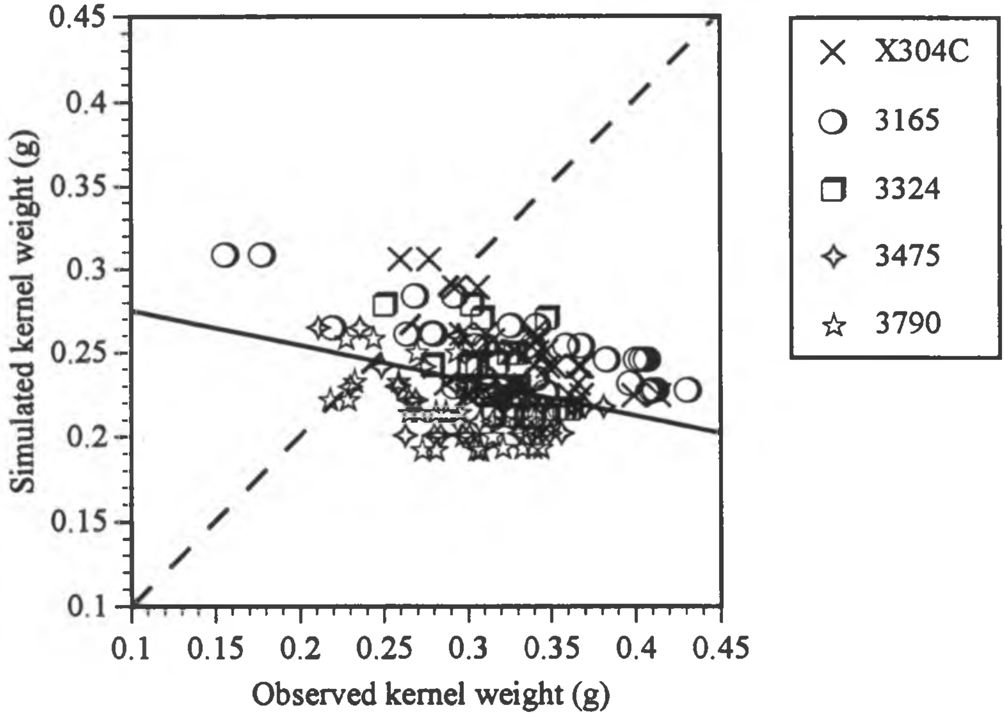

Figure 62. Comparison of observed and simulated single kernel weight at harvest maturity using explicit genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = -0.15 x + 0.279. Standard error for observations is 0.0176.

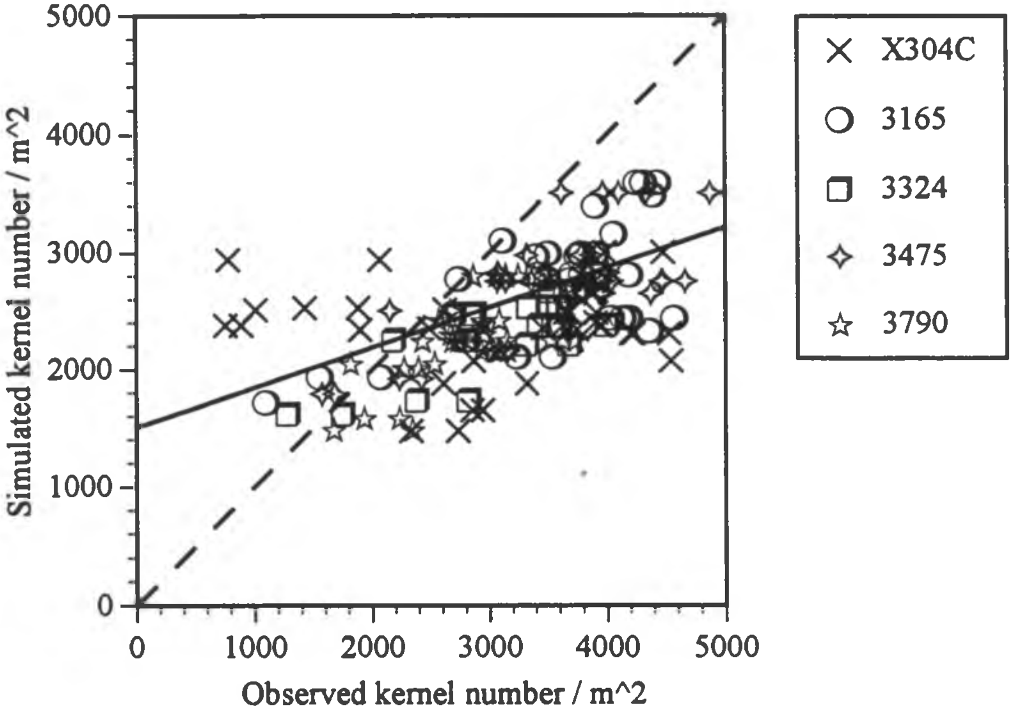

Figure 63. Comparison of observed and simulated kernels per m^2 at harvest maturity using explicit genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.30 x + 1531. Standard error for observations is 278.

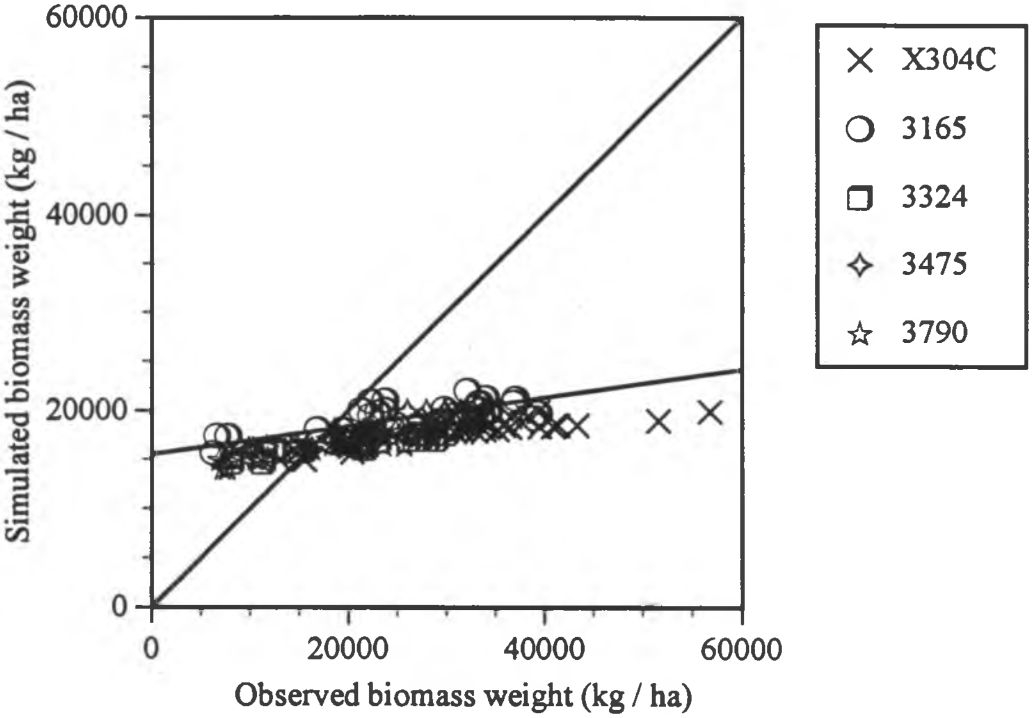

Figure 64. Comparison of observed and simulated aboveground biomass dry weight at harvest maturity using explicit genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.13 x + 14476. Standard error for observations is 2493.

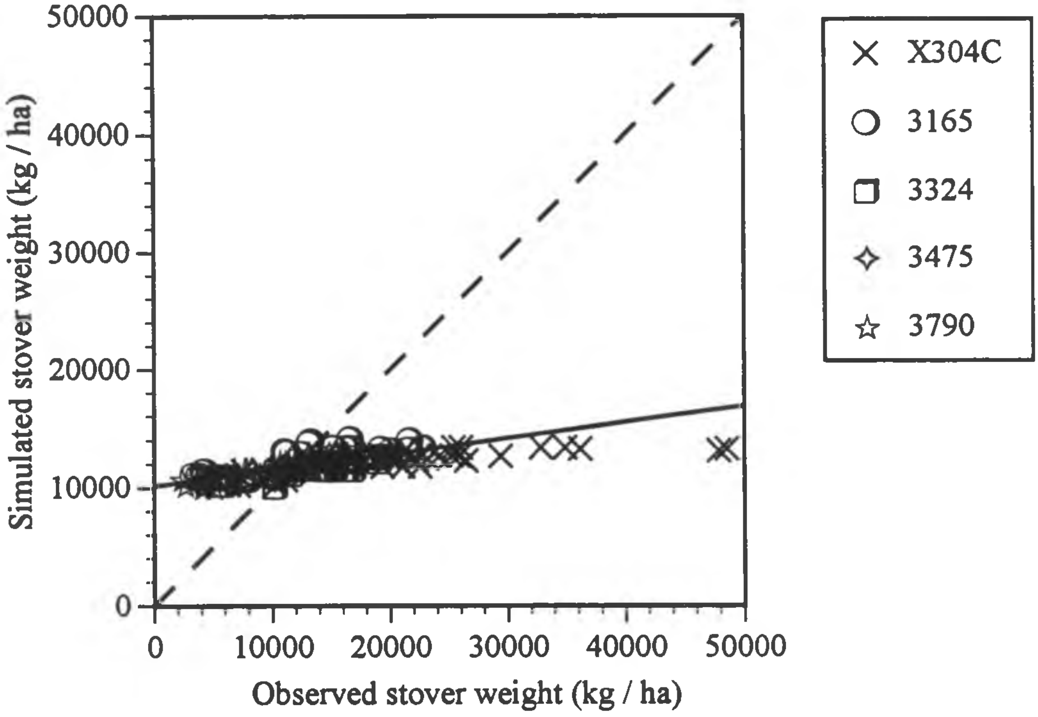

Figure 65. Comparison of observed and simulated stover dry weight at harvest maturity using explicit genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.088 x + 10684. Standard error for observations is 1805.

Table 44. Regression and error analysis of maize simulated with fitted genetic coefficients vs. observed growth characteristics for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790.

Statistic	Yield (kg ha^{-1})	Kernel weight (g)	Kernels m^{-2}	Biomass (kg ha^{-1})	Stover (kg ha^{-1})
slope	0.16	-0.19	0.29	0.31	0.33
y-intercept	9658	0.36	2332	14795	8117
r^2	0.14	0.068	0.16	0.51	0.49
observed mean	12267	0.316	3226	24304	13869
observed sd	4303	0.0461	869	9315	7619
simulated mean	11567	0.303	3262	22450	12673
simulated sd	1811	0.0329	626	4107	3559
MAE [1]	2970	0.0515	629	5789	4302
RMSE [2]	4052	0.0643	842	7219	5814
RMSE(u) [3]	1677	0.0317	572	2865	2523
RMSE(s) [4]	3689	0.0560	618	6626	5239
d [5]	0.50	0.23	0.62	0.69	0.70

[1] Mean absolute error.

[2] Root mean square error.

[3] Root mean square error, unsystematic.

[4] Root mean square error, systematic.

[5] Index of agreement.

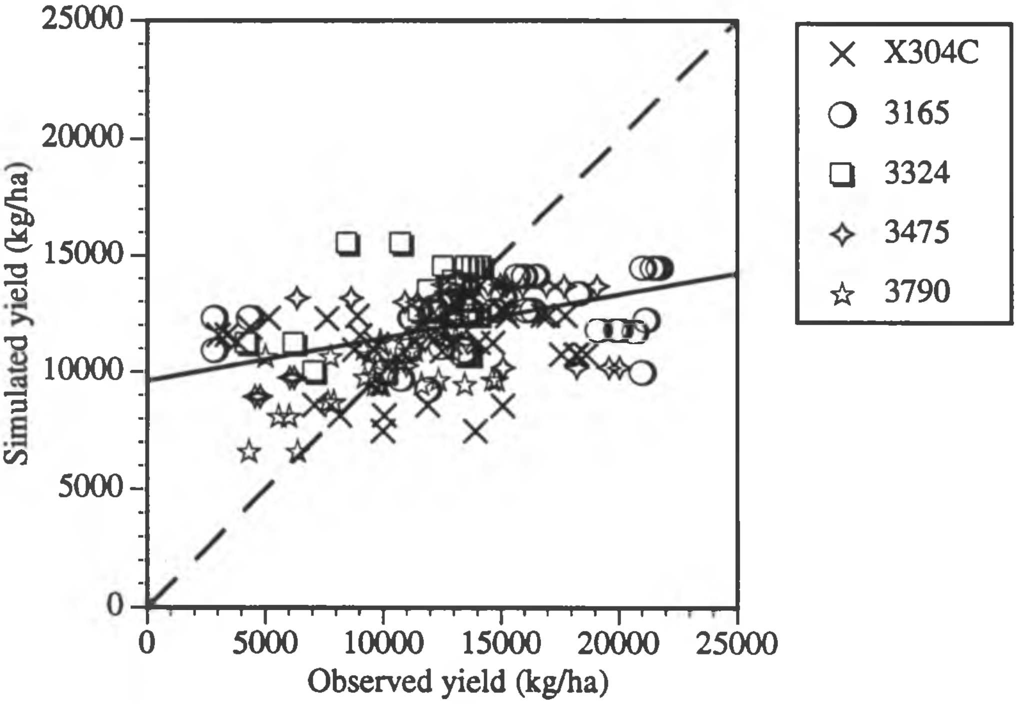

Figure 66. Comparison of observed and simulated yield at 15.5% mositure using fitted genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.16 x + 9658. Standard error for observations is 1229.

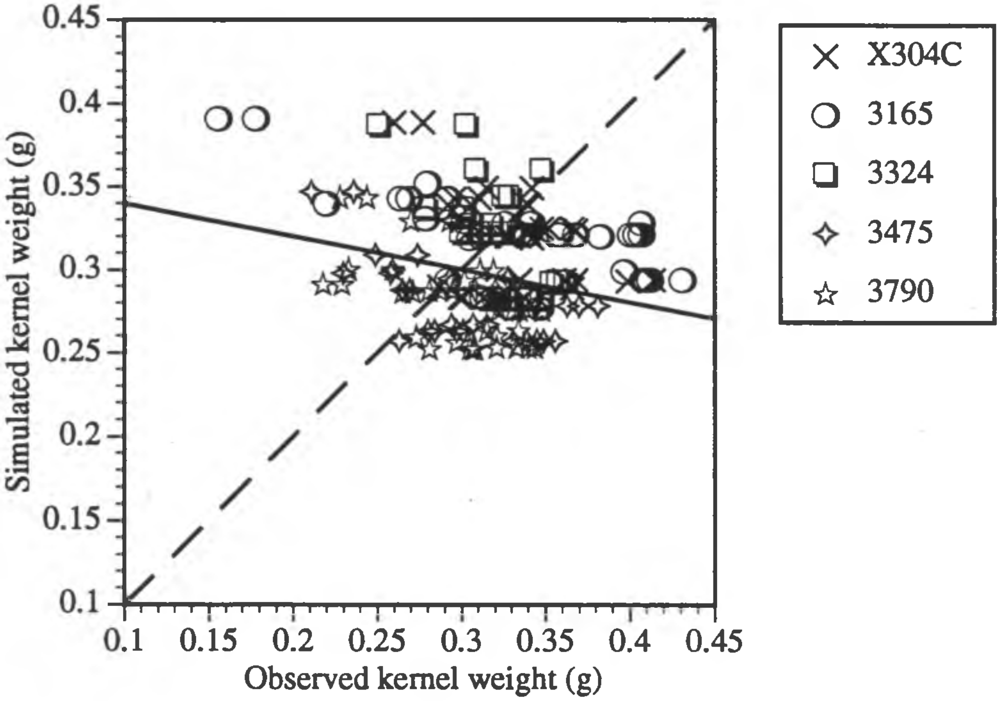

Figure 67. Comparison of observed and simulated single kernel weight using fitted genetic coefficients for five Pioneer hybrids. Solid line is regression where $y = -0.19x + 0.360$. Standard error for observations is 0.0176.

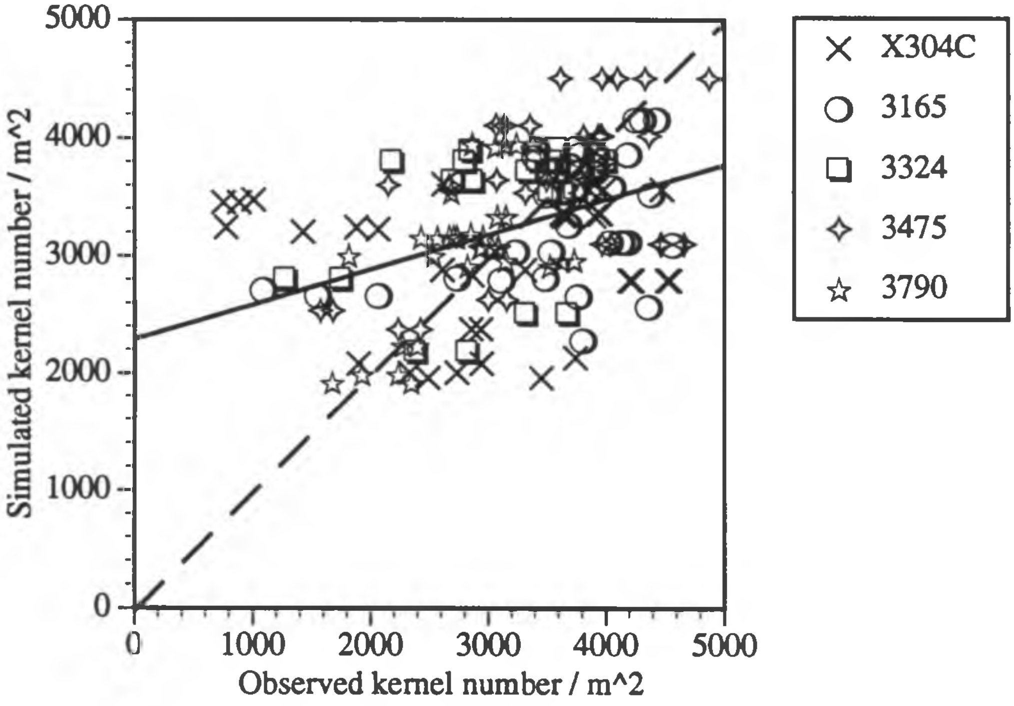

Figure 68. Comparison of observed and simulated kernel number per m^2 at harvest maturity using fitted genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.29 x + 2332. Standard error for observations is 278.

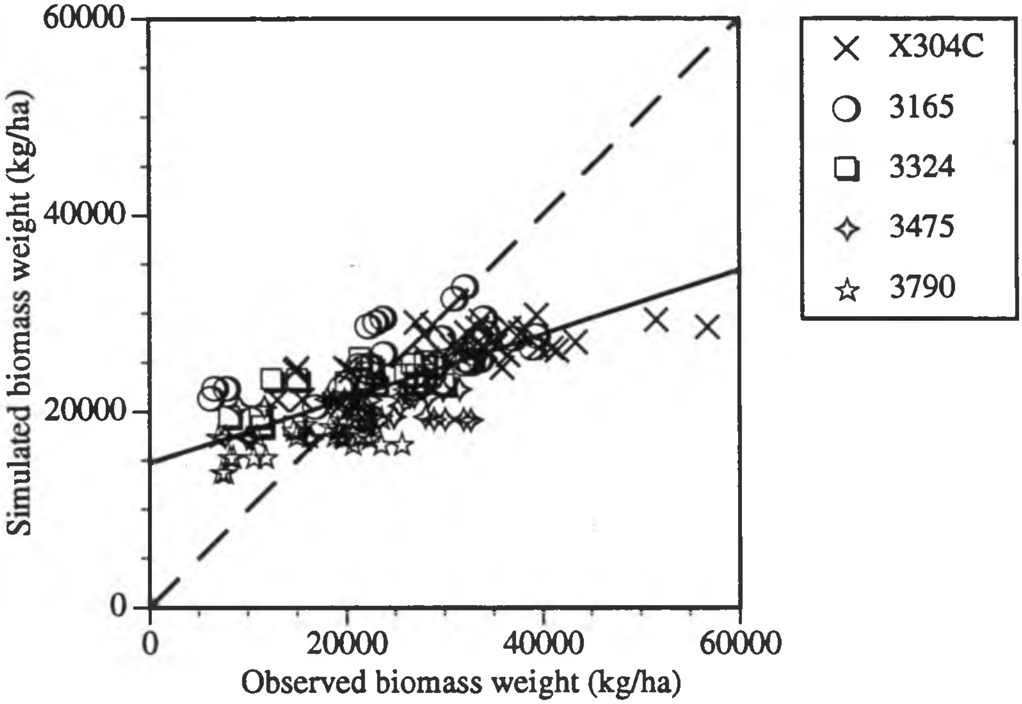

Figure 69. Comparison of observed and simulated aboveground biomass weight at harvest maturity using fitted genetic coefficients for five Pioneer hybrids. Solid line is linear regression where y = 0.31 x + 14795. Standard error for observations is 2493.

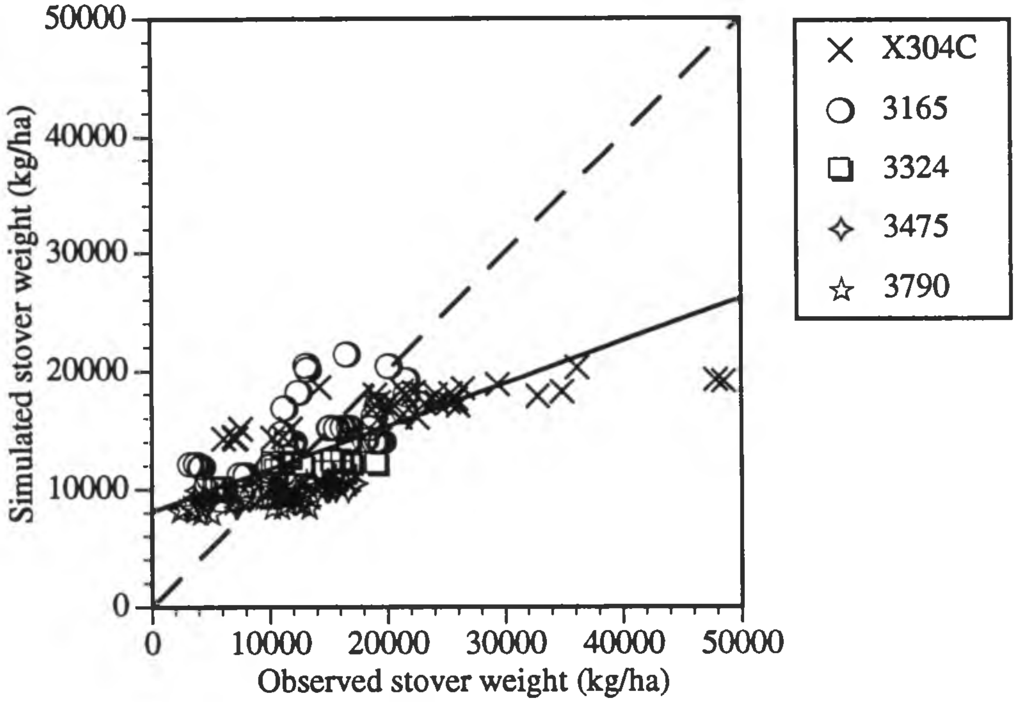

Figure 70. Comparison of observed and simulated stover weight at harvest maturity using fitted genetic coefficients for five Pioneer hybrids. Solid line is linear regression where $y = 0.33\ x + 8117$. Standard error for observations is 1805.

bias for development and characteristics. Generally, the fitted genetic coefficients and leaf number modifications gave simulations that fit the observed data better than explicit. One exception to this generalization was the days to tassel initiation which was better simulated when explicit genetic coefficients, rather than fitted, genetic coefficients were used (Tables 41 and 44, Figures 55 and 58). The over-estimate of days to tassel initiation for fitted genetic coefficients may be attributed to the determination method. Since P2 is the slope of the regression line of days to tassel initiation on photoperiod, in fitting the P2 genetic coefficient so that simulated tassel initiation date matched the observed, the regression line was forced through the point at 4 days and 12.5 h. However, the explicitly determined P2 was not forced through any point, so fitted P2 was generally higher than explicit P2. The result of the higher fitted P2 was over estimating tassel initiation, hence lower index of agreement than explicit. The indices of agreement for days to silking and maturity were slightly higher for the fitted than explicit genetic coefficients despite having higher root mean square error (Tables 41 and 44). Furthermore, the fitted genetic coefficients gave a slope closer to unity and y-intercept nearer zero than explicit so the proportion of RMSE(s) was smaller, but RMSE and mean absolute error (MAE) were larger. The smaller proportions of RMSE(s) for days to tassel initiation and silking, the slopes nearer unity and y-intercept nearer zero for days to silking and maturity indicated a lesser model bias when fitted genetic coefficients and leaf modifications were used.

The growth characteristics yield and yield components were not substantially affected when fitted genetic coefficients and leaf modifications were used while stover weight was. The regression of simulated yield and yield components on observed showed little differences in slope between fitted and explicit genetic coefficients (Tables 43 and 44). Fitted genetic coefficients reduced the RMSE and the proportion of RMSE(s), and increased the overall mean simulated yield and its components when compared to the explicit genetic coefficients. The null effect on regression slope and increased overall mean suggested that fitted genetic coefficients increased additively increased y-intercept of the linear regression for these growth characteristics. The result of the increased y-intercept was to reduce the RMSE(s) with a concomitant increase in RMSE(u). So, fitting genetic coefficients was able to increase the model response, i.e., y-intercept, to the environmental conditions in the field experiment, but some other model component must be changed to increase the model response, i.e., slope, to these same environmental factors. Stover weight, and consequently aboveground biomass, showed that fitted genetic coefficients and leaf modifications were able to decrease model bias. The regression line of simulated stover weight on observed had increased slope when fitted genetic coefficients and leaf modifications were used compared to explicit (Tables 43 and 44, Figures 65 and 70). Furthermore, the fitted genetic coefficients when compared to explicit genetic coefficients brought the y-intercept closer to zero, decreased RMSE, decreased the proportion of RMSE(s), and increased the overall simulated mean. So, the fitted genetic coefficients affected the model results more for stover weight than yield and its components, but further corrections were still necessary for all growth characteristics.

Discussion

A major question, as yet unresolved, is whether incandescent light quality and constant photoperiod are similar to naturally occurring conditions for soybean and maize development and growth. Incandescent light quality may be similar to natural light quality in its effect on soybean development. Delayed development was observed under long photoperiods of incandescent or natural light quality when the genes E_3 and E_4 were present (Saindon, et al., 1989a; Saindon, et al., 1989b). However, the three other loci that control development response to photoperiod have not been determined to cause similar effects under incandescent and natural light quality. Development rate in soybean was different under constant or shortening photoperiod depending on stage of development (McBlain et al., 1987). In time to flowering for soybean, the alleles E_1, E_2, and E_3 delayed flowering regardless of constant or shortening photoperiods. However, in time from flowering to maturity, the gene E_1 slightly delayed maturity under constant photoperiod and hastened maturity under shortening photoperiod while gene E_3 delayed maturity under constant photoperiod and slightly delayed maturity under shortening photoperiod. The effect of light quality and changing photoperiod on maize growth and development is not well understood. While this experiment did not detect any effect of light quality on growth and development of soybean and maize, the effect of constant photoperiod has not been determined.

In CERES-Maize, fitting genetic coefficients seemed to correct some model bias. There was less bias in the observed vs. simulated plots for maize development and growth when fitted genetic coefficients were used compared to explicit. The genetic coefficients seemed to have the ability to compensate for over- or under-response of the model's growth and development to the environment, or be able to compensate for bias in the input parameters. This compensating effect may make the model only suited to simulate crop development and growth under similar environmental conditions. Hence, the assertion that fitted genetic coefficients made CERES-Maize only applicable to the locations where the genetic coefficients were determined (Hodges et al., 1987; Liu et al., 1989) may be caused by genetic coefficients that uniquely adjusted crop growth and development to the environment where they were fitted.

Genetic coefficients for crop models SOYGRO and CERES-Maize can be determined with a fitting method, but the application of these models must be restricted. The fitted development genetic coefficients from both models displayed linear trends that depended on the environment where they were estimated. This indicates that the models cannot use the fitted genetic coefficients estimated in one environment to simulate development in a different environment. Instead, the fitted genetic coefficients should be used to simulate development in an environment similar to the one where the coefficients were estimated. Fitted growth genetic coefficients exhibited trends over the environments from which they were estimated. Again, this indicates that simulations with fitted genetic coefficients would be accurate only under environments similar in which the coefficients were estimated. So, the application of the fitted growth genetic coefficients must be restricted to the environments where they were determined.

Explicit determination of genetic coefficients for CERES-Maize was not an acceptable method. The simulated vs. observed comparisons showed that biases occurred for development and growth characteristics. These biases were indicative of problems within the model. When genetic coefficients were determined apart from the model, the model imperfections will result in biased simulations. The simulation bias was generally over-estimating development time and under-estimating growth under the present experimental conditions. So, genetic coefficients and its determination cannot be considered separately from the whole-model predictions.

One of the major problems with SOYGRO and CERES-Maize seemed to be their inability to well simulate the components of yield. In soybean, pods plant^{-1} response to photoperiod and temperature depended on genotype. Apparently, as temperature increased, pods plant^{-1} can increase under short photoperiod and decrease in long photoperiod (Raper and Thomas, 1978), or decrease under short photoperiod and increase in long photoperiod (Huxley et al., 1976; Saito, 1961;

Hesketh et al, 1973). The difference in response to temperature and photoperiod may be related to differences in genotype (van Schaik and Probst, 1958). The complexity of the pods plant^{-1} response to photoperiod may not be adequately addressed in SOYGRO which assumes that only pod abortion occurs as photoperiod increases. In maize, photoperiod may reduce kernel number by increasing the tassel-silk interval so that pollination is incomplete. Pioneer hybrid X304C had increased tassel-silk interval as photoperiod increased that resulted in lesser kernels plant^{-1}. However, CERES-Maize does not account for decreased kernel number due to delayed silking. In CERES-Maize, kernel number is mainly dependent on photosynthetic rate prior to silking (Jones et al., 1986). So, under certain conditions of long photoperiod, SOYGRO and CERES-Maize may not be able to well simulate yield components and, consequently, yield.

Genetic coefficients for SOYGRO and CERES-Maize are environment dependent under the present experimental conditions. The cause of the environment dependency may be related to model mis-specification or input parameter bias. Whether changes in the model mechanisms, philosophy, or input parameters can overcome the deficiency in estimating genetic coefficients are not well understood at this time.

CHAPTER 4

SENSITIVITY ANALYSIS OF DERIVED GENETIC COEFFICIENTS FOR SOYGRO AND CERES-MAIZE

Introduction

Results shown in Chapter 3 indicate that SOYGRO and CERES-Maize crop models did not accurately simulate growth and yield of soybean and maize under a range of environments and photoperiods. Fitted genetic coefficients displayed linear trends on photoperiod. The trends indicated that the genetic coefficients were compensating for over- or under-predicting crop response to the environment. Furthermore, error analysis suggested that model bias accounted for part of the poor match. However, specific model routines that caused the poor growth simulation were not readily identified.

Fitted genetic coefficients for SOYGRO and CERES-Maize displayed significant cultivar-by-photoperiod effects. The CERES-Maize genetic coefficients P2, P5, G2, and G3 and leaf production coefficients XLPGDD and PCHRON had significant cultivar-by- photoperiod interaction effect. SOYGRO genetic coefficients PHTHRS 6 to 9 and SDPDVR also showed significant cultivar-by-photoperiod interaction. The significant interaction indicated that the genetic coefficients had different linear relations to photoperiod among varieties. The instability of the fitted genetic coefficients suggested that the routines in the model associated with these genetic coefficients were possible sources of the model bias.

To prioritize further work on the model, the routines that have the greatest effect on biasing the simulation results must be identified. Each fitted genetic coefficient mean has an associated error that can be quantified by the standard error. A genetic coefficient may have a large standard error, but if the model is insensitive to that parameter, the variation in simulation results attributed to the input error would be relatively small and unimportant. Therefore, the magnitude of the standard error alone cannot indicate the importance of the genetic coefficient to prioritize further work since the model sensitivity to that coefficient is unknown.

The objective of this experiment was to determine which genetic coefficients, and presumably their associated routines, are important in causing model bias.

Methods and Materials

The SOYGRO and CERES-Maize genetic coefficient means and standard errors were obtained from a previously described fitting procedure. A field experiment was conducted with four soybean cultivars ('Bragg', 'Evans', 'Jupiter', and 'Williams') and five maize hybrids (Pioneer hybrids X304C, 3165, 3324, 3475, and 3790) over four planting dates. The soybean and maize were planted at two sites on Maui Island, Hawaii, elevation 282 and 640 m, where natural photoperiod was extended to natural + 0.5-, 14-, 17-, and 20-h with quartz lamps. Data collected included yield and yield components, plant dry weight, and dates of growth stages. Model inputs were produced to duplicate field weather, soil, and management conditions in each photoperiod treatment at each site for each year. The models were iteratively run with adjustments to the genetic coefficients until the model output on yield, yield components, plant dry weight, and growth stage dates were within 1% of the observed field data. For maize, three other coefficients besides the genetic coefficients were concurrently fitted. The arithmetic means and standard errors of the fitted genetic coefficients were calculated over the photoperiod treatment, site, and year combinations.

Sixteen SOYGRO genetic coefficients were selected to undergo sensitivity analysis. For the following reasons, seven genetic coefficients were not included in the analysis: VARDH, PHTHRS(1), PHTHRS(2), PHTHRS(3), PHTHRS(5), and FLWMAX. By definition, VARDH must be set to 1.0 (Jones et al., 1986) and PHTHRS(5) was earlier redefined as 6.20 (Thomas and Raper, 1983). The standard errors for PHTHRS(1) and PHTHRS(2) were very small. PHTHRS(3) values were not determined and so no associated variation was estimated. FLWMAX was not considered important as a genetic coefficient (Jones et al., 1989), and was simply set to two times PODVAR. The remaining 16 genetic coefficients used in the analysis were: SHVAR, SDVAR, SDPDVR, PODVAR, TRIFOL, SIZELF, SLAVAR, VARN1, VARN0, VARTH, and PHTHRS(4) through PHTHRS(10).

The sensitivity of model output to SOYGRO genetic coefficients was analyzed with an unreplicated fractional factorial experiment. A 2^{16-8} resolution V fractional factorial design from Statistical Engineering Laboratory (1957), plan

256.16.8, was used for treatment combination selection. The 16 chosen genetic coefficients in SOYGRO were varied ± one and two standard errors from the mean (Tables 45 and 46; see Table 12 for genetic coefficient definitions) to give two sets of two levels of each genetic coefficient. The sets of values for one and two standard errors were used in separate analyses. Using the mean minus standard error as a low value and mean plus standard error as a high value, 16 paired values were combined according to the fractional factorial plan to create 256 'genotypes' that were put into the genetic files for simulation. The simulation conditions included Makawao soil series (clayey, oxidic, isothermicHumoxic Tropohumult), 1 April planting date, and no water or nitrogen stress. Weather observations over five years was averaged from the Haleakala Experiment Station, Maui, Hawaii, and a synthetic weather file was made that had constant daily 24.0 °C maximum air temperature, 15.5 °C minimum air temperature, 17.85 MJ m^{-2} solar radiation, and 5.8 mm rainfall. PHFAC3 was set to 1.80 for only SOYGRO simulations. The Haleakala Experiment Station was located at 20.85° N latitude. A second fractional factorial simulation was performed, identical to the first except latitude was changed to 40.85 ° N. The difference in latitude implied a change in photoperiod with civil twilight exclusive. At 20.85° latitude, photoperiod was 12.22 and 13.26 h on 1 April and 21 June, and 12.50 and 14.93 h at 40.85°, as calculated by SOYGRO. The factorial experiment was to determine which genetic coefficient contributed to the bias in simulation

Table 45. Mean and standard error of 16 SOYGRO genetic coefficients for soybean cultivars 'Bragg' and 'Evans'.

Genetic coefficient	Bragg		Evans	
	Mean	Standard error	Mean	Standard error
SHVAR	12.46	0.28	11.90	0.56
SDVAR	4.66	0.22	4.44	0.20
SDPDVR	1.61	0.094	1.81	0.0799
PODVAR	589.1	270.9	2707.1	995.5
TRIFOL	0.330	0.020	0.356	0.0169
SIZELF	171.2	8.62	125.5	9.47
SLAVAR	287.1	9.87	265.3	11.4
VARN1	5.38	0.46	0.0	0.0
VARN0	10.56	0.26	8.93	1.16
VARTH	5.19	0.58	3.01	0.31
PHTHRS(4)	14.86	0.93	6.07	0.36
PHTHRS(6)	5.23	0.49	3.07	0.49
PHTHRS(7)	7.69	0.59	5.49	0.56
PHTHRS(8)	11.04	1.57	15.98	1.29
PHTHRS(9)	10.31	0.84	8.64	0.66
PHTHRS(10)	49.88	3.56	43.91	2.14

Table 46. Mean and standard error of 16 SOYGRO genetic coefficients for soybean cultivars 'Jupiter' and 'Williams'.

Genetic coefficient	Jupiter		Williams	
	mean	standard error	mean	standard error
SHVAR	11.77	0.45	14.15	0.61
SDVAR	4.46	0.46	4.93	0.14
SDPDVR	1.44	0.083	1.98	0.13
PODVAR	481.1	94.0	2131.8	1749.6
TRIFOL	0.328	0.019	0.418	0.0240
SIZELF	266.5	15.4	195.0	16.2
SLAVAR	252.4	11.9	289.0	11.9
VARN1	na	na	2.20	1.28
VARN0	10.45	0.45	9.48	0.64
VARTH	1.38	0.0	5.29	0.92
PHTHRS(4)	39.78	5.12	7.08	0.46
PHTHRS(6)	10.83	1.49	5.21	0.80
PHTHRS(7)	14.59	1.75	7.48	0.84
PHTHRS(8)	7.43	1.40	15.91	1.67
PHTHRS(9)	14.16	1.52	10.31	0.91
PHTHRS(10)	57.63	3.64	44.08	2.58

results, while the second factorial experiment was included to determine whether photoperiod affected the importance of genetic coefficient contribution.

A sensitivity analysis for CERES-Maize genetic coefficients was performed using a 2^8 unreplicated full factorial design. Eight coefficients in CERES-Maize were varied ± one and two standard errors from the mean (Tables 47 and 48; see Table 13 for genetic coefficient definitions) in separate analyses. The mean minus standard error and mean plus standard error of the eight coefficients was combined in a full factorial to create 256 'genotypes' that were put into the genetic files for simulation. The genetic file was modified to accommodate the extra coefficients P9, XLPGDD, and PCHRON. The simulation conditions were identical to the conditions for SOYGRO described above. However, the photoperiod calculations in CERES-Maize included civil twilight. Therefore, photoperiods on 1 April and 21 June were 13.06 and 14.23 h at 20.85° latitude, and 13.52 and 16.23 h at 40.85° latitude.

Results from the simulation of the 256 'genotypes' for SOYGRO and CERES-Maize were subjected to analysis of variance to determine the genetic coefficients that were associated with model bias. Yield and aboveground biomass were selected as dependent variables from the simulation output for analysis of variance. These two variables were considered important because they integrate many of the processes in the models (Furbringer and Borchiellini, 1993). In the analysis of variance for SOYGRO, all main effects and two-factor interactions were specified in the statistical model, the remaining sums of squares were pooled as experimental error. For

Table 47. Mean and standard error of five CERES-Maize genetic coefficients and 3 variables for Pioneer hybrids X304C, 3165, and 3324.

Variable	X304C		3165		3324	
	mean	std. error	mean	std. error	mean	std. error
P1	235	20.5	241	30.2	209	21.0
P2	0.35	0.14	1.52	0.319	0.61	0.28
P5	965	13.6	943	21.7	859	15.4
G2	646	53.7	711	32.6	721	36.9
G3	6.20	0.181	6.33	0.208	7.25	0.156
P9	52.6	0.859	50.0	1.07	47.5	1.32
XLPGDD	18.6	0.904	22.0	0.587	22.8	0.569
PCHRON	49.2	1.02	49.2	0.662	48.8	0.539

Table 48. Mean and standard error of five CERES-Maize genetic coefficients and 3 variables for Pioneer hybrids 3475 and 3790.

	3475		3790	
Variable	mean	std. error	mean	std. error
P1	210	18.9	209	20.4
P2	0.22	0.22	0.28	0.23
P5	832	12.9	804	11.6
G2	760	31.2	657	22.1
G3	6.78	0.150	7.05	0.162
P9	51.3	1.08	49.7	1.03
XLPGDD	25.7	0.835	30.1	0.936
PCHRON	48.8	0.708	51.5	0.731

CERES-Maize, all four- to eight-factor interactions were assumed negligible and, therefore, were pooled to estimate experimental error (Milliken and Johnson, 1989). As an additional indicator of importance to model bias, the percentage of total variation was calculated for each effect as,

$$\%\ of\ total\ variation = \frac{s.s.\ effect}{s.s.\ total}\ x\ 100$$

where s.s. effect was an effect sum of squares and s.s. total was the total sum of squares (Jain, 1991). The effects that were significant and accounted for a large portion of the variation in yield or biomass was considered important to model bias.

Results

Results from the analysis of variance for the sensitivity analysis simulations are in Tables 49 to 66. The reported values are sum of squares for effects that accounted for 2% or greater of the total sums of squares.

The percentage of total variation was used to interpret the results. The sensitivity analysis for yield and aboveground biomass performed on SOYGRO genetic coefficients at ± two standard errors cannot be interpreted using classical sensitivity analysis. All cultivars showed that main effects decreased in percentage of total sums of squares for yield and aboveground biomass while interaction effect percentages increased as the level of each factor increased (Tables 49 to 56). The increase in interactions indicated that the relation between the effect input values and

Table 49. Sums of squares for yield of 'Bragg' soybean. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)
PODVAR	368.0** (71.0)	547.4** (41.4)	64.3** (61.9)	165.3** (28.5)
PHTHRS(9)	60.9** (11.7)	49.9** (3.8)	9.5** (9.1)	36.8** (6.3)
VARN1			5.1** (4.9)	
VARN0			5.1** (4.9)	
PHTHRS(6)	20.8** (4.0)		4.6** (4.4)	
PODVAR x VARN1				21.2** (3.6)
PODVAR x VARN0				17.8** (3.1)
PODVAR x PHTHRS(4)		38.4** (2.9)		
VARTH			2.9** (2.8)	
PODVAR x PHTHRS(9)		32.4** (2.4)		21.8** (3.8)
PODVAR x PHTHRS(6)		31.6** (2.4)		

**significant at the 0.01 probability level.

Table 50. Sums of squares for yield of 'Evans' soybean. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)
TRIFOL	5.0** (29.7)	13.7** (15.6)	5.3** (25.0)	13.1** (7.4)
PODVAR		11.6** (13.3)		40.0** (22.6)
SIZELF	2.4** (14.6)	6.6** (7.6)	2.7** (12.9)	8.0** (4.5)
PHTHRS(4)	1.8** (11.0)		2.3** (10.7)	
PODVAR x VARN0				19.6** (11.1)
PHTHRS(9)		7.8** (8.9)		6.9** (3.9)
PODVAR x PHTHRS(9)		5.7** (6.6)		4.8** (2.7)
PODVAR x PHTHRS(6)		5.0** (5.7)		9.5** (5.4)
SLAVAR	0.9** (5.5)	2.4** (2.8)	1.0** (4.7)	
VARN0			1.1** (5.2)	
PHTHRS(6)	0.9** (5.1)		0.7** (3.2)	
SDVAR			0.6** (3.0)	
SDPDVR			0.6** (2.8)	
SHVAR	0.4** (2.6)		0.7** (3.4)	

** significant at the 0.01 probability level.

Table 51. Sums of squares for yield of 'Jupiter' soybean. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})
PHTHRS(9)	416.0** (49.9)	398.6** (29.8)	233.9** (42.8)	335.8** (27.8)
PHTHRS(6)	304.3** (36.5)	311.2** (23.2)	213.7** (39.1)	230.9** (19.1)
PODVAR	51.0** (6.1)	79.8** (6.0)	30.1** (6.2)	66.7** (5.5)
PODVAR x PHTHRS(6)		36.7** (2.7)		42.6** (3.5)
SDVAR		30.6** (2.3)		
SDVAR x PHTHRS(6)		29.9** (2.2)		26.3** (2.2)

** significant at the 0.01 probability level.

Table 52. Sums of squares for yield of 'Williams' soybean. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})
PODVAR	421.3** (84.7)	721.9** (55.4)	602.0** (81.5)	1050.1**(49.)
PODVAR x VARN0			24.5** (3.3)	43.5** (2.0)
SIZELF	14.8** (3.0)	39.2** (3.0)	16.3** (2.2)	49.2** (2.3)
PODVAR x PHTHRS(6)	13.9** (2.8)		15.5** (2.1)	
PODVAR x SIZELF		36.2** (2.8)		45.2** (2.1)
VARN0				52.4** (2.5)
PODVAR x SLAVAR		27.9** (2.2)		42.1** (2.0)

** significant at the 0.01 probability level.

Table 53. Sums of squares for aboveground biomass weight of 'Bragg' soybean. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)
PODVAR	842.2** (72.4)	1087.8** (41.)	75.7** (28.7)	245.5** (13.9)
VARN0			63.4** (24.0)	210.3** (11.9)
PHTHRS(8)		85.9** (3.2)	34.3** (13.0)	181.2** (10.3)
PHTHRS(9)	136.5** (11.7)	99.1** (3.7)	13.7** (5.2)	
VARTH			11.6** (4.4)	117.9** (6.7)
VARN1 x VARN0				68.1** (3.9)
TRIFOL	32.2** (2.8)	98.6** (3.7)	12.3** (4.7)	58.7** (3.3)
PODVAR x VARN1				61.3** (3.5)
PHTHRS(6)	39.4** (3.4)			
PODVAR x PHTHRS(4)		71.2** (2.7)		
PODVAR x VARN0				43.3** (2.4)
PHTHRS(4)	27.0** (2.4)		20.3** (7.7)	43.5** (2.5)
PODVAR x PHTHRS(9)		60.5** (2.3)		
VARN0 x VARTH			5.6** (2.1)	

** significant at the 0.01 probability level.

Table 54. Sums of squares for aboveground biomass weight of 'Evans' soybean. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})
TRIFOL	12.7** (34.9)	40.2** (27.8)	13.4** (29.9)	38.5** (14.8)
SIZELF	5.3** (14.5)	15.8** (10.9)	6.0 ** (13.5)	18.9** (7.2)
PHTHRS(9)		18.2** (12.6)		13.4** (5.1)
PHTHRS(4)	4.5** (12.3)		5.4** (12.2)	
PHTHRS(6)	3.9** (10.6)		3.4** (7.7)	
PODVAR x VARN0				27.2** (10.4)
PODVAR x PHTHRS(9)		11.9** (8.2)		9.3** (3.6)
PODVAR x PHTHRS(6)		10.7** (7.3)		19.4** (7.4)
PODVAR	2.1** (5.6)		3.2** (7.1)	24.5** (14.8)
VARN0			3.2** (7.1)	11.9** (4.6)
SLAVAR	2.3** (6.3)	6.1** (4.2)	2.6** (5.7)	9.1** (3.5)
VARN0 x VARTH				7.3** (2.8)
VARTH				7.0** (2.7)
PHTHRS(8)				5.5** (2.1)

** significant at the 0.01 probability level.

Table 55. Sums of squares for aboveground biomass weight of 'Jupiter' soybean. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)
PHTHRS(9)	953.4** (52.2)	868.7** (28.5)	489.6** (40.4)	700.5** (22.7)
PHTHRS(6)	481.2** (26.9)	483.6** (15.9)	292.3** (24.1)	326.2** (10.6)
PHTHRS(4)	162.0** (9.0)	392.2** (12.9)	270.7** (22.3)	633.5** (20.6)
PODVAR	111.0** (6.2)	152.1** (5.0)	66.9** (5.5)	125.4** (4.1)
PODVAR x PHTHRS(6)		68.5** (2.2)		79.6** (2.6)
TRIFOL		63.9** (2.1)		66.8** (2.2)

** significant at the 0.01 probability level.

Table 56. Sums of squares for aboveground biomass weight of 'Williams' soybean. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)
PODVAR	418.0** (69.6)	1730.6**(57.)	654.2** (69.3)	2475.** (53.)
SIZELF	48.6** (8.1)	93.0** (3.1)	47.9** (5.1)	108.7** (2.3)
PODVAR x PHTHRS(6)	35.8** (6.0)		35.4** (3.8)	
PODVAR x VARN0			47.8** (5.1)	
TRIFOL	21.5** (3.6)		23.9** (2.5)	
PHTHRS(9)	17.8** (3.0)		23.7** (2.5)	
PODVAR x SIZELF		85.1** (2.8)		
PODVAR x PHTHRS(9)	15.2** (2.5)		19.7** (2.1)	
VARN0				108.1** (2.3)
PODVAR x SLAVAR		69.1** (2.3)		101.4** (2.2)
PODVAR x PHTHRS(4)		59.5** (2.0)		91.5** (2.0)

** significant at the 0.01 probability level.

the simulation output, yield and biomass, was non-linear. Hence, classical sensitivity analysis would not be applicable for SOYGRO genetic coefficients (Havens and Fontaine, 1991). Furthermore, analysis of variance showed that all reported effects were highly significant for SOYGRO and CERES-Maize, probably because of the very small experimental error. Since classical sensitivity analysis cannot be applied and analysis of variance was too sensitive, percentage of total sums of squares was the basis for effect differentiation.

Generally, latitude did not affect the proportion of variation that SOYGRO genetic coefficients had on yield or aboveground biomass. The percentage of total sums of squares for each effect showed little difference when simulated latitude was changed from 20.85° to 40.85° (Tables 49 to 56). In some cases, the photoperiod sensitivity genetic coefficients VARN0, VARTH and VARN1 became prominent at 40.85°, but the proportion of variation was small, typically less than 5% points. The one exception was aboveground biomass for 'Bragg' where the proportion of variation drastically changed with latitude (Table 53). Otherwise, latitude was not a factor that would change the results of the sensitivity analysis.

The SOYGRO genetic coefficients that account for most of the variation in yield were PODVAR and PHTHRS(9). For cultivars 'Bragg' (Table 49) and 'Williams' (Table 52), PODVAR accounted for most of the variation in yield, up to 85%. PODVAR was a major contributor to variation in yield at high latitude and ± two standard errors for 'Evans' (Table 50), but was a minor contributor to variation in yield for 'Jupiter' (Table 51). PHTHRS(9) contributed up to 50% of yield variation for 'Jupiter', but was a minor contributor for the other cultivars. 'Evans' had TRIFOL as a major source of variation for yield, 7 to 30%, and 'Jupiter' had PHTHRS(6), 19 to 39%, as a major contributor. However, no other cultivar had these effects as major contributors in yield variation. Generally, PODVAR and PHTHRS(9) were the greatest contributor to variation in yield over most cultivars.

A pattern similar to yield was found for effect contribution to aboveground biomass variation . PODVAR was an important contributor to aboveground biomass variation for 'Bragg' and 'Williams', 29 to 72% and 69%, respectively (Tables 53 and 56). For 'Evans', the major contributor to variation was TRIFOL, 15 to 35% (Table 53). PHTHRS(9) was the major source of aboveground biomass variation for 'Jupiter', 23 to 52%. Generally, PODVAR was the major source of aboveground biomass variation, but TRIFOL and PHTHRS(9) were also contributors for some cultivars.

Latitude did not affect the proportions of yield or aboveground biomass variation in CERES-Maize. Comparing various effects that accounted for the proportion of yield and aboveground biomass variation, the difference among latitudes was typically less than 5% points (Tables 57 to 66). Therefore, latitude was considered a negligible factor in the sensitivity analysis.

The CERES-Maize genetic coefficient G2 was consistently the greatest contributor to yield variation. Over all Pioneer hybrids, G2 accounted for 33 to 65%

of yield variation and was the most important contributor (Tables 57 to 61). G3 was also an important source of variation for Pioneer hybrids 3165 and 3790 with contributions of 30 and 22% (Tables 58 and 61). P5 was important to yield variation in Pioneer hybrid 3165 (Table 58). However, G2 was the most important factor that explained yield variation.

Aboveground biomass variation was mostly attributed to CERES-Maize variables P1 and XLPGDD. P1 was the greatest contributor to aboveground biomass variation, 28 to 69%, for all Pioneer hybrids (Tables 51 to 55). XLPGDD was the next greatest contributor to variation for Pioneer hybrids X304C, 3165, 3475, and 3790, with the effect accounting for 11 to 47 % (Tables 62, 63, 65, 66). For Pioneer hybrid 3324, G2 was the second greatest source of aboveground biomass variation (Table 64). All other effects, including interactions, contributed less than 20% of variation.

Discussion

The time to last flower, PHTHRS(9), and pod addition rate, PODVAR, effect on the SOYGRO simulated yield and biomass suggested an incorrect sensitivity to photoperiod. The photothermal time from first flower to last flower was PHTHRS(9), one of the factors that determined the duration of potential pod production. There was a weak positive linear relation between nightlength and PHTHRS(9): r^2 was 0.70, 0.16 and 0.48 for 'Bragg', 'Evans', and 'Williams'. The

Table 57. Sums of squares for yield of Pioneer hybrid X304C maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})
G2	182.3** (81.2)	708.9** (81.6)	182.8** (81.1)	710.5** (81.7)
G3	28.4** (12.6)	112.5** (12.9)	28.5** (12.6)	112.8** (13.0)
P5	11.1** (5.0)	40.9** (4.7)	11.8** (5.2)	40.4** (4.6)

** significant at the 0.01 probability level.

Table 58. Sums of squares for yield of Pioneer hybrid 3165 maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})
G2	64.3** (45.5)	254.3** (45.4)	64.8** (45.2)	256.6** (46.1)
G3	42.9** (30.3)	165.3** (29.5)	43.2** (30.1)	166.6** (29.9)
P5	31.3** (22.1)	125.6** (22.4)	33.7** (23.5)	125.9** (22.6)

** significant at the 0.01 probability level.

Table 59. Sums of squares for yield of Pioneer hybrid 3324 maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

	20.85°		40.85°	
Effect	± 1 s.e. ($\times10^{-6}$)	± 2 s.e. ($\times10^{-6}$)	± 1 s.e. ($\times10^{-6}$)	± 2 s.e. ($\times10^{-6}$)
G2	83.6** (62.4)	324.7** (65.1)	84.4** (63.4)	330.3** (65.3)
P5	20.7** (15.5)	81.9** (16.3)	20.9** (15.7)	83.4** (16.5)
G3	19.6** (14.6)	72.1** (14.3)	19.7** (14.8)	72.6** (14.4)
P1	5.7** (4.3)	13.1** (2.6)	3.3** (2.4)	11.0** (2.2)

** significant at the 0.01 probability level.

Table 60. Sums of squares for yield of Pioneer hybrid 3475 maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

	20.85°		40.85°	
Effect	± 1 s.e. ($\times10^{-6}$)	± 2 s.e. ($\times10^{-6}$)	± 1 s.e. ($\times10^{-6}$)	± 2 s.e. ($\times10^{-6}$)
G2	45.7** (47.1)	179.6** (52.4)	46.1** (44.4)	180.6** (52.7)
G3	16.4** (16.9)	65.5** (19.1)	16.5** (15.9)	65.8** (19.2)
P5	12.7** (13.1)	54.9** (16.0)	12.8** (12.4)	56.8** (16.6)
P1	12.1** (12.5)	26.5** (7.7)	17.3** (16.7)	21.9** (6.4)
XLPGDD	4.4** (4.6)	7.8** (2.3)	4.3** (4.2)	7.5** (2.2)
P2	2.0** (2.0)		4.3** (4.2)	
P1 x P2	2.0** (2.0)			

** significant at the 0.01 probability level.

Table 61. Sums of squares for yield of Pioneer hybrid 3790 maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)
G2	20.0** (36.3)	79.2** (33.5)	20.4** (38.6)	82.1** (36.3)
G3	12.1** (22.0)	47.1** (19.9)	12.4** (23.4)	48.6** (21.5)
P5	7.6** (13.7)	33.6** (14.2)	7.4** (14.1)	34.1** (15.1)
P1	6.6** (12.0)	56.2** (24.2)	5.9** (11.2)	35.8** (15.8)
XLPGDD	6.9** (12.5)	13.5** (5.7)	1.7** (3.3)	12.5** (5.5)
P2			1.7** (3.3)	7.0** (3.1)
P2 x XLPGDD			1.7** (3.3)	

** significant at the 0.01 probability level.

Table 62. Sums of squares for aboveground biomass weight of Pioneer hybrid X304C maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)
P1	775.2** (52.5)	1276.7**(33.5)	484.5** (39.0)	1410.7**(35.5)
XLPGDD	537.0** (36.4)	1802.1**(47.2)	544.1** (43.8)	1720.4**(43.3)
G2	130.2** (8.8)	506.2** (13.3)	130.5** (10.5)	507.3** (12.8)
P1 x P2			34.0** (2.7)	
G3		80.3** (2.1)		80.5** (2.0)

** significant at the 0.01 probability level.

Table 63. Sums of squares for aboveground biomass weight of Pioneer hybrid 3165 maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})
P1	519.8** (65.3)	1794.2**(67.8)	586.4** (67.8)	1965.9**(68.4)
XLPGDD	101.0** (12.7)	354.4** (13.4)	117.4** (13.6)	325.5** (11.3)
P2	73.6** (9.2)		58.1** (6.7)	
G2	45.9** (5.8)	181.5** (6.9)	46.3** (5.3)	183.2** (6.4)
G3	30.6** (3.8)	118.1** (4.5)	30.8** (3.6)	119.0** (4.1)
P5	21.3** (2.7)	85.5** (3.2)	22.9** (2.6)	85.4** (3.0)

** significant at the 0.01 probability level.

Table 64. Sums of squares for aboveground biomass weight of Pioneer hybrid 3324 maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})	± 1 s.e. (x10^{-6})	± 2 s.e. (x10^{-6})
P1	161.6** (51.2)	557.8** (52.8)	172.8** (48.2)	568.9** (52.3)
G2	59.7** (18.9)	234.0** (22.2)	60.2** (16.8)	135.8** (21.7)
XLPGDD	64.3** (20.4)	103.8** (9.8)	52.5** (14.6)	106.2** (9.8)
P2			33.4** (9.3)	39.6** (3.6)
P5	14.3** (4.5)	56.7** (5.4)	14.4** (4.0)	57.6** (5.3)
G3	14.0** (4.4)	51.5** (4.9)	14.1** (3.9)	51.8** (4.8)

** significant at the 0.01 probability level.

Table 65. Sums of squares for aboveground biomass weight of Pioneer hybrid 3475 maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

Effect	20.85°		40.85°	
	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)
P1	81.5** (38.9)	32.1** (43.7)	146.4** (49.8)	252.0** (37.4)
XLPGDD	47.4** (22.7)	154.1** (21.0)	52.1** (17.7)	151.1** (22.4)
G2	32.6** (15.6)	128.2** (17.5)	32.9** (11.2)	129.0** (19.2)
P1 x P2	14.7** (7.1)			
G3	11.7** (5.6)	46.7** (6.4)	11.8** (4.0)	47.0** (7.0)
P2	10.4** (5.0)	24.7** (3.4)	39.9** (13.6)	38.3** (5.7)
P5	8.9** (4.2)	38.1** (5.2)	8.9** (3.0)	39.5** (5.9)

** significant at the 0.01 probability level.

Table 66. Sums of squares for aboveground biomass weight of Pioneer hybrid 3790 maize. Genetic coefficients were varied ± one or two standard errors from the mean. Simulations were run at 20.85° and 40.85° latitude. Values in parentheses are percentages of total sum of squares.

	20.85°		40.85°	
Effect	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)	± 1 s.e. ($x10^{-6}$)	± 2 s.e. ($x10^{-6}$)
P1	27.9** (29.4)	346.7** (61.3)	21.9** (28.0)	237.6** (46.1)
XLPGDD	37.0** (38.9)	95.4** (16.9)	9.2** (11.8)	104.1** (20.2)
G2	14.3** (15.1)	56.6** (10.0)	14.6** (18.7)	58.6** (11.4)
P2 x XLPGDD			9.2** (11.8)	
G3	8.7** (9.1)	33.6** (5.9)	8.8** (11.3)	34.7** (6.7)
P2			7.6** (9.7)	39.8** (7.7)
P5	5.3** (5.6)	23.4** (4.1)	5.2** (18.7)	23.7** (4.6)

** significant at the 0.01 probability level.

positive linear relation suggested that although PHTHRS(9) was in photothermal units, the photoperiod sensitivity calculation underestimated the true effect. This would result in a high PHTHRS(9) at long nightlength and low PHTHRS(9) at short nightlength when fitting the PHTHRS(9) values to field observations. Grimm et al. (1994) noted that soybean became more sensitive to photoperiod as plants developed toward maturity and suggested that a new photothermal relation to soybean development would be needed. This suggests that a different sensitivity to photoperiod would be needed for flowering and post-flowering phases instead of the same photoperiod sensitivity in all phases currently used in SOYGRO. The incorrect specification for photothermal time likely caused the variation in PHTHRS(9), hence the variation in time for potential pod production, that ultimately was manifested in variation in yield and aboveground biomass.

The other important factor that affected yield and aboveground biomass, the maximum rate of pod addition or PODVAR, may have be the pod abortion relationship to photoperiod in SOYGRO. Once the number of flowers was set according to the time of flowering and the flower production rate, pod number was determined by multiplying the potential number of pod production, PODVAR, by factors such as available amount of photosynthate, temperature, and photoperiod. The photoperiod factor, called PODNIT, was defined as,

$$PODNIT = \frac{\frac{1}{DNIT} - \frac{1}{VARTH}}{1 - \frac{1}{VARTH}}$$

DNIT was the photoperiod sensitivity factor that was calculated as,

$$DNIT = \frac{(\ DURNIT\ -\ VARN0\ )\ x\ (\ VARTH\ -\ VARDH\ )}{VARN1\ -\ VARN0} + VARDH$$

where DURNIT was the nightlength, and VARDH was 1.0 (Jones et al., 1986). As an illustration of the relationship between the photoperiod sensitive pod production factor and photoperiod, PODNIT was reduced from 1.68 at 11 h nightlength to 0.61 at 10 h when Bragg fitted genetic coefficients were used in the equation (Figure 71). The PODNIT at short nightlength became very small, so fitting the simulated pod number to the observed required PODVAR to be very large. Furthermore, a very weak linear relation of fitted PODVAR to nightlength indicated that not all variation attributable to nightlength was accounted for in the present equation. The r^2 for the linear regression was 0.15, 0.45, 0.09, and 0.23 for 'Bragg', 'Evans', 'Jupiter', and 'Williams'. Therefore, the PODNIT relation to nightlength may reduce pod production too severely, especially at the shorter nightlength.

The dependence of aboveground biomass variation in CERES-Maize on the juvenile phase, P1, and leaf primordia initiation rate, XLPGDD, may be related to its effect on leaf number and, ultimately, leaf area. From germination to tassel initiation,

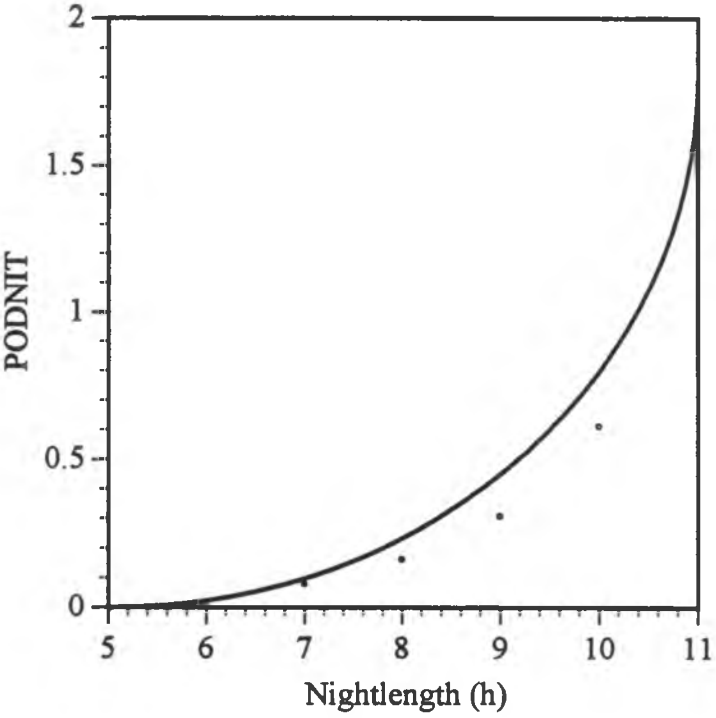

Figure 71. Approximate relationship between pod production nightlength factor and nightlength for 'Bragg' soybean using fitted genetic coefficients.

CERES-Maize calculated that one leaf primordia was initiated every 21 growing degree days (base temperature 8 °C) in addition to six leaf primordia already present in the seed (Jones et al., 1986). The juvenile phase, P1, was a portion of the germination to tassel initiation phase. Therefore, changing P1 changes the leaf number and leaf area. Likewise, changing the leaf primordia initiation rate would change leaf number and area. Because potential carbohydrate production is dependent on light interception, which in turn is dependent on leaf area, leaf area influenced aboveground biomass accumulation.

The variation in P1 may be partly attributable to the CERES-Maize assumption that the photoperiod inductive phase began four days prior to tassel initiation. In CERES-Maize, the photoperiod sensitive phase is assumed to start four days prior to tassel initiation when photoperiod is less than the threshold, 12.5 h (Jones et al., 1986). However, Kiniry et al. (1983) found that the photoperiod sensitive phase started 4 to 8 days prior to tassel initiation. If the actual beginning of the photoperiod sensitive phase was greater than the assumed four days, the determined P1 would vary with the ambient temperature: P1 would be less in low temperature than in high. The mean fitted P1 determined at the cool site, Haleakala, was 215.5 while at the warmer site P1 was 226.0. The difference in P1 between the two sites indicated that the end of juvenile phase to tassel initiation may not be four days. However, this difference was relatively small and can only partly account for P1 variation.

The leaf primordia initiation rate in CERES-Maize may also account for aboveground biomass variation. CERES-Maize assumes leaf primordia initiation rate is only dependent on temperature. Hence, the leaf primordia is calculated to initiate at a set interval of growing degree days. However, photoperiod is known to affect leaf primordia initiation rate (Grant, 1989). Warrington and Kanemasu (1983b) found that leaf initiation rate increased as photoperiod increased, as much as 25% faster, and that the effect was more pronounced under cool temperature. The fitted, leaf primordia initiation rate, XLPGDD, showed a weak linear relation to photoperiod. Linear regression of XLPGDD on photoperiod had r^2 of 0.66, 0.33, 0.13, 0.46, and 0.35 for Pioneer hybrids X304C, 3165, 3324, 3475, and 3790. So, specifying a photoperiod effect on leaf primordia initiation rate may increase the leaf area and aboveground biomass response to daylength.

G2 was the factor that most affected yield in CERES-Maize and may be partly related to leaf area problems discussed above. In CERES-Maize, the yield component kernel number is a function of the potential kernel number, G2, and photosynthate production from silking to beginning kernel growth (Jones et al., 1986). Since photosynthate production is a function of leaf area, any bias in leaf area calculation would be compensated for in the fitted G2, giving G2 greater variation. So, G2 seemed to be a large factor in yield variation. Another factor in G2 variation was its photoperiod dependence observed in Pioneer hybrid X304C. Photoperiod effect on tassel-silking interval and kernel number is not a function in CERES-Maize, so any effect would be absorbed in the fitted G2 causing variation.

Little work on the SOYGRO and CERES-Maize may produce much effect on the applicability of these models to environments that differ especially in photoperiod. The potential problems in SOYGRO and CERES-Maize that seemed photoperiod related were identified. In SOYGRO, the relation between photoperiod and photothermal time and the relations between nightlength and pod production were important contributors to model bias in yield and biomass. CERES-Maize yield and aboveground biomass bias seemed to be related to when the photoperiod sensitive phase starts and the relation of leaf primordia initiation to photoperiod. With the specification of these effects, the model bias should be reduced and the applicability of the model increased to sites that widely differ in photoperiod.

CHAPTER 5

SUMMARY AND CONCLUSIONS

As model refinements are made, a standard set of data over many environments will be needed to test the modifications. One of the major drawbacks in modeling crop plants is the shortage of data sets to test a modified model. Usually, modelers must develop data through field experimentation or borrow data sets. However, the number and range of environments that these data sets represent are usually limited, especially early in the development cycle. Hence, the models are not well tested. A standard set of data to validate models should be developed from environments that include extremes in temperature, photoperiod, solar radiation, rainfall, soil water holding capacity, and soil pH. The standard data set to test models against will not only allow quicker testing, but make comparisons among alternate models uniform. Presently, judging the utility of alternate models is difficult because the models are tested against different observed data sets. Therefore, data sets that reflect the extremes in agricultural systems will be needed as models are refined to simulate crop response to marginal conditions.

To increase the utility of the simulation model, genetic coefficients should be easily determinable. Two methods to determine genetic coefficients for SOYGRO and CERES-maize were evaluated. An explicit method to determine CERES-Maize genetic coefficients worked fairly well for development, but not for growth. The procedure to determine the growth coefficients from the real-system may have been inadequately defined. The fitting method to determine genetic coefficients was able to generate adequate development coefficients, but not growth coefficients for SOYGRO and CERES-Maize. The problem may have been that the relations within the model were not well validated in extreme conditions, so the model did not truly reflect the real system. Then, fitting coefficients to match the real system resulted in genetic coefficients that compensated for model biases. Seemingly, in a simple method to derive genetic coefficients, the coefficients cannot be considered apart from the model. Therefore, refinements in SOYGRO and CERES-Maize are needed to improve this method to determine genetic coefficients.

Currently, the genetic coefficients for SOYGRO and CERES-Maize are environment dependent. The growth genetic coefficients for SOYGRO and CERES-Maize were dependent on environment as seen in the trends over photoperiods and sites. This implies that the genetic coefficients determined in one environment cannot be used to simulate crop growth in another environment, especially when the environments greatly differ in photoperiod. To improve the models, more knowledge of the interaction between environment and plant growth and development is necessary. Under natural conditions, temperature and photoperiod are correlated. Then, an empirical model based on field data would contain photoperiod or temperature sensitivity with concomitant effects of the other built into the environmental effects on crop development and growth. This model would not well simulate crop development and growth where temperature and photoperiod are not closely correlated such as along a mountain slope or tropical regions. Other implications of the genetic coefficient dependency on environment are not well understood at this time.

APPENDIX A

Soybean data, summer 1988

Table A.1 Soybean data from Haleakala Experiment Station, control photoperiod treatment.

```
            INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

               SOYBEAN GENETIC COEFFICIENT NURSERIES


INSTITUTE
    NAME(INNAME):                       IBSNAT
    ID (INSTID):                        IB

RESEARCHER(S)
    NAME(RENAME):                       R.OGOSHI
    ID (RESID):                         RO

EXPERIMENT
    NAME (EXNAME):                      SOYBEAN CONTROL (P0) DAYLENGTH STUDY
    ID (EXPN):                          IDSS88H0

LOCATION
    NAME:                               HALEAKALA
    ID (LOC):                           HK

SEEDING
    YEAR (IYR)                                      1988
    DATE (ISOW;JULIAN DATE)                          155
    SEED DEPTH (SDEPTH;CM)                             4
    ESTABLISHED PLANT POPULATION (PLANTS;M-2)       33.3
    ROW WIDTH (ROW;CM)                                75

PHOTOPERIOD (HOURS)                                 NATURAL

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
     0 ____ ____ ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J))
```

Table A.1 (continued)

PLOTDATA - PHENOLOGY

****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT UPPER NODES; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD2	SDGR	MTUR
FEHR	STAGE:			V0	V1	V4	R1	R2	R3	R4		R7
1	4	1	160	---	189	291	235	238	259	266	267	347
1	2	2	160	---	189	---	189	---	---	194	201	247
1	3	3	160	---	189	291	268	275	275	280	286	345
1	1	4	160	---	189	229	---	208	---	226	229	277
2	1	1	160	---	189	229	---	208	---	226	229	277
2	3	2	160	---	189	271	261	272	275	278	281	347
2	4	3	160	---	189	266	235	238	253	266	272	347
2	2	4	160	---	189	---	189	---	---	194	201	240

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS

****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS(G/PLANT)			SEED	
			AREA	WT	PER	PER		AT MATURITY			WT	N
			MM2	MG	PLANT	PLANT	M.STEM	PODS	STEM	GRAIN	MG	%
1	4	1	18310	518	66.5	63.0	21.9	7.24	49.0	15.47	211	___
1	2	2	936	400	27.3	11.9	11.3	5.16	1.70	6.78	171	7.52
1	3	3	22276	946	113.2	65.7	21.0	13.92	42.4	18.05	199	___
1	1	4	16000	715	45.0	31.0	13.1	6.15	8.87	16.35	198	4.64
2	1	1	12360	503	36.5	28.0	12.2	5.41	8.32	14.05	216	6.69
2	3	2	18403	615	69.0	56.5	19.6	9.35	39.7	10.54	166	___
2	4	3	19960	699	39.1	49.4	23.4	3.54	27.4	8.85	201	___
2	2	4	1120	400	25.9	9.7	8.3	4.50	2.00	9.87	196	7.52

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS

****

Difficult to detect physiological maturity because of disease on pods.

Table A.2 Soybean data from Haleakala Experiment Station, natural photoperiod treatment.

```
                 INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                    SOYBEAN GENETIC COEFFICIENT NURSERIES


INSTITUTE
   NAME(INNAME):                      IBSNAT
   ID (INSTID):                       IB

RESEARCHER (S)
   NAME(RENAME):                      R.OGOSHI
   ID (RESID):                        RO

EXPERIMENT
   NAME (EXNAME):                     SOYBEAN NATURAL (P1) DAYLENGTH STUDY
   ID (EXPN):                         IDSS88H1

LOCATION
   NAME:                              HALEAKALA
   ID (LOC):                          HK

SEEDING
   YEAR (IYR)                                     1988
   DATE (ISOW;JULIAN DATE)                         155
   SEED DEPTH (SDEPTH;CM)                            4
   ESTABLISHED PLANT POPULATION (PLANTS;M-2)      33.3
   ROW WIDTH (ROW;CM)                               75

PHOTOPERIOD (HOURS)                               NATURAL+0.5H

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
     0 ____ ____ ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J))
```

Table A.2 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT UPPER NODES; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD2	SDGR	MTUR
FEHR STAGE:			V0	V1	V4		R1	R2	R3	R4		R7
1	3	1	160	---	189	280	280	289	289	292	296	347
1	2	2	160	---	189	---	189	---	---	194	201	247
1	1	3	160	---	189	229	---	208	223	228	235	302
1	4	4	160	---	189	296	236	238	250	258	266	336
2	1	1	160	---	189	228	189	208	223	228	236	296
2	3	2	160	---	189	275	272	289	289	292	296	347
2	2	3	160	---	189	---	---	---	---	194	201	247
2	4	4	160	---	189	258	229	235	250	258	266	323

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS
****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS(G/PLANT)			SEED	
			AREA	WT	PER	PER		AT MATURITY			WT	N
			MM2	MG	PLANT	PLANT	M.STEM	PODS	STEM	GRAIN	MG	%
1	3	1	18840	726	161.0	127.8	23.7	17.93	68.1	27.74	168	7.88
1	2	2	701	300	32.1	13.2	10.9	7.21	1.75	8.82	190	6.54
1	1	3	16580	819	57.0	35.7	11.6	11.13	14.37	15.51	199	6.81
1	4	4	18760	567	89.0	58.7	21.9	10.19	42.7	11.40	146	6.62
2	1	1	16240	849	54.5	36.4	12.6	10.07	15.48	19.91	242	7.11
2	3	2	21653	830	87.6	91.3	24.0	13.02	59.9	17.10	192	7.92
2	2	3	950	400	31.1	14.6	11.5	5.08	1.68	10.58	217	7.24
2	4	4	20720	705	59.6	41.5	17.3	7.17	24.8	9.69	210	7.00

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS
****

Difficult to detect physiological maturity because of disease on pods.

Table A.3 Soybean data from Haleakala Experiment Station, 14 h photoperiod treatment.

```
                INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                   SOYBEAN GENETIC COEFFICIENT NURSERIES


    INSTITUTE
       NAME(INNAME):                    IBSNAT
       ID (INSTID):                     IB

    RESEARCHER (S)
       NAME(RENAME):                    R.OGOSHI
       ID (RESID):                      RO

    EXPERIMENT
       NAME (EXNAME):                   SOYBEAN 14H (P2) DAYLENGTH STUDY
       ID (EXPN):                       IDSS88H2

    LOCATION
       NAME:                            HALEAKALA
       ID (LOC):                        HK

    SEEDING
       YEAR (IYR)                                  1988
       DATE (ISOW;JULIAN DATE)                      155
       SEED DEPTH (SDEPTH;CM)                         4
       ESTABLISHED PLANT POPULATION (PLANTS;M-2)   33.3
       ROW WIDTH (ROW;CM)                            75

    PHOTOPERIOD (HOURS)                              14

    IRRIGATION.
      JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
      AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

    NITROGEN FERTILIZATION
      JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
      AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
         0 ____ ____ ____ ____ ____ ____ ____ ____ ____
      DEPTH OF INCORPORATION OF J,TH FERTILIZATION
      (DFERT(J);CM,SURFACE APPLIED =1)
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
      CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
           AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
           M.NITRATE = 5)(IFTYPE(J))
```

Table A.3 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT ANY NODE; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD2	SDGR	MTUR
FEHR	STAGE:		V0	V1	V4		R1	R2	R3	R4		R7
1	3	1	160	---	189	266	267	275	275	281	292	006
1	4	2	160	---	189	266	240	250	267	278	281	351
1	1	3	160	---	189	228	---	211	223	229	236	301
1	2	4	160	---	189	---	---	---	---	194	201	242
2	2	1	160	---	189	---	---	---	---	194	201	242
2	3	2	160	---	189	275	272	278	296	302	307	027
2	4	3	160	---	189	280	228	230	246	253	259	351
2	1	4	160	---	189	229	228	208	211	223	229	296

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS
****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS (G/PLANT)			SEED	
			AREA	WT	PER	PER		AT	MATURITY		WT	N
			MM2	MG	PLANT	PLANT	M.STEM	PODS	STEM	GRAIN	MG	%
1	3	1	20866	503	74.0	88.7	20.5	8.87	56.8	7.12	168	8.59
1	4	2	19140	670	72.9	73.1	22.5	6.64	53.5	4.05	155	___
1	1	3	14320	660	69.4	45.0	13.6	14.63	18.69	28.91	237	6.41
1	2	4	---	---	23.5	10.2	9.0	3.75	1.08	7.40	177	6.90
2	2	1	---	---	20.6	11.6	10.2	3.34	1.14	7.48	199	7.26
2	3	2	19135	776	46.6	119.2	22.8	3.40	37.0	0.67	98	7.89
2	4	3	13700	489	87.0	91.0	23.0	2.33	75.0	1.51	153	7.38
2	1	4	13060	631	43.6	32.7	12.8	7.08	11.01	12.72	184	6.02

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS
****

2/4/3 The last leaf was very small, difficult to estimate full expansion.
2/4/3 Severe pheasant damage before final harvest. Only 2 plants harvested.
1/4/2 and 1/3/1 Some pheasant damage to pods and seeds at final harvest.
2/3/2 Only 5 plants for final harvest. Wt/seed based on 10 seeds. Some pheasant damage apparent.

Table A.4 Soybean data from Haleakala Experiment Station, 17 h photoperiod treatment.

```
                INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                   SOYBEAN GENETIC COEFFICIENT NURSERIES


    INSTITUTE
        NAME(INNAME):                       IBSNAT
        ID (INSTID):                        IB

    RESEARCHER (S)
        NAME(RENAME):                       R.OGOSHI
        ID (RESID):                         RO

    EXPERIMENT
        NAME (EXNAME):                      SOYBEAN 17H (P3) DAYLENGTH STUDY
        ID (EXPN):                          IDSS88H3

    LOCATION
        NAME:                               HALEAKALA
        ID (LOC):                           HK

    SEEDING
        YEAR (IYR)                                     1988
        DATE (ISOW;JULIAN DATE)                         155
        SEED DEPTH (SDEPTH;CM)                            4
        ESTABLISHED PLANT POPULATION (PLANTS;M-2)      33.3
        ROW WIDTH (ROW;CM)                               75

    PHOTOPERIOD (HOURS)                                  17

    IRRIGATION.
      JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
      AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

    NITROGEN FERTILIZATION
      JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
      AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
         0 ____ ____ ____ ____ ____ ____ ____ ____ ____
      DEPTH OF INCORPORATION OF J,TH FERTILIZATION
      (DFERT(J);CM,SURFACE APPLIED =1)
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
      CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
           AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
           M.NITRATE = 5)(IFTYPE(J))
```

Table A.4 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT ANY NODE; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD2	SDGR	MTUR
FEHR	STAGE:		V0	V1	V4		R1	R2	R3	R4		R7
1	1	1	160	---	189	292	247	250	268	280	282	358
1	2	2	160	---	189	---	---	194	---	197	201	258
1	4	3	160	---	189	003	292	308	322	336	339	71
1	3	4	160	---	189	315	289	307	317	321	324	60
2	2	1	160	---	189	---	---	194	---	197	201	249
2	3	2	160	---	189	336	___	___	___	___	___	93
2	4	3	160	---	189	301	272	292	324	330	338	72
2	1	4	160	---	189	292	246	250	258	267	272	312

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS
****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS(G/PLANT)			SEED	
			AREA	WT	PER	PER		AT	MATURITY		WT	N
			MM2	MG	PLANT	PLANT	M.STEM	PODS	STEM	GRAIN	MG	%
1	1	1	15505	460	76.6	72.0	17.0	5.07	24.1	5.55	171	9.57
1	2	2	19600	615	25.2	11.1	9.3	3.69	1.17	4.19	210	7.64
1	4	3	15005	512	0	131.2	23.1	0	65.5	0	0	0
1	3	4	15068	538	0	60.0	23.8	0	62.6	0	0	0
2	2	1	8890	468	19.5	10.7	8.8	3.47	1.05	5.75	194	6.99
2	3	2	---	---	0	228.0	30.0	0	143.0	0	0	0
2	4	3	18183	618	0	66.8	24.4	0	54.2	0	0	0
2	1	4	16666	547	50.6	42.0	16.4	6.89	23.0	9.91	165	6.24

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS
****

Flowers appear in rows near shadecloth wall but not on adjacent rows (8/27).
1/3/4 Looks like a wilt killed half the plants by 1/23/89, still not mature.
1/1/1 Grain was partially eaten by rats in the Krauss Hall Lab.
1/3/4 Most leaves on dropped. Pods still green 3/3/89.
1/3/1 and 2/4/3 Five plants sampled for final harvest.

Table A.5 Soybean data from Haleakala Experiment Station, 20 h photoperiod treatment.

```
                INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                   SOYBEAN GENETIC COEFFICIENT NURSERIES


INSTITUTE
   NAME(INNAME):                       IBSNAT
   ID (INSTID):                        IB

RESEARCHER (S)
   NAME(RENAME):                       R.OGOSHI
   ID (RESID):                         RO

EXPERIMENT
   NAME (EXNAME):                      SOYBEAN 20H (P4) DAYLENGTH STUDY
   ID (EXPN):                          IDSS88H4

LOCATION
   NAME:                               HALEAKALA
   ID (LOC):                           HK

SEEDING
   YEAR (IYR)                                     1988
   DATE (ISOW;JULIAN DATE)                         155
   SEED DEPTH (SDEPTH;CM)                            4
   ESTABLISHED PLANT POPULATION (PLANTS;M-2)      33.3
   ROW WIDTH (ROW;CM)                               75

PHOTOPERIOD (HOURS)                                 20

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
    0 ____ ____ ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J))
```

Table A.5 (continued)

PLOTDATA - PHENOLOGY
****
NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT ANY NODE; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD2	SDGR	MTUR
FEHR STAGE:			V0	V1	V4		R1	R2	R3	R4		R7
1	3	1	160	---	189	006	___	___	___	___	___	73
1	2	2	160	---	189	---	---	194	197	---	201	258
1	1	3	160	---	189	292	270	278	303	308	310	44
1	4	4	160	---	189	292	271	278	303	310	317	72
2	4	1	160	---	189	___	271	279	302	336	345	44
2	2	2	160	---	189	---	---	194	197	---	201	261
2	3	3	160	---	189	005	___	___	___	___	___	___
2	1	4	160	---	189	291	289	302	308	310	317	44

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS
****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS(G/PLANT)			SEED	
			AREA	WT	PER	PER		AT	MATURITY		WT	N
			MM2	MG	PLANT	PLANT	M.STEM	PODS	STEM	GRAIN	MG	%
1	3	1	___	___	117.4	24.6	___	0	74.4	0	0	0
1	2	2	12660	703	23.3	12.2	10.4	3.78	2.48	7.35	175	7.03
1	1	3	20100	542	69.6	136.3	22.8	7.17	56.8	6.30	185	6.85
1	4	4	14194	559	0	66.8	19.3	0	50.0	0	0	0
2	4	1	13194	461	41.9	101.3	25.8	4.37	54.2	5.41	190	7.89
2	2	2	12980	674	32.5	16.7	13.3	4.76	3.58	8.28	180	7.45
2	3	3	___	___	___	___	___	___	___	___	___	___
2	1	4	15588	714	0	89.4	18.4	0	52.0	0	0	0

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS
****
1/3/1 Leaf crinkling on plants near corn 10/28/88.
The row nearest to the shadecloth died 1/23/89, still hasn't flowered.
1/3/1 and 2/1/4 Five plants sampled for final harvest.

Table A.6 Soybean data from Kuiaha Experiment Site, control photoperiod treatment.

```
             INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                  SOYBEAN GENETIC COEFFICIENT NURSERIES


INSTITUTE
   NAME(INNAME):                     IBSNAT
   ID (INSTID):                      IB

RESEARCHER (S)
   NAME(RENAME):                     R.OGOSHI
   ID (RESID):                       RO

EXPERIMENT
   NAME (EXNAME):                    SOYBEAN CONTROL (P0) DAYLENGTH STUDY
   ID (EXPN):                        IDSS88K0

LOCATION
   NAME:                             KUIAHA
   ID (LOC):                         KU

SEEDING
   YEAR (IYR)                                    1988
   DATE (ISOW;JULIAN DATE)                        155
   SEED DEPTH (SDEPTH;CM)                           4
   ESTABLISHED PLANT POPULATION (PLANTS;M-2)     33.3
   ROW WIDTH (ROW;CM)                              75

PHOTOPERIOD (HOURS)                              NATURAL

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))

  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)

  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)

  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
     0 ____ ____ ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)

  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J))
```

Table A.6 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT UPPER NODES; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD2	SDGR	MTUR
FEHR	STAGE:		V0	V1	V4		R1	R2	R3	R4		R7
1	1	1	159	---	189	242	194	197	208	211	215	267
1	3	2	159	---	189	244	240	242	249	253	256	322
1	4	3	159	---	189	246	215	215	235	242	250	333
1	2	4	159	---	189	---	---	---	---	---	194	236
2	1	1	159	---	189	---	194	197	---	208	211	267
2	3	2	159	---	189	242	235	238	244	246	253	308
2	2	3	159	---	189	---	---	---	---	---	194	240
2	4	4	159	---	189	242	215	215	229	235	238	310

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS
****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS (G/PLANT)			SEED	
			AREA MM2	WT MG	PER PLANT	PER PLANT	M.STEM	AT MATURITY PODS	STEM	GRAIN	WT MG	N %
1	1	1	12120	463	41.1	28.0	10.6	8.11	4.72	12.97	182	6.13
1	3	2	16808	790	67.3	45.3	18.1	8.10	25.50	12.30	157	7.66
1	4	3	12750	542	114.3	71.8	19.5	11.25	40.7	10.60	99	7.08
1	2	4	711	400	19.3	10.3	7.4	2.65	1.02	7.37	186	7.03
2	1	1	13630	530	37.8	28.5	10.9	8.86	5.05	14.95	220	7.05
2	3	2	19160	783	66.7	42.4	15.7	9.90	19.40	23.40	210	7.19
2	2	3	746	400	17.9	9.9	7.8	2.31	1.08	7.01	191	6.89
2	4	4	14000	650	44.2	37.6	16.5	5.80	24.1	7.80	147	6.85

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS
****

Difficult to detect physiological maturity because of disease on pods.

Table A.7 Soybean data from Kuiaha Experiment Site, natural photoperiod treatment.

INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

SOYBEAN GENETIC COEFFICIENT NURSERIES

INSTITUTE
NAME(INNAME): IBSNAT
ID (INSTID): IB

RESEARCHER (S)
NAME(RENAME): R.OGOSHI
ID (RESID): RO

EXPERIMENT
NAME (EXNAME): SOYBEAN NATURAL (P1) DAYLENGTH STUDY
ID (EXPN): IDSS88K1

LOCATION
NAME: KUIAHA
ID (LOC): KU

SEEDING

YEAR (IYR)	1988
DATE (ISOW;JULIAN DATE)	155
SEED DEPTH (SDEPTH;CM)	4
ESTABLISHED PLANT POPULATION (PLANTS;M-2)	33.3
ROW WIDTH (ROW;CM)	75

PHOTOPERIOD (HOURS) NATURAL+0.5H

IRRIGATION.
JULIAN DATE OF J,TH IRRIGATION (JDAY(J))

____ ____ ____ ____ ____ ____ ____ ____ ____ ____

AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)

____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
JULIAN DATE OF J,TH FERTILIZATION(JFDAY)

____ ____ ____ ____ ____ ____ ____ ____ ____ ____

AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
0 ____ ____ ____ ____ ____ ____ ____ ____ ____

DEPTH OF INCORPORATION OF J,TH FERTILIZATION
(DFERT(J);CM,SURFACE APPLIED =1)

____ ____ ____ ____ ____ ____ ____ ____ ____ ____

CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1; AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4; M.NITRATE = 5)(IFTYPE(J))

Table A.7 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT UPPER NODES; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD2	SDGR	MTUR
FEHR STAGE:			V0	V1	V4		R1	R2	R3	R4		R7
1	3	1	159	---	189	253	240	242	258	261	264	317
1	4	2	159	---	189	250	215	215	235	242	250	319
1	1	3	159	---	189	229	201	201	215	215	222	274
1	2	4	159	---	189	---	---	---	---	---	194	242
2	4	1	159	---	189	242	222	222	236	242	253	321
2	2	2	159	---	189	---	---	---	---	---	194	242
2	3	3	159	---	189	253	236	242	258	261	264	317
2	1	4	159	---	189	229	---	201	211	215	222	274

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS
****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS(G/PLANT)			SEED	
			AREA	WT	PER	PER		AT MATURITY			WT	N
			MM2	MG	PLANT	PLANT	M.STEM	PODS	STEM	GRAIN	MG	%
1	3	1	18113	570	62.9	49.0	18.2	7.30	29.00	14.70	201	7.39
1	4	2	12780	493	41.5	46.5	17.0	5.77	24.60	7.58	177	6.57
1	1	3	13190	614	53.6	32.5	12.7	6.26	8.34	20.4	218	6.99
1	2	4	816	400	28.5	10.6	9.6	3.89	1.02	9.16	180	7.67
2	4	1	13370	564	56.7	52.5	20.9	5.43	29.40	3.49	141	7.14
2	2	2	803	400	31.9	11.9	9.8	4.22	1.41	11.52	186	7.33
2	3	3	18450	580	56.6	40.3	18.0	7.73	20.10	17.57	215	7.38
2	1	4	12470	482	34.7	27.7	11.2	4.49	5.09	12.47	198	6.37

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS
****

Table A.8 Soybean data from Kuiaha Experiment Site, 14 h photoperiod treatment.

```
               INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                  SOYBEAN GENETIC COEFFICIENT NURSERIES


INSTITUTE
   NAME(INNAME):                  IBSNAT
   ID (INSTID):                   IB

RESEARCHER (S)
   NAME(RENAME):                  R.OGOSHI
   ID (RESID):                    RO

EXPERIMENT
   NAME (EXNAME):                 SOYBEAN 14H (P2) DAYLENGTH STUDY
   ID (EXPN):                     IDSS88K2

LOCATION
   NAME:                          KUIAHAALA
   ID (LOC):                      KU

SEEDING
   YEAR (IYR)                                          1988
   DATE (ISOW;JULIAN DATE)                              155
   SEED DEPTH (SDEPTH;CM)                                 4
   ESTABLISHED PLANT POPULATION (PLANTS;M-2)           33.3
   ROW WIDTH (ROW;CM)                                    75

PHOTOPERIOD (HOURS)                                    14

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))

  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)

  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)

  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
     0 ____ ____ ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)

  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J))
```

Table A.8 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT ANY NODE; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD2	SDGR	MTUR
FEHR STAGE:			V0	V1	V4		R1	R2	R3	R4		R7
1	3	1	159	---	189	244	235	238	268	272	274	333
1	2	2	159	---	189	---	---	---	---	---	194	238
1	1	3	159	---	189	229	---	201	211	215	222	272
1	4	4	159	---	189	242	215	215	238	242	244	321
2	1	1	159	---	189	229	---	201	---	211	215	272
2	3	2	159	---	189	242	236	236	268	272	274	333
2	2	3	159	---	189	---	---	---	---	---	194	242
2	4	4	159	---	189	246	215	215	236	242	244	321

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS
****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS(G/PLANT)			SEED	
			AREA	WT	PER	PER		AT	MATURITY		WT	N
			MM2	MG	PLANT	PLANT	M.STEM	PODS	STEM	GRAIN	MG	%
1	3	1	17323	786	111.9	64.6	16.8	15.6	41.7	43.6	262	6.75
1	2	2	---	---	28.9	12.1	9.4	3.79	1.04	9.47	171	6.71
1	1	3	10157	760	39.0	28.9	12.2	4.77	6.86	15.13	189	6.57
1	4	4	13895	806	47.8	37.0	18.4	5.48	26.6	6.20	155	7.21
2	1	1	11665	696	42.5	26.2	12.8	4.94	7.54	15.06	172	6.97
2	3	2	17510	975	67.6	44.5	16.7	8.16	30.9	20.57	226	7.27
2	2	3	---	---	37.0	15.2	10.9	5.03	1.56	10.97	143	7.10
2	4	4	12245	590	59.9	36.3	16.0	7.74	24.7	9.69	144	6.70

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS
****

2/3/2 R1 and R2 happened simultaneously ? (8/22/88 2 p.m.)
2/4/4 Flowering after pods.
2/4/4 ?????? harvested about 1m of our harvest row 10/28/88. Will be forced to harvest remaining plants.

Table A.9 Soybean data from Kuiaha Experiment Site, 17 h photoperiod treatment.

INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

SOYBEAN GENETIC COEFFICIENT NURSERIES

INSTITUTE	
NAME(INNAME):	IBSNAT
ID (INSTID):	IB
RESEARCHER (S)	
NAME(RENAME):	R.OGOSHI
ID (RESID):	RO
EXPERIMENT	
NAME (EXNAME):	SOYBEAN 17H (P3) DAYLENGTH STUDY
ID (EXPN):	IDSS88K3
LOCATION	
NAME:	KUIAHA
ID (LOC):	KU
SEEDING	
YEAR (IYR)	1988
DATE (ISOW;JULIAN DATE)	155
SEED DEPTH (SDEPTH;CM)	4
ESTABLISHED PLANT POPULATION (PLANTS;M-2)	33.3
ROW WIDTH (ROW;CM)	75
PHOTOPERIOD (HOURS)	17
IRRIGATION.	
JULIAN DATE OF J,TH IRRIGATION (JDAY(J))	
____ ____ ____ ____ ____ ____ ____ ____ ____ ____	
AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)	
____ ____ ____ ____ ____ ____ ____ ____ ____ ____	
NITROGEN FERTILIZATION	
JULIAN DATE OF J,TH FERTILIZATION(JFDAY)	
____ ____ ____ ____ ____ ____ ____ ____ ____ ____	
AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)	
0 ____ ____ ____ ____ ____ ____ ____ ____ ____	
DEPTH OF INCORPORATION OF J,TH FERTILIZATION (DFERT(J);CM,SURFACE APPLIED =1)	
____ ____ ____ ____ ____ ____ ____ ____ ____ ____	
CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1; AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4; M.NITRATE = 5)(IFTYPE(J))	

Table A.9 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT ANY NODE; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD2	SDGR	MTUR
FEHR STAGE:			V0	V1	V4		R1	R2	R3	R4		R7
1	4	1	159	---	189	280	244	250	282	292	302	33
1	3	2	159	---	189	292	___	___	___	___	___	___
1	2	3	159	---	189	---	---	---	---	194	208	247
1	1	4	159	---	189	292	249	253	275	278	281	25
2	3	1	159	---	189	336	___	___	___	___	___	___
2	4	2	159	---	189	296	246	256	---	---	317	55
2	2	3	159	---	189	229	---	---	194	197	201	247
2	1	4	159	---	189	292	249	258	275	282	289	37

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS
****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS (G/PLANT)			SEED	
			AREA	WT	PER	PER		AT MATURITY			WT	N
			MM2	MG	PLANT	PLANT	M.STEM	PODS	STEM	GRAIN	MG	%
1	4	1	13945	412	0	63.0	15.0	0	30.6	0	0	-
1	3	2	___	___	___	___	___	___	___	___	___	___
1	2	3	---	---	29.8	14.6	11.1	4.96	1.54	11.02	176	6.58
1	1	4	16200	669	0	90.4	15.6	0	65.0	0	0	-
2	3	1	___	___	___	___	___	___	___	___	___	___
2	4	2	14285	418	0	160.1	21.1	0	99.1	0	0	-
2	2	3	---	---	38.3	16.7	12.1	6.83	2.66	15.07	215	6.87
2	1	4	16576	669	0	108.9	20.3	0	45.8	0	0	___

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS
****

1/4/1, 1/1/4, and 2/4/2 Pods fell off the plants 1/13/89.
1/3/2 and 2/3/1 Slugs on plants 3/4/89.

Table A.10 Soybean data from Kuiaha Experiment Site, 20 h photoperiod treatment.

INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

SOYBEAN GENETIC COEFFICIENT NURSERIES

INSTITUTE
NAME(INNAME): IBSNAT
ID (INSTID): IB

RESEARCHER (S)
NAME(RENAME): R.OGOSHI
ID (RESID): RO

EXPERIMENT
NAME (EXNAME): SOYBEAN 20H (P4) DAYLENGTH STUDY
ID (EXPN): IDSS88K4

LOCATION
NAME: KUIAHA
ID (LOC): KU

SEEDING

YEAR (IYR)	1988
DATE (ISOW;JULIAN DATE)	155
SEED DEPTH (SDEPTH;CM)	4
ESTABLISHED PLANT POPULATION (PLANTS;M-2)	33.3
ROW WIDTH (ROW;CM)	75

PHOTOPERIOD (HOURS) 20

IRRIGATION.
JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
____ ____ ____ ____ ____ ____ ____ ____ ____ ____
AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
JULIAN DATE OF J,TH FERTILIZATION(JFDAY)
____ ____ ____ ____ ____ ____ ____ ____ ____ ____
AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
0 ____ ____ ____ ____ ____ ____ ____ ____ ____
DEPTH OF INCORPORATION OF J,TH FERTILIZATION
(DFERT(J);CM,SURFACE APPLIED =1)
____ ____ ____ ____ ____ ____ ____ ____ ____ ____
CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
M.NITRATE = 5)(IFTYPE(J))

Table A.10 (continued)

PLOTDATA - PHENOLOGY

****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES RECORDED AS DAYS FROM JANUARY 1. EMRG=EMERGENCE; UNIFE=UNIFOLIATE FULLY EXPANDED; 4 ND=4 NODES INCL.UNIFOLIATE; LLFE=LAST LEAF ON MAIN STEM FULLY EXPANDED; FFLW=FIRST FLOWER; LFLW=LAST FLOWER ON MAIN AXES; SDGR=START OF SEED GROWTH AT ANY NODE; MTUR=50% PODS YELLOW

REP	ENT	PLT	EMRG	UNIFE	4 ND	LLFE	FFLW	LFLW	POD0.5	POD	SDGR	MTUR
FEHR	STAGE:		V0	V1	V4	R1	R2	R3	R4			R7
1	1	1	159	---	189	296	292	317	322	324	329	042
1	3	2	159	---	189	308	___	___	___	___	___	___
1	4	3	159	---	189	301	286	292	324	338	351	96
1	2	4	159	---	189	229	194	---	197	201	208	272
2	2	1	159	---	189	229	194	---	197	201	208	271
2	3	2	159	---	189	354	___	___	___	___	___	___
2	1	3	159	---	189	301	291	---	317	322	330	42
2	4	4	159	---	189	301	292	301	324	345	351	96

PLOTDATA - LEAF,SHOOT AND SEED MEASUREMENTS

****

LEAF DIMENSIONS FROM 10 REPRESENTATIVE LEAVES (ALL TRIFOLIATES) AT FLOWERING. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	LEAVES		PODS	NODES		COMPONENTS(G/PLANT)			SEED	
			AREA	WT	PER	PER		AT	MATURITY		WT	N
			MM2	MG	PLANT	PLANT	M.STEM	PODS	STEM	GRAIN	MG	%
1	1	1	13858	480	0	43.4	12.8	0	27.0	0	0	-
1	3	2	___	___	___	___	___	___	___	___	___	___
1	4	3	14559	500	0	265.4	24.2	0	268.8	0	0	0
1	2	4	14245	848	72.7	29.4	17.3	12.00	9.69	21.00	159	7.08
2	2	1	12079	747	61.6	27.0	16.4	9.02	9.64	16.88	160	7.27
2	3	2	___	___	___	___	___	___	___	___	___	___
2	1	3	15979	640	0	133.5	18.7	0	51.5	0	0	-
2	4	4	12447	372	0	163.8	23.8	0	164.6	0	0	-

Ent. no.: 1=Bragg; 2=Evans; 3=Jupiter; 4=Padre.

GENERAL OBSERVATIONS

****

1/1/1 West half of row is dying back from apex downward, no fowers on those yet. Those with flowers on the eastern border are still green, no die back.
1/4/3, 2/1/3, and 2/4/4 Pods fell off the plants 1/13/89.
1/1/1 Five plants harvested at final biomass.
2/1/3 Six plants harvested at final biomass.

APPENDIX B

Soybean data, winter 1988

Table B.1 Soybean data from Haleakala Experiment Station, control photoperiod treatment.

IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
****

PERSONNEL
RESEARCHER: Richard Ogoshi
INSTITUTION: IBSNAT

EXPERIMENT
TITLE: IBSNAT DAYLENGTH;WINTER;SOYBEANS 1989
ID: IDWS89H0

TREATMENTS
GENOTYPES: 4
MANAGEMENT: 0

LOCATION
NAME: HALEAKALA

PLOTS
*****

PLANTING DATE Jan. 19, 1989

PLANT DENSITY (PLANTS/M2) 33.3

ORGANISATION
NO.OF ROWS (#): 2
ROW LENGTH (M): 3
ROW SPACING (CM): 75
ORIENTATION OF ROWS: E-W
ALONG OR ACROSS DRAINS: n.a.
SPACE BETWEEN PLOTS (CM): 0
GROSS AREA (M 2): 4.5

HARVEST
NO.OF ROWS: 1
ROW LENGTH (M): 0.4
AREA (M 2): 0.3
METHOD: hand

RANDOMIZATION/REPLICATION
DESIGN: RCB
NO.OF REPS.-SOWN: 2
-HARVESTED: 2

PROBLEMS
****

Table B.1 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 |    |    |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 4ND|FFLW|LFLW|NNSF|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 |  30|  44|  74|  65|  70|   3|  70|  77|  83|  80|____|____|
| 1 |  3 |  2 |  27|  41|  63| 121| 126|  12| 126| 134| 141| 118|____|____|
| 1 |  1 |  3 |  27|  42|  70|  68|  82|   3|  76|  81|  82|  80| 146|____|
| 1 |  4 |  4 | -- | -- |____|____|____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  2 |  1 |  27|  44|  72|  65|  70|   3|  70|  74|  81|  89|____|____|
| 2 |  4 |  2 | -- | -- |____|____|____|____|____|____|____|____|____|____|
| 2 |  1 |  3 |  28|  45|  68|  69|  82|   4|  80|  82|  87|  81| 142|____|
| 2 |  3 |  4 |  30|  46|  68| 122| 134|  10| 134| 141| 142| 121|____|____|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 1
PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 |44.7|.296|____|____|____|____|____|____|____|____|____|____|
| 1 |  3 |  2 | 222|1.38|____|____|____|____|____|____|____|____|____|____|
| 1 |  1 |  3 |50.5|.260|____|____|____|____|____|____|____|____|____|____|
| 1 |  4 |  4 |____|____|____|____|____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  2 |  1 |42.3|.264|____|____|____|____|____|____|____|____|____|____|
| 2 |  4 |  2 |____|____|____|____|____|____|____|____|____|____|____|____|
| 2 |  1 |  3 |57.1|.261|____|____|____|____|____|____|____|____|____|____|
| 2 |  3 |  4 | 217|1.22|____|____|____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************

 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table B.2 Soybean data from Haleakala Experiment Station, natural photoperiod treatment.

```
        IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                   PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;WINTER;SOYBEANS 1989
         ID:             IDWS89H1

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     1

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                   Jan. 19, 1989

      PLANT DENSITY (PLANTS/M2)       33.3

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              0.4
         AREA (M 2):                  0.3
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table B.2 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 |    |    |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 4ND|FFLW|LFLW|NNSF|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 |  28|  41|  62|  68|  81|   4|  72|  80|  84|  82| 142|____|
| 1 |  2 |  2 |  30|  45|  72|  68|  70|   3|  70|  74|  82|  80|____|____|
| 1 |  4 |  3 | -- | -- |____|____|____|____|____|____|____|____|____|____|
| 1 |  3 |  4 |  27|  41|  63| 124| 137|   9| 138| 161| 175| 121|____|____|
---------------------------------------------------------------------------
| 2 |  2 |  1 |  30|  45|  72|  66|  70|   3|  68|  76|  84|  89| 142|____|
| 2 |  1 |  2 |  28|  45|  68|  69|  83|   4|  83|  87|  89|  87| 143|____|
| 2 |  3 |  3 |  28|  42|  68| 122| 137|  10| 142| 154| 161| 118|____|____|
| 2 |  4 |  4 | -- | -- |____|____|____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 1
PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 |60.1|.275|____|____|____|____|____|____|____|____|____|____|
| 1 |  2 |  2 |46.5|.283|____|____|____|____|____|____|____|____|____|____|
| 1 |  4 |  3 |____|____|____|____|____|____|____|____|____|____|____|____|
| 1 |  3 |  4 | 239|1.46|____|____|____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  2 |  1 |63.4|.461|____|____|____|____|____|____|____|____|____|____|
| 2 |  1 |  2 |87.6|.327|____|____|____|____|____|____|____|____|____|____|
| 2 |  3 |  3 | 298|1.77|____|____|____|____|____|____|____|____|____|____|
| 2 |  4 |  4 |____|____|____|____|____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************

 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table B.3 Soybean data from Kuiaha Experiment Site, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;WINTER;SOYBEANS 1989
         ID:            IDWS89K0

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    0

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                   Jan. 19, 1989

      PLANT DENSITY (PLANTS/M2)       33.3

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              0.4
         AREA (M 2):                  0.3
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table B.3 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE  | V0 | V1 |    |    |    |    |    |    |    |    |    |    |
ASPECT        |EMRG|UNFE| 4ND|FFLW|LFLW|NNSF|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 |  30|  42|____|____|____|____|____|____|____|____|____|____|
| 1 |  1 |  2 |  30|  41|  62|  60|  77| 3  |  66|  68|  70|  76|____|____|
| 1 |  4 |  3 | -- | -- |____|____|____|____|____|____|____|____|____|____|
| 1 |  3 |  4 |  27|  39|  61|  66|  85|   4|  81|  84|  89|  87| 141| 153|
---------------------------------------------------------------------------
| 2 |  4 |  1 | -- | -- |____|____|____|____|____|____|____|____|____|____|
| 2 |  1 |  2 |  27|  41|  60|  60|  77| 4  |  62|  67|  70|  70|____|____|
| 2 |  2 |  3 |  27|  41|  62|  58|  77| 3  |  - |  62|  70|  72|  72|____|
| 2 |  3 |  4 |  26|  41|  - |  70|  85|   7|  81|  84|  87|  80| 141| 143|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 1
PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT        |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS         |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 |____|____|____|____|____|____|____|____|____|____|____|____|
| 1 |  1 |  2 |36.9|.140|____|____|____|____|____|____|____|____|____|____|
| 1 |  4 |  3 |____|____|____|____|____|____|____|____|____|____|____|____|
| 1 |  3 |  4 |92.6|.339|10.6| 3.2| 9.3|1.42|2.15|3.43| 173|6.30|____|____|
---------------------------------------------------------------------------
| 2 |  4 |  1 |____|____|____|____|____|____|____|____|____|____|____|____|
| 2 |  1 |  2 |42.0|.156|____|____|____|____|____|____|____|____|____|____|
| 2 |  2 |  3 |31.7|.124|____|____|____|____|____|____|____|____|____|____|
| 2 |  3 |  4 | 147|.528|18.4| 6.1| 8.8|2.79|3.99|8.67| 258|7.25|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************

 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table B.4 Soybean data from Kuiaha Experiment Site, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;WINTER;SOYBEANS 1989
         ID:            IDWS89K1

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    1

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                  Jan. 19, 1989

      PLANT DENSITY (PLANTS/M2)      33.3

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             0.4
         AREA (M 2):                 0.3
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                    -HARVESTED:      2

PROBLEMS
********
```

Table B.4 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1.

GROWTH STAGE			V0	V1										
ASPECT			EMRG	UNFE	4ND	FFLW	LFLW	NNSF	PD05	POD2	SDGR	LLFE	PYEL	PBRN
REP	ENT	PLT												
1	1	1	--	--										
1	4	2	--	--										
1	2	3	27	41	63	58	70	3	-	61	70	72		
1	3	4	30	41	74	73	93	3	85	89	97	84	161	174
2	2	1	30	41	58	58	70	4	-	61	70	72		
2	4	2	--	--										
2	3	3	27	40	72	72	93	6	83	85	89	81	150	154
2	1	4	27	40	58	58	77	4	62	66	70	70		

PLOTDATA - GROWTH CHARACTERISTICS

AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 1 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.

SAMPLING TIME			SEED GR.		---- MATURITY;5-10 PLANT SUBSAMPLE ----									
ASPECT			MXAL	MXWL	PDPP	BRPP	NDPS	PDWT	STWT	GRWT	SDWT	SDN%		
UNITS														
REP	ENT	PLT												
1	1	1												
1	4	2												
1	2	3	49.6	.200										
1	3	4	171	.552	30.7	6.3	10.6	5.37	7.18	14.5	259	6.94		
2	2	1	39.7	.160										
2	4	2												
2	3	3	177	.574	24.7	6.7	9.9	3.98	8.39	11.2	261	7.68		
2	1	4	57.6	.190										

KEY POSITIONS AND NAMES/PEDIGREES

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							BRAGG
2							EVANS
3							JUPITER
4							WILLIAMS

APPENDIX C

Soybean data, summer 1989

Table C.1 Soybean data from Haleakala Experiment Station, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
         ID:            IDSS89H0

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    0

      LOCATION
         NAME:          HALEAKALA

PLOTS
*****
      PLANTING DATE                   Sep. 9, 1989

      PLANT DENSITY (PLANTS/M2):      Bragg/Evans,33.3;Jupiter/Williams,22.2

      ORGANISATION
         NO.OF ROWS (#):              Bragg/Evans, 2; Jupiter/Williams,1
         ROW LENGTH (M):              3
         ROW SPACING (CM):            Bragg/Evans,75;Jupiter/Williams,112.5
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              0.4
         AREA (M 2):                  Bragg/Evans,0.3;Jupiter/Williams,0.45
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                   -HARVESTED:        2

PROBLEMS
********
```

Table C.1 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*****************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V4 | V5 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 4ND| 5ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 234| 249| 267| 273| 293| 304| 299| 303| 305| 300| 362|____|
| 1 |  2 |  2 | 235| 250| 273| 280| 268| 273| 270| 273| 276| 286| 315| 322|
| 1 |  4 |  3 | 234| 245| 268| 280| 269| 273| 270| 272| 276| 284| 319| 325|
| 1 |  1 |  4 | 234| 248| 266| 273| 277| 284| 280| 283| 286| 285| 329| 333|
---------------------------------------------------------------------------
| 2 |  3 |  1 | 234| 245| 267| 273| 293| 303| 299| 303| 310| 296| 363|____|
| 2 |  1 |  2 | 234| 249| 266| 272| 278| 287| 280| 283| 286| 286| 329| 335|
| 2 |  2 |  3 | 235| 249| 273| 287| 268| 277| 270| 272| 275| 285| 322| 325|
| 2 |  4 |  4 | 234| 245| 273| 280| 268| 273| 270| 273| 275| 284| 319| 329|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
***********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 208|1.12|____|____|____|____|____|____|____|____|____|____|
| 1 |  2 |  2 |63.5|.312| 1.3| 0.3| 6.4|0.51|0.92|0.43| 208|7.77|____|____|
| 1 |  4 |  3 |74.8|.307| 6.7| 0.0| 7.4|0.94|0.94|1.96| 195|8.04|____|____|
| 1 |  1 |  4 |94.9|.300|11.8| 2.5| 8.7|1.89|1.51|4.13| 201|8.20|____|____|
---------------------------------------------------------------------------
| 2 |  3 |  1 | 239|1.49|____|____|____|____|____|____|____|____|____|____|
| 2 |  1 |  2 | 113|.360|17.1| 3.2| 9.1|2.82|2.25|5.85| 196|7.86|____|____|
| 2 |  2 |  3 |63.4|.325| 3.0| 0.2| 8.0|0.60|0.76|0.53| 168|7.40|____|____|
| 2 |  4 |  4 |86.6|.330| 5.4| 0.0| 6.8|0.80|0.54|2.57| 208|7.86|____|____|
---------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
***********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table C.2 Soybean data from Haleakala Experiment Station, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
               PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
         ID:            IDSS89H1

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    1

      LOCATION
         NAME:          HALEAKALA

PLOTS
*****
      PLANTING DATE                  Sep. 9, 1989

      PLANT DENSITY (PLANTS/M2)      Bragg/Evans,33.3;Jupiter/Williams,22.2

      ORGANISATION
         NO.OF ROWS (#):             Bragg/Evans, 2; Jupiter/Williams, 1
         ROW LENGTH (M):             3
         ROW SPACING (CM):           Bragg/Evans,75;Jupiter/Williams,112.5
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             0.4
         AREA (M 2):                 Bragg/Evans,0.3;Jupiter/Williams,0.45
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table C.2 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS

`***************************************`

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1.

GROWTH STAGE			V0	V1	V4	V5								
ASPECT			EMRG	UNFE	4ND	5ND	FFLW	LFLW	PD05	POD2	SDGR	LLFE	PYEL	PBRN
REP	ENT	PLT												
1	4	1	234	245	266	273	268	273	270	273	275	288	321	326
1	1	2	235	248	266	273	276	281	283	286	290	286	336	338
1	3	3	234	245	266	273	303	315	310	313	319	310		
1	2	4	234	248	275	280	268	273	270	273	275	285	319	325
2	2	1	234	249	273	280	268	273	270	273	276	280	319	325
2	1	2	234	249	265	269	276	285	282	285	290	286	336	338
2	3	3	235	245	265	270	303	315	310	313	318	305		
2	4	4	234	245	273	279	268	273	270	273	277	285	320	327

PLOTDATA - GROWTH CHARACTERISTICS

`*********************************`

AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.

SAMPLING TIME			SEED GR.		---- MATURITY;5-10 PLANT SUBSAMPLE ----									
ASPECT			MXAL	MXWL	PDPP	BRPP	NDPS	PDWT	STWT	GRWT	SDWT	SDN%		
UNITS														
REP	ENT	PLT												
1	4	1	111	.415	10.2	0.6	8.9	1.59	0.97	4.53	217	8.23		
1	1	2	121	.353	18.9	3.4	9.6	3.03	2.16	6.26	190	7.68		
1	3	3	231	1.52										
1	2	4	78.8	.454	13.2	0.0	7.3	1.53	0.69	3.80	174	6.85		
2	2	1	119	.728	10.1	0.0	6.8	1.12	0.65	2.79	184	7.43		
2	1	2	93.0	.441	20.2	3.4	9.9	3.29	2.84	5.27	170	7.54		
2	3	3	133	.365										
2	4	4	79.8	.280	5.7	0.3	7.6	0.92	0.77	2.63	223	7.40		

KEY POSITIONS AND NAMES/PEDIGREES

`*********************************`

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							BRAGG
2							EVANS
3							JUPITER
4							WILLIAMS

Table C.3 Soybean data from Haleakala Experiment Station, 14 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
         ID:             IDSS89H2

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     1

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                   June 16, 1989

      PLANT DENSITY (PLANTS/M2)       Bragg/Evans,33.3;Jupiter/Williams,22.2

      ORGANISATION
         NO.OF ROWS (#):              Bragg/Evans, 2; Jupiter/Williams, 1
         ROW LENGTH (M):              3
         ROW SPACING (CM):            Bragg/Evans,75;Jupiter/Williams,112.5
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              0.4
         AREA (M 2):                  Bragg/Evans,0.3;Jupiter/Williams,0.45
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                   -HARVESTED:        2

PROBLEMS
********
```

Table C.3 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V4 | V5 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 4ND| 5ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 | 173| 183| 203| 209| 201| 216| 209| 211| 216| 220| 257| 262|
| 1 |  1 |  2 | 172| 183| 203| 207| 232| 248| 241| 245| 254| 248| 300| 304|
| 1 |  3 |  3 | 172| 183| 202| 203| 314| 327| 318| 321| 329| 303|____|____|
| 1 |  4 |  4 | 172| 183| 203| 207| 203| 220| 214| 216| 222| 241| 268| 276|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 172| 183| 202| 203| 232| 248| 241| 248| 251| 254| 300| 305|
| 2 |  3 |  2 | 172| 183| 203| 210| 314| 327| 318| 321| 328| 318|____|____|
| 2 |  2 |  3 | 173| 184| 203| 210| 201| 211| 207| 211| 214| 220| 255| 259|
| 2 |  4 |  4 | 172| 183| 203| 210| 203| 222| 214| 216| 220| 236| 268| 276|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT        |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS         |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 |85.9|.354|26.2| 1.6| 9.4|3.23|1.17|12.6| 158|7.25|____|____|
| 1 |  1 |  2 | 149|.744|44.8| 6.0|15.6|8.38|14.1|14.7| 174|6.58|____|____|
| 1 |  3 |  3 |____|____|____|____|____|____|____|____|____|____|____|____|
| 1 |  4 |  4 | 112|.354|19.2| 1.6|12.2|3.96|3.15|11.7| 246|7.05|____|____|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 171|.845|46.6| 6.1|14.9|7.18|13.0|7.85| 114|6.39|____|____|
| 2 |  3 |  2 |____|____|____|____|____|____|____|____|____|____|____|____|
| 2 |  2 |  3 |72.0|.276|22.9| 1.2| 8.6|2.75|1.16|7.37| 151|6.82|____|____|
| 2 |  4 |  4 | 113|.353|12.4| 1.1|10.6|2.49|3.06|6.63| 251|7.14|____|____|
---------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | _ | _ | _ | _ | _ | _ | BRAGG
| 2 | _ | _ | _ | _ | _ | _ | EVANS
| 3 | _ | _ | _ | _ | _ | _ | JUPITER
| 4 | _ | _ | _ | _ | _ | _ | WILLIAMS
```

Table C.4 Soybean data from Haleakala Experiment Station, 17 h photoperiod treatment.

```
      IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                 PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
         ID:             IDSS89H3

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     1

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                     June 16, 1989

      PLANT DENSITY                     Bragg/Evans,33.3;Jupiter/Williams 22.2

      ORGANISATION
         NO.OF ROWS (#):                Bragg/Evans, 2; Jupiter/Williams, 1
         ROW LENGTH (M):                3
         ROW SPACING (CM):              Bragg/Evans,75;Jupiter/Williams,112.5
         ORIENTATION OF ROWS:           E-W
         ALONG OR ACROSS DRAINS:        n.a.
         SPACE BETWEEN PLOTS (CM):      0
         GROSS AREA (M 2):              4.5

      HARVEST
         NO.OF ROWS:                    1
         ROW LENGTH (M):                0.4
         AREA (M 2):                    Bragg/Evans,0.3;Jupiter/Williams,0.45
         METHOD:                        hand

      RANDOMIZATION/REPLICATION
         DESIGN:                        RCB
         NO.OF REPS.-SOWN:              2
                   -HARVESTED:          2

PROBLEMS
********
```

Table C.4 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1.

GROWTH STAGE			V0	V1	V4	V5								
ASPECT			EMRG	UNFE	4ND	5ND	FFLW	LFLW	PD05	POD2	SDGR	LLFE	PYEL	PBRN
REP	ENT	PLT												
1	3	1	173	183	202	203								
1	1	2	172	184	202	203								
1	2	3	172	183	202	203	202	229	214	216	220	245		
1	4	4	172	183	203	205	214	238	235	241	247			
2	4	1	172	183	203	207	214	247	235	240	247			
2	1	2	172	183	202	203								
2	2	3	172	183	203	209	202	226	212	214	216	245		
2	3	4	172	183	203	210								

PLOTDATA - GROWTH CHARACTERISTICS

AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.

SAMPLING TIME			SEED GR.		---- MATURITY;5-10 PLANT SUBSAMPLE ----									
ASPECT			MXAL	MXWL	PDPP	BRPP	NDPS	PDWT	STWT	GRWT	SDWT	SDN%		
UNITS														
REP	ENT	PLT												
1	3	1												
1	1	2												
1	2	3	129	.430								6.28		
1	4	4												
2	4	1												
2	1	2												
2	2	3	117	.370								5.98		
2	3	4												

KEY POSITIONS AND NAMES/PEDIGREES

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							BRAGG
2							EVANS
3							JUPITER
4							WILLIAMS

Cows damaged all plots. Data are unreliable.

Table C.5 Soybean data from Haleakala Experiment Station, 20 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
         ID:            IDSS89H4

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    1

      LOCATION
         NAME:          HALEAKALA

PLOTS
*****
      PLANTING DATE                  June 16, 1989

      PLANT DENSITY (PLANTS/M2)      Bragg/Evans,33.3;Jupiter/Williams,22.2


      ORGANISATION
         NO.OF ROWS (#):             Bragg/Evans,2;Jupiter/Williams,1
         ROW LENGTH (M):             3
         ROW SPACING (CM):           Bragg/Evans,75;Jupiter/Williams,112.5
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             0.4
         AREA (M 2):                 Bragg/Evans,0.3;Jupiter/Williams,0.45
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table C.5 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS

****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1.

GROWTH STAGE			V0	V1	V4	V5								
ASPECT			EMRG	UNFE	4ND	5ND	FFLW	LFLW	PD05	POD2	SDGR	LLFE	PYEL	PBRN
REP	ENT	PLT												
1	1	1	172	184	203	210								
1	4	2	172	183	203	207	237							
1	3	3	172	183	203	208								
1	2	4	172	183	203	210	205	233	217	221	229	250		
2	2	1	172	183	203	210	205	233	216	223	226	250		
2	4	2	174	183	203	208	237		250					
2	1	3	172	183	203	208								
2	3	4	172	183	209	210								

PLOTDATA - GROWTH CHARACTERISTICS

****

AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.

SAMPLING TIME			SEED GR.		---- MATURITY;5-10 PLANT SUBSAMPLE ----									
ASPECT			MXAL	MXWL	PDPP	BRPP	NDPS	PDWT	STWT	GRWT	SDWT	SDN%		
UNITS														
REP	ENT	PLT												
1	1	1												
1	4	2												
1	3	3												
1	2	4	102	.314								6.15		
2	2	1	97.5	.308										
2	4	2												
2	1	3												
2	3	4												

KEY POSITIONS AND NAMES/PEDIGREES

****

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							BRAGG
2							EVANS
3							JUPITER
4							WILLIAMS

Cows damaged all plots. Data are unreliable.

Table C.6 Soybean data from Kuiaha Experiment Site, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
         ID:            IDSS89K0

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    0

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                  Sep. 8, 1989

      PLANTING DENSITY (PLANTS/M2)   Bragg/Evans,33.;Jupiter/Williams,22.2

      ORGANISATION
         NO.OF ROWS (#):             Bragg/Evans,2;Jupiter/Williams,1
         ROW LENGTH (M):             3
         ROW SPACING (CM):           Bragg/Evans,75;Jupiter/Williams,112.5
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             0.4
         AREA (M 2):                 Bragg/Evans,0.3;Jupiter/Williams,0.45
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table C.6 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*****************************************
NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V4 | V5 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 4ND| 5ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 256| 265| 284| 293| 296| 307| 304| 307| 311| 307| 356| 362|
| 1 |  1 |  2 | 256| 266| 281| 292| 284| 293| 289| 291| 294| 296| 337| 340|
| 1 |  2 |  3 | 257| 265| 286| -- | 279| 290| 282| 285| 289| 286| 326| 332|
| 1 |  4 |  4 | 256| 265| 286| -- | 281| 294| 284| 287| 289| 293| 333| 338|
---------------------------------------------------------------------------
| 2 |  2 |  1 | 256| 265| 286| -- | 278| 290| 282| 286| 291| 291| 326| 332|
| 2 |  3 |  2 | 256| 264| 280| 285| 294| 307| 303| 305| 310| 306| 356| 362|
| 2 |  1 |  3 | 256| 265| 280| 285| 281| 290| 288| 291| 292| 292| 338| 342|
| 2 |  4 |  4 | 256| 264| 280| 286| 278| 290| 283| 287| 291| 303| 335| 338|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
**********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|____|____|
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 115|.376|10.3| 1.9| 9.8|1.55|1.33|3.33| 188|6.67|____|____|
| 1 |  1 |  2 |85.9|.352|10.6| 2.4| 8.5|1.61|1.35|4.46| 209|7.10|____|____|
| 1 |  2 |  3 |49.2|.139| 9.6| 0.5| 6.2|1.19|0.50|3.43| 164|6.82|____|____|
| 1 |  4 |  4 | -- | -- | 7.0| 0.3| 6.4|1.08|0.35|3.19| 199|7.00|____|____|
---------------------------------------------------------------------------
| 2 |  2 |  1 |45.9|.141| 6.9| 0.0| 5.5|0.76|0.66|2.33| 167|6.61|____|____|
| 2 |  3 |  2 | 179|.986|23.7| 4.3|11.5|3.67|3.33|6.81| 205|7.49|____|____|
| 2 |  1 |  3 | 105|.523|15.7| 2.3| 8.2|2.67|2.09|7.72| 234|7.52|____|____|
| 2 |  4 |  4 |74.9|.206|19.5| 1.0|10.6|3.39|1.77|9.35| 189|6.33|____|____|
---------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
**********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table C.7 Soybean data from Kuiaha Experiment Site, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

        PERSONNEL
           RESEARCHER:    Richard Ogoshi
           INSTITUTION:   IBSNAT

        EXPERIMENT
           TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
           ID:            IDSS89K1

        TREATMENTS
           GENOTYPES:     4
           MANAGEMENT:    1

        LOCATION
           NAME:          KUIAHA

PLOTS
*****
        PLANTING DATE                    Sep. 8, 1989

        PLANT DENSITY (PLANTS/M2)        Bragg/Evans,33.3;Jupiter/Williams,22.2

        ORGANISATION
           NO.OF ROWS (#):               Bragg/Evans,2;Jupiter/Williams,1
           ROW LENGTH (M):               3
           ROW SPACING (CM):             Bragg/Evans,75;Jupiter/Williams,112.5
           ORIENTATION OF ROWS:          E-W
           ALONG OR ACROSS DRAINS:       n.a.
           SPACE BETWEEN PLOTS (CM):     0
           GROSS AREA (M 2):             4.5

        HARVEST
           NO.OF ROWS:                   1
           ROW LENGTH (M):               0.4
           AREA (M 2):                   Bragg/Evans,0.3;Jupiter/Williams,0.45
           METHOD:                       hand

        RANDOMIZATION/REPLICATION
           DESIGN:                       RCB
           NO.OF REPS.-SOWN:             2
                      -HARVESTED:        2

PROBLEMS
********
```

Table C.7 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1.

GROWTH STAGE			V0	V1	V4	V5								
ASPECT			EMRG	UNFE	4ND	5ND	FFLW	LFLW	PD05	POD2	SDGR	LLFE	PYEL	PBRN
REP	ENT	PLT												
1	2	1	257	267	285	--	279	290	282	289	285	293	336	338
1	4	2	257	265	281	286	279	289	284	290	287	294	335	338
1	3	3	257	265	280	287	298	312	307	317	310	311	359	363
1	1	4	256	265	279	286	283	296	287	296	290	290	342	345
2	4	1	256	265	280	285	278	290	283	286	289	286	337	340
2	2	2	257	266	280	293	279	290	283	286	291	294	333	336
2	3	3	257	265	280	287	298	313	307	310	317	311	356	363
2	1	4	256	265	280	285	283	296	289	291	294	290	342	345

PLOTDATA - GROWTH CHARACTERISTICS
****

AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.

SAMPLING TIME			SEED GR.		---- MATURITY;5-10 PLANT SUBSAMPLE ----								___	___
ASPECT			MXAL	MXWL	PDPP	BRPP	NDPS	PDWT	STWT	GRWT	SDWT	SDN%	____	____
UNITS			____	____	____	____	____	____	____	____	____	____	____	____
REP	ENT	PLT												
1	2	1	41.6	.098	8.1	0.4	6.9	0.86	0.50	1.95	152	5.97	____	____
1	4	2	61.4	.168	14.2	1.0	9.5	2.56	1.45	7.18	211	6.95	____	____
1	3	3	275	1.59	42.7	5.5	13.6	7.56	6.52	17.6	233	7.59	____	____
1	1	4	103	.608	16.2	1.9	8.1	2.69	2.08	3.22	185	7.57	____	____
2	4	1	68.7	.177	25.1	0.8	11.8	4.14	1.77	9.74	183	7.34	____	____
2	2	2	49.8	.174	16.2	0.5	8.9	2.31	0.96	4.77	187	7.35	____	____
2	3	3	200	1.11	36.1	4.6	13.2	5.16	4.91	11.4	182	7.95	____	____
2	1	4	102	.501	12.7	1.4	7.6	1.75	1.33	2.32	183	7.81	____	____

KEY POSITIONS AND NAMES/PEDIGREES
****

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1	__	__	__	__	__	__	BRAGG
2	__	__	__	__	__	__	EVANS
3	__	__	__	__	__	__	JUPITER
4	__	__	__	__	__	__	WILLIAMS

Table C.8 Soybean data from Kuiaha Experiment Site, 14 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
         ID:            IDSS89K2

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    1

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                   June 16, 1989

      PLANT DENSITY (PLANTS/M2)       Bragg/Evans,33.3;Jupiter/Williams,22.2

      ORGANISATION
         NO.OF ROWS (#):              Bragg/Evans,2;Jupiter/Williams,1
         ROW LENGTH (M):              1
         ROW SPACING (CM):            Bragg/Evans,75;Jupiter/Williams,112.5
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              0.4
         AREA (M 2):                  Bragg/Evans,0.3;Jupiter/Williams,0.45
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table C.8 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V4 | V5 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 4ND| 5ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 170| 179| 200| 206| 248| 258| 258| 266| 269| 258| 318| 324|
| 1 |  4 |  2 | 170| 179| 196| 205| 196| 212| 207| 209| 211| 221| 249| 254|
| 1 |  2 |  3 | 172| 181| 196| 205| 196| 211| 202| 205| 208| 214| 241| 244|
| 1 |  1 |  4 | 170| 180| 194| 198| 206| 221| 217| 221| 225| 221| 286| 293|
---------------------------------------------------------------------------
| 2 |  2 |  1 | 172| 180| 194| 205| 195| 211| 202| 205| 208| 212| 242| 248|
| 2 |  4 |  2 | 170| 179| 194| 198| 196| 213| 207| 209| 211| 221| 251| 255|
| 2 |  3 |  3 | 171| 179| 194| 200| 244| 257| 280| 283| 289| 258|  24|  33|
| 2 |  1 |  4 | 171| 180| 195| 202| 206| 218| 217| 222| 223| 221| 286| 297|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 250|1.15|38.3| 6.2|15.6|6.90|24.3|10.4| 214|8.00|____|____|
| 1 |  4 |  2 | 115|.398|25.6| 1.8|12.8|5.56|4.18|15.1| 214|7.43|____|____|
| 1 |  2 |  3 |89.5|.460|18.1| 1.3| 7.7|2.05|1.22|5.94| 152|6.68|____|____|
| 1 |  1 |  4 | 118|.440|24.4| 5.1|10.6|3.18|6.01|5.86| 184|7.33|____|____|
---------------------------------------------------------------------------
| 2 |  2 |  1 | 109|.547|31.8| 2.2| 9.3|4.20|1.96|10.4| 148|6.79|____|____|
| 2 |  4 |  2 | 143|.519|29.8| 2.4|13.4|4.40|2.81|10.1| 173|7.31|____|____|
| 2 |  3 |  3 | 226|1.01|____|____|____|____|____|____|____|____|____|____|
| 2 |  1 |  4 | 133|.430|24.0| 5.9|10.7|3.93|7.06|6.38| 192|7.56|____|____|
---------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table C.9 Soybean data from Kuiaha Experiment Site, 17 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
         ID:             IDSS89K3

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     1

      LOCATION
         NAME:           KUIAHA

PLOTS
*****
      PLANTING DATE                   June 16, 1989

      PLANT DENSITY (PLANTS/M2)       Bragg/Evans,33.3;Jupiter/Williams,22.2

      ORGANISATION
         NO.OF ROWS (#):              Bragg/Evans,2;Jupiter/Williams,1
         ROW LENGTH (M):              3
         ROW SPACING (CM):            Bragg/Evans,75;Jupiter/Williams,112.5
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              0.4
         AREA (M 2):                  Bragg/Evans,0.3;Jupiter/Williams,0.45
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                   -HARVESTED:        2

PROBLEMS
********
```

Table C.9 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*****************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
----------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V4 | V5 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 4ND| 5ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
----------------------------------------------------------------------------
 REP  ENT  PLT
----------------------------------------------------------------------------
| 1 |  1 |  1 | 171| 180| 194| 206| 278| 307| 296| 307| 311| 278| -- |  55|
| 1 |  4 |  2 | 171| 179| 200| 202| 208| 244| 233| 241| 245| 263| 341| 349|
| 1 |  2 |  3 | 172| 180| 195| 200| 197| 224| 208| 210| 211| 234| 257| 262|
| 1 |  3 |  4 | 171| 179| 196| 205|  17|  51|  29|  51|  55|____|____|____|
----------------------------------------------------------------------------
| 2 |  2 |  1 | 172| 179| 194| 202| 196| 224| 206| 208| 210| 234| 255| 258|
| 2 |  3 |  2 | 172| 179| 195| 205|  17|  51|  27|  51|  55|____|____|____|
| 2 |  4 |  3 | 172| 179| 195| 202| 205| 241| 232| 236| 241| 258| 303| 349|
| 2 |  1 |  4 | 172| 180| 195| 205| 252| 269| 280| 289| 293| 296|  55|  62|
----------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
----------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
----------------------------------------------------------------------------
| 1 |  1 |  1 | 197|.655|____|____|____|____|____|____|____|____|____|____|
| 1 |  4 |  2 | 164|.487|57.0| 5.8|21.8|8.92|21.2|9.78| 163|8.49|____|____|
| 1 |  2 |  3 | 127|.402|33.0| 1.6|13.4|4.80|4.16|10.1| 163|7.10|____|____|
| 1 |  3 |  4 | 285|1.11|____|____|____|____|____|____|____|____|____|____|
----------------------------------------------------------------------------
| 2 |  2 |  1 | 159|.525|37.8| 2.8|12.3|5.04|4.46|10.1| 159|7.07|____|____|
| 2 |  3 |  2 | 242|.795|____|____|____|____|____|____|____|____|____|____|
| 2 |  4 |  3 | 158|.474| 122| 8.0|25.0|20.5|71.4|6.05| 185|7.45|____|____|
| 2 |  1 |  4 | 190|.895|____|____|____|____|____|____|____|____|____|____|
----------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
----------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table C.10 Soybean data from Kuiaha Experiment Site, 20 h photoperiod treatment.

```
      IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                 PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1989
         ID:             IDSS89K4

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     1

      LOCATION
         NAME:           KUIAHA

PLOTS
*****
      PLANTING DATE                  June 16, 1989

      PLANT DENSITY (PLANTS/M2)      Bragg/Evans,33.3;Jupiter/Williams,22.2

      ORGANISATION
         NO.OF ROWS (#):             Bragg/Evans, 2; Jupiter/Williams, 1
         ROW LENGTH (M):             3
         ROW SPACING (CM):           Bragg/Evans,75;Jupiter/Williams,112.5
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             0.4
         AREA (M 2):                 Bragg/Evans,0.3;Jupiter/Williams,0.45
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                    -HARVESTED:      2

PROBLEMS
********
```

Table C.10 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V4 | V5 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 4ND| 5ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  4 |  1 | 170| 179| 196| 205| 226| 248| 240| 243| 248| 258|  19|  24|
| 1 |  3 |  2 | 171| 179| 195| 205|____|____|____|____|____|____|____|____|
| 1 |  2 |  3 | 173| 180| 194| 198| 200| 230| 212| 216| 221| 234| 265| 269|
| 1 |  1 |  4 | 171| 180| 194| 202| 273| 311| 311| 320| 324| 279|____|____|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 171| 180| 194| 200| 280| 310| 315| 321| 324| 290|____|____|
| 2 |  3 |  2 | 171| 179| 195| 202|____|____|____|____|____|____|____|____|
| 2 |  4 |  3 | 170| 179| 195| 205| 229| 265| 248| 252| 266| 279|  19|  33|
| 2 |  2 |  4 | 172| 180| 195| 204| 202| 235| 212| 217| 221| 241| 268| 272|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  4 |  1 | 249|.878|____|____|____|____|____|____|____|____|____|____|
| 1 |  3 |  2 |____|____|____|____|____|____|____|____|____|____|____|____|
| 1 |  2 |  3 | 162|.540|51.9| 3.6|17.4|6.57|12.7|10.9| 124|6.26|____|____|
| 1 |  1 |  4 |____|____|____|____|____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 210|1.13|____|____|____|____|____|____|____|____|____|____|
| 2 |  3 |  2 |____|____|____|____|____|____|____|____|____|____|____|____|
| 2 |  4 |  3 | 260|.896|____|____|____|____|____|____|____|____|____|____|
| 2 |  2 |  4 | 121|.373|23.3| 3.3|13.6|3.47|5.72|5.13| 134|6.25|____|____|
---------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

APPENDIX D

Soybean data, summer 1990

Table D.1 Soybean data from Haleakala Experiment Station, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
         ID:             IDSS90H0

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     0

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                   July 2, 1990

      PLANT DENSITY (PLANTS/M2)       33.3

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              0.4
         AREA (M 2):                  0.3
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table D.1 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V5 | V6 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 5ND| 6ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 187| 200| 218| 225| 260| 269| 264| 267| 276| 263| 316| 320|
| 1 |  4 |  2 | 187| 200| 218| 225| 216| 229| 220| 225| 229| 236| 270| 276|
| 1 |  2 |  3 | 187| 201| 218| 225| 218| 229| 220| 222| 227| 230| 263| 267|
| 1 |  1 |  4 | 187| 201| 218| 220| 229| 237| 237| 240| 241| 242| 288| 292|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 187| 201| 218| 220| 229| 237| 236| 240| 243| 240| 289| 293|
| 2 |  2 |  2 | 187| 201| 218| 225| 218| 229| 220| 222| 226| 233| 267| 271|
| 2 |  3 |  3 | 187| 200| 218| 220| 263| 271| 271| 274| 278| 263| 320| 330|
| 2 |  4 |  4 | 187| 199| 218| 220| 216| 230| 221| 225| 229| 234| 271| 278|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          |cm2 | g  |____|____|____| g  | g  | g  | mg |____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 |233.|1.38|62.7| 8.2|16.1|9.17|15.2|21.6| 202|____|____|____|
| 1 |  4 |  2 |134.|.689|18.3| 1.4|11.3|3.74|2.06|9.09| 234|____|____|____|
| 1 |  2 |  3 |108.|.592|15.2| 0.8| 7.0|1.99|0.92|5.25| 183|____|____|____|
| 1 |  1 |  4 |155.|.741|30.8| 7.1|11.2|5.65|4.44|12.9| 211|____|____|____|
---------------------------------------------------------------------------
| 2 |  1 |  1 |169.|.844|36.1| 6.5|12.1|5.90|4.93|15.1| 213|____|____|____|
| 2 |  2 |  2 |111.|.616|22.2| 2.3| 7.4|2.65|1.22|7.54| 195|____|____|____|
| 2 |  3 |  3 |283.|1.52|84.6| 8.9|18.8|15.0|30.7|29.5| 203|____|____|____|
| 2 |  4 |  4 |205.|1.01|20.0| 1.7|11.1|3.46|3.47|10.7| 227|____|____|____|
---------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table D.2 Soybean data from Haleakala Experiment Station, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
         ID:             IDSS90H1

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     0

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                  July 2, 1990

      PLANT DENSITY (PLANTS/M2)      33.3

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             0.4
         AREA (M 2):                 0.3
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table D.2 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE  | V0 | V1 | V5 | V6 |    |    |    |    |    |    |    |    |
ASPECT        |EMRG|UNFE| 5ND| 6ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 | 188| 201| 218| 220| 229| 238| 237| 241| 247| 242| 295| 303|
| 1 |  3 |  2 | 190| 201| 218| 220| 263| 278| 276| 278| 282| 267| 327| 334|
| 1 |  4 |  3 | 187| 199| 218| 220| 216| 229| 221| 226| 229| 236| 271| 278|
| 1 |  2 |  4 | 187| 200| 218| 220| 216| 229| 220| 222| 226| 230| 267| 271|
---------------------------------------------------------------------------
| 2 |  3 |  1 | 190| 201| 218| 220| 263| 276| 277| 279| 283| 267| 327| 334|
| 2 |  1 |  2 | 187| 201| 218| 221| 229| 242| 241| 243| 248| 242| 293| 302|
| 2 |  4 |  3 | 187| 199| 218| 220| 216| 229| 223| 226| 229| 235| 270| 278|
| 2 |  2 |  4 | 187| 200| 218| 226| 218| 229| 219| 221| 226| 230| 263| 271|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT        |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS         | cm2| g  |____|____|____| g  | g  | g  | mg |____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 |145.|.639|44.6| 6.4|12.6|7.03| 5.3|17.4| 202|____|____|____|
| 1 |  3 |  2 |262.|1.29|132.|10.6|17.8|20.9|34.4|42.9| 221|____|____|____|
| 1 |  4 |  3 |195.|1.08|31.1| 1.6|12.9|5.46|3.96|13.1| 219|____|____|____|
| 1 |  2 |  4 |140.|.811|21.9| 1.5| 7.7|2.78|1.42|6.51| 199|____|____|____|
---------------------------------------------------------------------------
| 2 |  3 |  1 |274.|1.59|119.|10.8|18.5|20.4|34.1|42.5| 207|____|____|____|
| 2 |  1 |  2 |176.|.740|46.2| 5.1|12.2|7.60| 9.6|14.6| 201|____|____|____|
| 2 |  4 |  3 |197.|.948|23.0| 1.9|12.8|4.05|3.66|10.3| 229|____|____|____|
| 2 |  2 |  4 |118.|.653|14.8| 0.7| 6.8|____|1.12|5.73| 187|____|____|____|
---------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table D.3 Soybean data from Haleakala Experiment Station, 14 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
         ID:            IDSS90H2

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    0

      LOCATION
         NAME:          HALEAKALA

PLOTS
*****
      PLANTING DATE                July 2, 1990

      PLANT DENSITY (PLANTS/M2)    33.3

      ORGANISATION
         NO.OF ROWS (#):            2
         ROW LENGTH (M):            3
         ROW SPACING (CM):          75
         ORIENTATION OF ROWS:       E-W
         ALONG OR ACROSS DRAINS:    n.a.
         SPACE BETWEEN PLOTS (CM):  0
         GROSS AREA (M 2):          4.5

      HARVEST
         NO.OF ROWS:                1
         ROW LENGTH (M):            0.4
         AREA (M 2):                0.3
         METHOD:                    hand

      RANDOMIZATION/REPLICATION
         DESIGN:                    RCB
         NO.OF REPS.-SOWN:          2
                    -HARVESTED:     2

PROBLEMS
********
```

Table D.3 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V5 | V6 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 5ND| 6ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  4 |  1 | 187| 199| 218| 220| 221| 229| 223| 225| 229| 241| 278| 283|
| 1 |  3 |  2 | 188| 199| 218| 220| 288| 295| 291| 296| 302| 278|   5|   9|
| 1 |  1 |  3 | 187| 200| 218| 220| 233| 242| 243| 247| 251| 243| 302| 306|
| 1 |  2 |  4 | 187| 200| 218| 226| 219| 232| 220| 222| 227| 233| 262| 267|
---------------------------------------------------------------------------
| 2 |  3 |  1 | 187| 200| 218| 221| 290| 302| 303| 306| 314| 302|   5|   9|
| 2 |  2 |  2 | 187| 200| 218| 225| 219| 230| 220| 222| 226| 232| 263| 267|
| 2 |  1 |  3 | 187| 200| 218| 220| 233| 243| 243| 247| 253| 251| 303| 306|
| 2 |  4 |  4 | 187| 199| 218| 220| 216| 229| 221| 226| 229| 236| 271| 278|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          | cm2| g  |____|____|____| g  | g  | g  | mg |____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  4 |  1 |154.|.713|27.0| 1.1|12.4|4.51|3.19|9.46| 194|____|____|____|
| 1 |  3 |  2 |227.|.812|____|____|____|____|____|____|____|____|____|____|
| 1 |  1 |  3 |170.|.722|49.3| 6.6|13.1|8.04|10.1|17.1| 234|____|____|____|
| 1 |  2 |  4 |102.|.607|21.3| 1.0| 7.6|2.29|1.12|4.87| 183|____|____|____|
---------------------------------------------------------------------------
| 2 |  3 |  1 |258.|.925|____|____|____|____|____|____|____|____|____|____|
| 2 |  2 |  2 |94.4|.557|17.0| 0.3| 7.5|2.17|1.12|4.78| 167|____|____|____|
| 2 |  1 |  3 |165.|.671|43.4| 6.1|12.9|7.27| 8.7|18.9| 241|____|____|____|
| 2 |  4 |  4 |137.|.603|15.2| 1.6|12.2|3.14|4.39|8.26| 219|____|____|____|
---------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table D.4 Soybean data from Haleakala Experiment Station, 17 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
         ID:            IDSS90H3

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    0

      LOCATION
         NAME:          HALEAKALA

PLOTS
*****
      PLANTING DATE                  July 2, 1990

      PLANT DENSITY (PLANTS/M2)      33.3

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             0.4
         AREA (M 2):                 0.3
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table D.4 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
******************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
----------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V5 | V6 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 5ND| 6ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
----------------------------------------------------------------------------
 REP  ENT  PLT
----------------------------------------------------------------------------
| 1 |  2 |  1 | 187| 201| 218| 223| 218| 236| 225| 229| 232| 247| 276| 281|
| 1 |  4 |  2 | 187| 199| 218| 220| 237| 267| 248| 255| 261| 269| 320| 355|
| 1 |  3 |  3 | 187| 200| 218| 221|____|____|____|____|____|____|____|____|
| 1 |  1 |  4 | 187| 201| 218| 220| 271| 292| 277| 281| 291| 295|____|____|
----------------------------------------------------------------------------
| 2 |  4 |  1 | 187| 200| 218| 221| 230| 253| 244| 249| 255| 260| 306| 319|
| 2 |  3 |  2 | 187| 199| 218| 220|____|____|____|____|____|____|____|____|
| 2 |  2 |  3 | 187| 201| 218| 221| 220| 241| 229| 233| 234| 247| 281| 288|
| 2 |  1 |  4 | 187| 200| 218| 221| 263| 278| 278| 291| 297| 302|____|____|
----------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
***********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
----------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          | cm2|  g |____|____|____|  g |  g |  g | mg |____|____|____|
 REP  ENT  PLT
----------------------------------------------------------------------------
| 1 |  2 |  1 |133.|.484|28.1| 2.4|10.7|3.76|3.39|9.83| 181|____|____|____|
| 1 |  4 |  2 |216.|.728|____|____|____|____|____|____|____|____|____|____|
| 1 |  3 |  3 |____|____|____|____|____|____|____|____|____|____|____|____|
| 1 |  1 |  4 |180.|.724|____|____|____|____|____|____|____|____|____|____|
----------------------------------------------------------------------------
| 2 |  4 |  1 |207.|.702|42.0| 4.0|17.6|6.21|11.2|10.6| 194|____|____|____|
| 2 |  3 |  2 |____|____|____|____|____|____|____|____|____|____|____|____|
| 2 |  2 |  3 |174.|.634|33.5| 1.6|13.7|4.59|4.53|12.2| 209|____|____|____|
| 2 |  1 |  4 |167.|.506|____|____|____|____|____|____|____|____|____|____|
----------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
***********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
----------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table D.5 Soybean data from Haleakala Experiment Station, 20 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

       PERSONNEL
          RESEARCHER:     Richard Ogoshi
          INSTITUTION:    IBSNAT

       EXPERIMENT
          TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
          ID:             IDSS90H4

       TREATMENTS
          GENOTYPES:      4
          MANAGEMENT:     0

       LOCATION
          NAME:           HALEAKALA

PLOTS
*****
       PLANTING DATE                   July 2, 1990

       PLANT DENSITY (PLANTS/M2)       33.3

       ORGANISATION
          NO.OF ROWS (#):              2
          ROW LENGTH (M):              3
          ROW SPACING (CM):            75
          ORIENTATION OF ROWS:         E-W
          ALONG OR ACROSS DRAINS:      n.a.
          SPACE BETWEEN PLOTS (CM):    0
          GROSS AREA (M 2):            4.5

       HARVEST
          NO.OF ROWS:                  1
          ROW LENGTH (M):              0.4
          AREA (M 2):                  0.3
          METHOD:                      hand

       RANDOMIZATION/REPLICATION
          DESIGN:                      RCB
          NO.OF REPS.-SOWN:            2
                     -HARVESTED:       2

PROBLEMS
********
```

Table D.5 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*****************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
-----------------------------------------------------------------------------
GROWTH STAGE    | V0  | V1  | V5  | V6  |    |    |    |    |    |    |    |    |
ASPECT          |EMRG|UNFE| 5ND|  6ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
-----------------------------------------------------------------------------
 REP  ENT  PLT
-----------------------------------------------------------------------------
| 1 |  4 |  1 | 187| 200| 218| 222| 249| 277| 267| 271| 277| 269|   2|   9|
| 1 |  1 |  2 | 187| 201| 218| 223| 316| 330| 318| 322| 330| 327|____|____|
| 1 |  2 |  3 | 187| 200| 218| 220| 223| 241| 235| 240| 243| 261| 320| 322|
| 1 |  3 |  4 | 187| 200| 218| 225|____|____|____|____|____|____|____|____|
-----------------------------------------------------------------------------
| 2 |  1 |  1 | 187| 201| 218| 220| 291| 320| 317| 319| 330| 306|____|____|
| 2 |  3 |  2 | 188| 200| 218| 222|____|____|____|____|____|____|____|____|
| 2 |  2 |  3 | 187| 199| 218| 221| 229| 240| 236| 241| 245| 260| 298| 320|
| 2 |  4 |  4 | 187| 199| 218| 221| 245| 271| 257| 262| 271| 281|   2|   9|
-----------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
-----------------------------------------------------------------------------
SAMPLING TIME   | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT          |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS           | cm2|  g |____|____|____|  g |  g |  g | mg |____|____|____|
 REP  ENT  PLT
-----------------------------------------------------------------------------
| 1 |  4 |  1 |171.|.560|____|____|____|____|____|____|____|____|____|____|
| 1 |  1 |  2 |161.|.509|____|____|____|____|____|____|____|____|____|____|
| 1 |  2 |  3 |179.|.703|71.2| 4.3|21.6|10.5|22.2|17.4| 193|____|____|____|
| 1 |  3 |  4 |____|____|____|____|____|____|____|____|____|____|____|____|
-----------------------------------------------------------------------------
| 2 |  1 |  1 |176.|.626|____|____|____|____|____|____|____|____|____|____|
| 2 |  3 |  2 |____|____|____|____|____|____|____|____|____|____|____|____|
| 2 |  2 |  3 |187.|.688|83.0| 4.2|19.7|11.7|21.5|17.2| 197|____|____|____|
| 2 |  4 |  4 |151.|.447|____|____|____|____|____|____|____|____|____|____|
-----------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
-----------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table D.6 Soybean data from Kuiaha Experiment Site, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
         ID:             IDSS90K0

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     0

      LOCATION
         NAME:           KUIAHA

PLOTS
*****

      ORGANISATION
         NO.OF ROWS (#):               2
         ROW LENGTH (M):               3
         ROW SPACING (CM):             75
         ORIENTATION OF ROWS:          E-W
         ALONG OR ACROSS DRAINS:       n.a.
         SPACE BETWEEN PLOTS (CM):     0
         GROSS AREA (M 2):             4.5

      HARVEST
         NO.OF ROWS:                   1
         ROW LENGTH (M):               0.4
         AREA (M 2):                   0.3
         METHOD:                       hand

      RANDOMIZATION/REPLICATION
         DESIGN:                       RCB
         NO.OF REPS.-SOWN:             2
                    -HARVESTED:        2

PROBLEMS
********
```

Table D.6 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
  NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES
AS DAYS FROM JANUARY 1.
---------------------------------------------------------------------------
GROWTH STAGE   | V0 | V1 | V5 | V6 |    |    |    |    |    |    |    |    |
ASPECT         |EMRG|UNFE| 5ND| 6ND|FFLW|LFLW|PD05|POD2|SDGR|LLFE|PYEL|PBRN|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 187| 195| 215| 218| 248| 263| 257| 263| 270| 253| 312| 320|
| 1 |  4 |  2 | 187| 195| 212| 216| 212| 223| 218| 220| 223| 234| 271| 276|
| 1 |  1 |  3 | 187| 196| 213| 216| 218| 233| 230| 232| 234| 232| 283| 292|
| 1 |  2 |  4 | 187| 197| 218| 220| 215| 221| 216| 218| 222| 227| 260| 270|
---------------------------------------------------------------------------
| 2 |  2 |  1 | 187| 196| 218| 220| 215| 223| 216| 218| 222| 226| 260| 270|
| 2 |  3 |  2 | 187| 196| 216| 218| 248| 263| 257| 263| 271| 254| 311| 314|
| 2 |  4 |  3 | 187| 196| 214| 218| 213| 222| 219| 220| 223| 234| 270| 276|
| 2 |  1 |  4 | 188| 198| 214| 216| 220| 232| 227| 230| 234| 230| 281| 285|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR
10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.
---------------------------------------------------------------------------
SAMPLING TIME  | SEED GR.|---- MATURITY;5-10 PLANT SUBSAMPLE ----|___ |___ |
ASPECT         |MXAL|MXWL|PDPP|BRPP|NDPS|PDWT|STWT|GRWT|SDWT|SDN%|____|____|
UNITS          | cm2|  g |____|____|____|  g |  g |  g | mg |____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 |208.|.854|76.2|10.1|15.8|11.1|18.6|21.5| 230|____|____|____|
| 1 |  4 |  2 |148.|.683|28.8| 2.5|11.5|5.02|3.12|13.7| 227|____|____|____|
| 1 |  1 |  3 |115.|.431|33.5| 6.6|10.3|5.07|6.70|7.56| 215|____|____|____|
| 1 |  2 |  4 |98.9|.504|19.8| 1.5| 7.6|2.76|1.42|8.41| 197|____|____|____|
---------------------------------------------------------------------------
| 2 |  2 |  1 |78.6|.430|18.3| 2.7| 6.6|2.23|1.02|7.48| 194|____|____|____|
| 2 |  3 |  2 |251.|1.17|69.1| 9.5|15.6|10.7|17.1|24.2| 247|____|____|____|
| 2 |  4 |  3 |136.|.597|24.2| 1.5|11.4|3.86|2.32|13.0| 228|____|____|____|
| 2 |  1 |  4 |127.|.470|47.0| 6.7|11.4|7.21|4.47|22.9| 241|____|____|____|
---------------------------------------------------------------------------

KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | BRAGG
| 2 | __ | __ | __ | __ | __ | __ | EVANS
| 3 | __ | __ | __ | __ | __ | __ | JUPITER
| 4 | __ | __ | __ | __ | __ | __ | WILLIAMS
```

Table D.7 Soybean data from Kuiaha Experiment Site, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
         ID:             IDSS90K1

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     0

      LOCATION
         NAME:           KUIAHA

PLOTS
*****
      PLANTING DATE                   July 2, 1990

      PLANT DENSITY (PLANTS/M2)       33.3

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              0.4
         AREA (M 2):                  0.3
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                   -HARVESTED:        2

PROBLEMS
********
```

Table D.7 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1.

GROWTH STAGE			V0	V1	V5	V6								
ASPECT			EMRG	UNFE	5ND	6ND	FFLW	LFLW	PD05	POD2	SDGR	LLFE	PYEL	PBRN
REP	ENT	PLT												
1	2	1	187	196	218	220	215	222	215	216	222	227	262	267
1	3	2	188	195	214	216	251	267	261	264	271	256	309	313
1	1	3	188	196	209*	216	221	232	230	233	234	230	281	284
1	4	4	187	196	216	219	214	223	220	222	228	234	271	276
2	4	1	187	196	216	218	213	223	218	222	227	234	271	276
2	2	2	187	197	218	220	215	223	215	216	222	227	261	269
2	3	3	188	197	215	218	251	267	260	264	271	255	309	313
2	1	4	188	198	214	218	221	232	230	233	235	232	281	285

PLOTDATA - GROWTH CHARACTERISTICS
****

AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.

SAMPLING TIME			SEED GR.		---- MATURITY;5-10 PLANT SUBSAMPLE ----									
ASPECT			MXAL	MXWL	PDPP	BRPP	NDPS	PDWT	STWT	GRWT	SDWT	SDN%		
UNITS			cm2	g				g	g	g	mg			
REP	ENT	PLT												
1	2	1	102.	.474	26.2	1.9	8.3	2.83	1.32	9.22	169			
1	3	2	245.	1.29	131.	12.9	19.3	17.3	35.7	48.3	230			
1	1	3	138.	.562	52.8	9.0	11.3	7.33	6.29	24.0	224			
1	4	4	133.	.660	24.6	2.1	11.0	4.22	2.52	13.8	222			
2	4	1	150.	.657	30.7	2.5	12.4	5.05	2.72	15.7	204			
2	2	2	107.	.536	19.1	0.9	7.5	2.15	1.02	7.43	189			
2	3	3	223.	1.23	96.2	10.2	17.6	13.8	27.0	41.4	251			
2	1	4	107.	.334	34.0	6.6	10.6	3.93	3.12	12.6	211			

KEY POSITIONS AND NAMES/PEDIGREES
****

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							BRAGG
2							EVANS
3							JUPITER
4							WILLIAMS

*true V4

Table D.8 Soybean data from Kuiaha Experiment Site, 14 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
         ID:            IDSS90K2

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    0

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                 July 2, 1990

      PLANT DENSITY (PLANTS/M2)     33.3

      ORGANISATION
         NO.OF ROWS (#):            2
         ROW LENGTH (M):            3
         ROW SPACING (CM):          75
         ORIENTATION OF ROWS:       E-W
         ALONG OR ACROSS DRAINS:    n.a.
         SPACE BETWEEN PLOTS (CM):  0
         GROSS AREA (M 2):          4.5

      HARVEST
         NO.OF ROWS:                1
         ROW LENGTH (M):            0.4
         AREA (M 2):                0.3
         METHOD:                    hand

      RANDOMIZATION/REPLICATION
         DESIGN:                    RCB
         NO.OF REPS.-SOWN:          2
                   -HARVESTED:      2

PROBLEMS
********
```

Table D.8 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1.

GROWTH STAGE			V0	V1	V5	V6								
ASPECT			EMRG	UNFE	5ND	6ND	FFLW	LFLW	PD05	POD2	SDGR	LLFE	PYEL	PBRN
REP	ENT	PLT												
1	3	1	188	195	210*	216	254	269	264	268	274	269		
1	2	2	187	197	215	218	214	221	215	216	221	227	262	267
1	1	3	187	198	209*	218	221	233	232	234	243	232	285	297
1	4	4	187	197	215	218	214	235	217	222	227	234	270	276
2	4	1	187	196	214	216	213	234	218	222	226	235	270	276
2	3	2	188	196	213	216	257	267	274	277	281	261		
2	1	3	187	196	210*	216	219	235	230	234	236	232	292	303
2	2	4	187	196	218	221	215	223	215	216	223	226	262	267

PLOTDATA - GROWTH CHARACTERISTICS
****

AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.

SAMPLING TIME			SEED GR.		---- MATURITY;5-10 PLANT SUBSAMPLE ----									
ASPECT			MXAL	MXWL	PDPP	BRPP	NDPS	PDWT	STWT	GRWT	SDWT	SDN%		
UNITS			cm2	g				g	g	g	mg			
REP	ENT	PLT												
1	3	1	279.	1.50										
1	2	2	114.	.564	22.8	2.6	6.9	2.77	1.22	9.57	196			
1	1	3	161.	.614	48.3	8.7	11.2	7.14	6.12	23.6	247			
1	4	4	145.	.711	52.2	5.0	14.2	8.77	5.12	26.0	189			
2	4	1	145.	.635	43.0	3.0	13.6	6.70	3.82	19.4	201			
2	3	2	247.	1.23										
2	1	3	143.	.562	40.6	7.7	11.6	5.86	6.30	14.9	226			
2	2	4	90.4	.401	22.7	1.2	7.0	2.79	1.32	7.90	201			

KEY POSITIONS AND NAMES/PEDIGREES
****

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							BRAGG
2							EVANS
3							JUPITER
4							WILLIAMS

*true V4

Table D.9 Soybean data from Kuiaha Experiment Site, 17 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
         ID:            IDSS90K3

      TREATMENTS
         GENOTYPES:     4
         MANAGEMENT:    0

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                  July 2, 1990

      PLANT DENSITY (PLANTS/M2)      33.3

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             0.4
         AREA (M 2):                 0.3
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                    -HARVESTED:      2

PROBLEMS
********
```

Table D.9 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1.

GROWTH STAGE			V0	V1	V5	V6								
ASPECT			EMRG	UNFE	5ND	6ND	FFLW	LFLW	PD05	POD2	SDGR	LLFE	PYEL	PBRN
REP	ENT	PLT												
1	3	1	188	195	209*	216								
1	4	2	187	195	213	218	229	240	243	249	253	241	320	330
1	1	3	188	198	214	218	286	292	297	302	306	288		
1	2	4	187	197	214	218	214	236	222	223	228	250	288	296
2	4	1	187	196	215	218	230	241	240	250	255	262	302	320
2	1	2	188	197	214	215	286	297	307	312	315	292		
2	2	3	187	198	215	218	214	237	216	222	228	249	285	292
2	3	4	190	197	215	218								

PLOTDATA - GROWTH CHARACTERISTICS
****

AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.

SAMPLING TIME			SEED GR.		---- MATURITY;5-10 PLANT SUBSAMPLE ----									
ASPECT			MXAL	MXWL	PDPP	BRPP	NDPS	PDWT	STWT	GRWT	SDWT	SDN%		
UNITS			cm2	g				g	g	g	mg			
REP	ENT	PLT												
1	3	1												
1	4	2	219.	.696	51.5	4.9	24.9	9.17	27.9	18.0	219			
1	1	3	177.	.655										
1	2	4	149.	.560	109.	3.7	20.1	18.4	14.5	38.0	203			
2	4	1	173.	.513	109.	8.2	24.4	19.1	26.0	57.7	241			
2	1	2	187.	.726										
2	2	3	143.	.453	89.4	3.7	17.1	14.4	12.6	27.3	223			
2	3	4												

KEY POSITIONS AND NAMES/PEDIGREES
****

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							BRAGG
2							EVANS
3							JUPITER
4							WILLIAMS

*true V4

Table D.10 Soybean data from Kuiaha Experiment Site, 20 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;SOYBEANS 1990
         ID:             IDSS90K4

      TREATMENTS
         GENOTYPES:      4
         MANAGEMENT:     0

      LOCATION
         NAME:           KUIAHA

PLOTS
*****
      PLANTING DATE                  July 2, 1990

      PLANT DENSITY (PLANTS/M2)      33.3

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             0.4
         AREA (M 2):                 0.3
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table D.10 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS

****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1.

GROWTH STAGE			V0	V1	V5	V6								
ASPECT			EMRG	UNFE	5ND	6ND	FFLW	LFLW	PD05	POD2	SDGR	LLFE	PYEL	PBRN
REP	ENT	PLT												
1	2	1	187	196	215	218	219	243	229	234	236	260	295	305
1	3	2	190	197	212	217								
1	1	3	188	198	209*	216	307	311	314	325	330	309		
1	4	4	188	196	216	218	250	278	269	272	276	274	362	
2	2	1	188	197	215	218	227	241	236	243	245	257	306	327
2	4	2	187	197	215	218	249	277	269	272	276	281	12	
2	1	3	188	199	209*	217	321	327	327	332	338	330		
2	3	4	190	200	216	218								

PLOTDATA - GROWTH CHARACTERISTICS

****

AREA PER LEAF FROM 10 OF LARGEST LEAVES (ALL TRIFOL.). NEXT SIX FROM 5 OR 10 PLANTS AT MATURITY. YIELD AND SEED WT.FROM LARGE PLOT HARVESTS.

SAMPLING TIME			SEED GR.		---- MATURITY;5-10 PLANT SUBSAMPLE ----									
ASPECT			MXAL	MXWL	PDPP	BRPP	NDPS	PDWT	STWT	GRWT	SDWT	SDN%		
UNITS			cm2	g				g	g	g	mg			
REP	ENT	PLT												
1	2	1	191.	.618	70.7	5.9	21.2	8.49	19.2	22.2	196			
1	3	2												
1	1	3	189.	.699										
1	4	4	254.	1.21										
2	2	1	200.	.591	39.2	4.8	27.0	7.84	50.8	13.8	189			
2	4	2	251.	1.06										
2	1	3												
2	3	4												

KEY POSITIONS AND NAMES/PEDIGREES

****

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							BRAGG
2							EVANS
3							JUPITER
4							WILLIAMS

*true V4

APPENDIX E

Maize data, summer 1988

Table E.1 Maize data from Haleakala Experiment Station, control photoperiod treatment.

```
              INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                  MAIZE GENETIC COEFFICIENT NURSERIES


INSTITUTE
    NAME(INNAME):                   IBSNAT
    ID (INSTID):                    IB

RESEARCHER (S)
    NAME(RENAME):                   R.OGOSHI
    ID (RESID):                     RO

EXPERIMENT
    NAME (EXNAME):                  MAIZE CONTROL (P0) DAYLENGTH STUDY
    ID (EXPN):                      IDSM88H0

LOCATION
    NAME:                           HALEAKALA
    ID (LOC):                       HK

SEEDING
    YEAR (IYR)                                 1988
    DATE (ISOW;JULIAN DATE)                    174
    SEED DEPTH (SDEPTH;CM)                     4
    ESTABLISHED PLANT POPULATION (PLANTS;M-2)  6.67
    ROW WIDTH (ROW;CM)                         75

PHOTOPERIOD (HOURS)                            NATURAL

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
   138  204  234 ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
    60   60   60 ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)
    10    0    0 ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J)) 1
```

Table E.1 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG= EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR. =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
	ZADOKS:		10	(13)		(30)		39		89
1	2	1	180	---	196	201	---	229	228	277
1	4	2	180	---	196	201	229	230	229	286
1	3	3	180	---	196	207	239	242	242	308
1	1	4	180	---	196	207	236	242	238	315
2	2	1	180	---	196	201	---	229	227	279
2	3	2	180	---	196	207	238	242	240	312
2	1	3	180	---	196	207	237	239	238	312
2	4	4	180	---	196	207	227	230	229	279

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF LGTH CM	3RD LAST LEAF WDTH MM	LEAF NO.	SHOOT WTS.(G) AT MATURITY STOVER	SHOOT WTS.(G) AT MATURITY GRAIN	KERNEL WT MG	KERNEL N %
1	2	1	50.5	102	_____	135.8	146.75	321	1.69
1	4	2	46.5	90	_____	180.4	209.35	343	1.37
1	3	3	67.9	94	_____	216.7	211.6	349	2.12
1	1	4	59.0	87	_____	237.2	255.0	376	1.43
2	2	1	49.1	115	_____	171.4	166.05	340	1.95
2	3	2	51.4	105	_____	363.4	234.0	354	2.12
2	1	3	51.2	82	_____	218.4	253.1	431	1.22
2	4	4	48.9	105	_____	137.8	172.95	298	1.43

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 3475;

GENERAL OBSERVATIONS
****

#4 little late--poor position + insects

Some sort of leaf damage (stink bug?): about 20% on entries 2 and 4, about 10% on entries 1 and 3.

Table E.2 Maize data from Haleakala Experiment Station, natural photoperiod treatment.

INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

MAIZE GENETIC COEFFICIENT NURSERIES

INSTITUTE
NAME(INNAME): IBSNAT
ID (INSTID): IB

RESEARCHER (S)
NAME(RENAME): R.OGOSHI
ID (RESID): RO

EXPERIMENT
NAME (EXNAME): MAIZE NATURAL (P1) DAYLENGTH STUDY
ID (EXPN): IDSM88H1

LOCATION
NAME: HALEAKALA
ID (LOC): HK

SEEDING
YEAR (IYR) 1988
DATE (ISOW;JULIAN DATE) 174
SEED DEPTH (SDEPTH;CM) 4
ESTABLISHED PLANT POPULATION (PLANTS;M-2) 6.67
ROW WIDTH (ROW;CM) 75

PHOTOPERIOD (HOURS) NATURAL + 0.5H

IRRIGATION.
JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
____ ____ ____ ____ ____ ____ ____ ____ ____ ____
AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
JULIAN DATE OF J,TH FERTILIZATION(JFDAY)
138 204 234 ____ ____ ____ ____ ____ ____ ____
AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
60 60 60 ____ ____ ____ ____ ____ ____ ____
DEPTH OF INCORPORATION OF J,TH FERTILIZATION
(DFERT(J);CM,SURFACE APPLIED =1)
10 0 0 ____ ____ ____ ____ ____ ____ ____
CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
M.NITRATE = 5)(IFTYPE(J)) 1

Table E.2 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG= EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
	ZADOKS:		10	(13)		(30)		39		89
1	1	1	180	---	196	207	232	237	235	305
1	4	2	180	---	196	207	---	230	228	286
1	2	3	180	---	196	207	---	230	228	286
1	3	4	180	---	196	207	241	244	244	323
2	1	1	180	---	196	207	237	242	239	321
2	3	2	180	---	196	207	241	244	244	323
2	4	3	180	---	196	207	---	230	229	289
2	2	4	180	---	196	201	---	229	228	286

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF		LEAF	SHOOT WTS.(G)		KERNEL	KERNEL
			LGTH	WDTH	NO.	AT MATURITY		WT	N
			CM	MM		STOVER	GRAIN	MG	%
1	1	1	62.9	100	_____	249.2	249.4	404	1.28
1	4	2	63.1	108	_____	227.8	249.40	376	1.47
1	2	3	57.2	107	_____	221.8	206.35	339	1.60
1	3	4	55.0	82	_____	332.8	219.9	363	2.06
2	1	1	65.7	94	_____	254.4	255.9	409	1.42
2	3	2	58.7	80	_____	422.8	252.5	333	2.32
2	4	3	54.0	97	_____	178.6	212.5	386	1.43
2	2	4	50.5	104	_____	178.6	163.9	340	1.61

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 347;

GENERAL OBSERVATIONS
****

Some leaf damage (stink bug?), less than 10%.

Table E.3 Maize data from Haleakala Experiment Station, 14 h photoperiod treatment.

```
              INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                     MAIZE GENETIC COEFFICIENT NURSERIES


INSTITUTE
   NAME(INNAME):                      IBSNAT
   ID (INSTID):                       IB

RESEARCHER (S)
   NAME(RENAME):                      R.OGOSHI
   ID (RESID):                        RO

EXPERIMENT
   NAME (EXNAME):                     MAIZE 14H (P2) DAYLENGTH STUDY
   ID (EXPN):                         IDSM88H2

LOCATION
   NAME:                              HALEAKALA
   ID (LOC):                          HK

SEEDING
   YEAR (IYR)                                    1988
   DATE (ISOW;JULIAN DATE)                        174
   SEED DEPTH (SDEPTH;CM)                           4
   ESTABLISHED PLANT POPULATION (PLANTS;M-2)     6.67
   ROW WIDTH (ROW;CM)                              75

PHOTOPERIOD (HOURS)                              14

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
   138  204  234 ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
    60   60   60 ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)
    10    0    0 ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J)) 1
```

Table E.3 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG= EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
ZADOKS:			10	(13)		(30)		39		89
1	4	1	180	---	196	207	230	235	232	301
1	2	2	180	---	201	207	---	231	230	292
1	3	3	180	---	196	207	242	249	247	322
1	1	4	180	---	201	207	239	242	240	321
2	3	1	180	---	201	207	242	249	245	315
2	1	2	180	---	196	207	237	239	238	310
2	4	3	180	---	196	207	---	229	229	285
2	2	4	180	---	196	207	---	230	228	285

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF LGTH CM	3RD LAST LEAF WDTH MM	LEAF NO.	SHOOT WTS.(G) AT MATURITY STOVER	SHOOT WTS.(G) AT MATURITY GRAIN	KERNEL WT MG	KERNEL N %
1	4	1	69.6	98	_____	177.5	268.2	353	1.41
1	2	2	64.1	106	_____	175.0	183.4	352	1.56
1	3	3	67.5	94	_____	399.0	218.4	358	2.14
1	1	4	55.3	97	_____	191.0	227.5	414	1.41
2	3	1	64.8	91	_____	326.7	242.7	373	1.94
2	1	2	62.7	95	_____	296.6	258.2	387	1.38
2	4	3	65.2	103	_____	227.0	228.6	387	1.46
2	2	4	63.8	110	_____	155.5	192.2	318	1.46

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 347.

GENERAL OBSERVATIONS
****

Less than 5% leaf damage (stink bug?).

Table E.4 Maize data from Haleakala Experiment Station, 17 h photoperiod treatment.

```
              INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                     MAIZE GENETIC COEFFICIENT NURSERIES


    INSTITUTE
       NAME(INNAME):                    IBSNAT
       ID (INSTID):                     IB

    RESEARCHER (S)
       NAME(RENAME):                    R.OGOSHI
       ID (RESID):                      RO

    EXPERIMENT
       NAME (EXNAME):                   MAIZE 17H (P3) DAYLENGTH STUDY
       ID (EXPN):                       IDSM88H3

    LOCATION
       NAME:                            HALEAKALA
       ID (LOC):                        HK

    SEEDING
       YEAR (IYR)                                 1988
       DATE (ISOW;JULIAN DATE)                     174
       SEED DEPTH (SDEPTH;CM)                        4
       ESTABLISHED PLANT POPULATION (PLANTS;M-2)  6.67
       ROW WIDTH (ROW;CM)                           75

    PHOTOPERIOD (HOURS)                           17

    IRRIGATION.
      JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
      AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
      ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

    NITROGEN FERTILIZATION
      JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
       138  204  234 ____ ____ ____ ____ ____ ____ ____
      AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
        60   60   60 ____ ____ ____ ____ ____ ____ ____
      DEPTH OF INCORPORATION OF J,TH FERTILIZATION
      (DFERT(J);CM,SURFACE APPLIED =1)
        10    0    0 ____ ____ ____ ____ ____ ____ ____
      CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
           AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
           M.NITRATE = 5)(IFTYPE(J)) 1
```

Table E.4 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG= EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
ZADOKS:			10	(13)		(30)			39	89
1	3	1	180	---	201	207	263	266	266	356
1	1	2	180	---	201	211	251	254	253	329
1	4	3	180	---	201	207	237	242	240	305
1	2	4	180	---	201	207	232	237	234	301
2	4	1	180	---	196	207	236	239	238	301
2	3	2	180	---	196	207	260	263	266	341
2	2	3	180	---	196	207	229	235	231	291
2	1	4	180	---	201	207	248	250	249	321

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF LGTH CM	3RD LAST LEAF WDTH MM	LEAF NO.	SHOOT WTS.(G) AT MATURITY STOVER	SHOOT WTS.(G) AT MATURITY GRAIN	KERNEL WT MG	KERNEL N %
1	3	1	77.0	101	_____	364.8	198.6	354	2.07
1	1	2	62.2	98	_____	296.0	215.9	385	1.23
1	4	3	64.6	112	_____	211.2	232.0	338	1.50
1	2	4	64.1	114	_____	166.3	194.1	336	1.77
2	4	1	65.4	122	_____	239.3	276.0	387	1.45
2	3	2	68.3	104	_____	415.5	264.1	325	1.94
2	2	3	68.1	111	_____	162.2	147.1	307	1.69
2	1	4	57.9	89	_____	348.8	309.5	380	1.40

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 347.

GENERAL OBSERVATIONS
****

#4 little late--poor position + insects.

Table E.5 Maize data from Haleakala Experiment Station, 20 h photoperiod treatment.

INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

MAIZE GENETIC COEFFICIENT NURSERIES

INSTITUTE
NAME(INNAME): IBSNAT
ID (INSTID): IB

RESEARCHER (S)
NAME(RENAME): R.OGOSHI
ID (RESID): RO

EXPERIMENT
NAME (EXNAME): MAIZE 20H (P4) DAYLENGTH STUDY
ID (EXPN): IDSM88H4

LOCATION
NAME: HALEAKALA
ID (LOC): HK

SEEDING
YEAR (IYR) 1988
DATE (ISOW;JULIAN DATE) 174
SEED DEPTH (SDEPTH;CM) 4
ESTABLISHED PLANT POPULATION (PLANTS;M-2) 6.67
ROW WIDTH (ROW;CM) 75

PHOTOPERIOD (HOURS) 17

IRRIGATION.
JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
____ ____ ____ ____ ____ ____ ____ ____ ____ ____
AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
JULIAN DATE OF J,TH FERTILIZATION(JFDAY)
138 204 234 ____ ____ ____ ____ ____ ____ ____
AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
60 60 60 ____ ____ ____ ____ ____ ____ ____
DEPTH OF INCORPORATION OF J,TH FERTILIZATION
(DFERT(J);CM,SURFACE APPLIED =1)
10 0 0 ____ ____ ____ ____ ____ ____ ____
CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1; AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4; M.NITRATE = 5)(IFTYPE(J)) 1

Table E.5 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG= EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
	ZADOKS:		10	(13)		(30)		39		89
1	1	1	180	---	201	207	253	256	256	337
1	2	2	180	---	201	207	236	240	239	303
1	3	3	180	---	201	207	270	272	286	359
1	4	4	180	---	201	207	242	246	246	305
2	2	1	180	---	201	211	235	238	238	300
2	4	2	180	---	201	207	239	244	244	305
2	1	3	180	---	201	207	251	254	253	337
2	3	4	180	---	196	211	266	269	275	358

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF LGTH CM	3RD LAST LEAF WDTH MM	LEAF NO.	SHOOT WTS.(G) AT MATURITY STOVER	SHOOT WTS.(G) AT MATURITY GRAIN	KERNEL WT MG	KERNEL N %
1	1	1	66.5	110	_____	315.8	268.8	403	1.35
1	2	2	70.1	112	_____	166.0	142.5	356	1.77
1	3	3	65.4	93	_____	574.0	139.0	374	2.85
1	4	4	77.4	113	_____	239.0	218.5	340	1.46
2	2	1	67.2	107	_____	129.5	152.4	340	1.64
2	4	2	65.9	105	_____	278.9	243.5	350	1.53
2	1	3	62.1	95	_____	334.0	264.4	410	1.27
2	3	4	74.9	111	_____	410.2	177.6	362	4.58

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 347.

GENERAL OBSERVATIONS
****

Table E.6 Maize data from Kuiaha Experiment Site, control photoperiod treatment.

```
              INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                  MAIZE GENETIC COEFFICIENT NURSERIES


INSTITUTE
   NAME(INNAME):                      IBSNAT
   ID (INSTID):                       IB

RESEARCHER (S)
   NAME(RENAME):                      R.OGOSHI
   ID (RESID):                        RO

EXPERIMENT
   NAME (EXNAME):                     MAIZE CONTROL (P0) DAYLENGTH STUDY
   ID (EXPN):                         IDSM88K0

LOCATION
   NAME:                              KUIAHA
   ID (LOC):                          KU

SEEDING
   YEAR (IYR)                                     1988
   DATE (ISOW;JULIAN DATE)                         174
   SEED DEPTH (SDEPTH;CM)                            4
   ESTABLISHED PLANT POPULATION (PLANTS;M-2)      6.67
   ROW WIDTH (ROW;CM)                               75

PHOTOPERIOD (HOURS)                               NATURAL

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
   138  204  234 ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
    60   60   60 ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)
    10    0    0 ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J)) 1
```

Table E.6 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG= EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
ZADOKS:			10	(13)		(30)		39		89
1	3	1	180	---	194	201	232	235	236	296
1	1	2	180	---	196	207	230	235	232	301
1	2	3	180	---	201	201	---	---	223	280
1	4	4	180	---	201	207	---	229	228	285
2	2	1	180	---	196	201	---	---	223	280
2	3	2	180	---	194	201	234	237	236	296
2	4	3	180	---	196	201	---	229	228	286
2	1	4	180	---	196	201	232	237	235	301

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF LGTH CM	3RD LAST LEAF WDTH MM	LEAF NO.	SHOOT WTS.(G) AT MATURITY STOVER	SHOOT WTS.(G) AT MATURITY GRAIN	KERNEL WT MG	KERNEL N %
1	3	1	50.7	98	_____	319.9	214.45	366	1.99
1	1	2	49.5	89	_____	228.7	276.60	401	1.41
1	2	3	47.2	95	_____	155.0	137.05	323	1.89
1	4	4	52.2	90	_____	168.7	210.65	357	1.56
2	2	1	47.0	104	_____	179.3	186.85	364	1.65
2	3	2	54.0	95	_____	249.0	217.35	357	2.14
2	4	3	55.9	100	_____	276.0	238.25	333	1.56
2	1	4	63.4	90	_____	242.0	256.80	422	1.43

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 347.

GENERAL OBSERVATIONS
****

Table E.7 Maize data from Kuiaha Experiment Site, natural photoperiod treatment.

INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

MAIZE GENETIC COEFFICIENT NURSERIES

INSTITUTE
NAME(INNAME): IBSNAT
ID (INSTID): IB

RESEARCHER (S)
NAME(RENAME): R.OGOSHI
ID (RESID): RO

EXPERIMENT
NAME (EXNAME): MAIZE NATURAL (P1) DAYLENGTH STUDY
ID (EXPN): IDSM88K1

LOCATION
NAME: KUIAHA
ID (LOC): KU

SEEDING
YEAR (IYR) 1988
DATE (ISOW;JULIAN DATE) 174
SEED DEPTH (SDEPTH;CM) 4
ESTABLISHED PLANT POPULATION (PLANTS;M-2) 6.67
ROW WIDTH (ROW;CM) 75

PHOTOPERIOD (HOURS) NATURAL + 0.5H

IRRIGATION.
JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
____ ____ ____ ____ ____ ____ ____ ____ ____ ____
AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
JULIAN DATE OF J,TH FERTILIZATION(JFDAY)
138 204 234 ____ ____ ____ ____ ____ ____ ____
AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
60 60 60 ____ ____ ____ ____ ____ ____ ____
DEPTH OF INCORPORATION OF J,TH FERTILIZATION
(DFERT(J);CM,SURFACE APPLIED =1)
10 0 0 ____ ____ ____ ____ ____ ____ ____
CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
M.NITRATE = 5)(IFTYPE(J)) 1

Table E.7 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG= EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
	ZADOKS:		10	(13)		(30)		39		89
1	1	1	180	---	196	207	231	237	235	291
1	4	2	180	---	196	207	---	229	228	285
1	3	3	180	---	194	207	235	238	237	301
1	2	4	180	---	196	201	---	229	223	280
2	2	1	180	---	196	201	---	229	223	280
2	3	2	180	---	194	201	234	237	236	301
2	4	3	180	---	196	207	---	229	228	285
2	1	4	180	---	196	201	234	237	236	300

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF LGTH CM	WDTH MM	LEAF NO.	SHOOT WTS.(G) AT MATURITY STOVER	GRAIN	KERNEL WT MG	KERNEL N %
1	1	1	61.2	86	_____	313.6	288.55	420	1.26
1	4	2	59.0	104	_____	202.2	250.35	335	1.47
1	3	3	60.4	94	_____	349.2	201.50	371	2.13
1	2	4	56.9	106	_____	177.4	171.35	333	1.73
2	2	1	65.2	100	_____	192.6	166.75	333	1.78
2	3	2	61.1	92	_____	373.8	223.60	364	2.25
2	4	3	78.7	108	_____	259.6	233.55	326	1.59
2	1	4	62.5	94	_____	243.5	262.60	442	1.55

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 347.

GENERAL OBSERVATIONS
****

Table E.8 Maize data from Kuiaha Experiment Site, 14 h photoperiod treatment.

INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

MAIZE GENETIC COEFFICIENT NURSERIES

INSTITUTE
NAME(INNAME): IBSNAT
ID (INSTID): IB

RESEARCHER (S)
NAME(RENAME): R.OGOSHI
ID (RESID): RO

EXPERIMENT
NAME (EXNAME): MAIZE 14H (P2) DAYLENGTH STUDY
ID (EXPN): IDSM88K2

LOCATION
NAME: KUIAHA
ID (LOC): KU

SEEDING
YEAR (IYR) 1988
DATE (ISOW;JULIAN DATE) 174
SEED DEPTH (SDEPTH;CM) 4
ESTABLISHED PLANT POPULATION (PLANTS;M-2) 6.67
ROW WIDTH (ROW;CM) 75

PHOTOPERIOD (HOURS) 14

IRRIGATION.
JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
____ ____ ____ ____ ____ ____ ____ ____ ____ ____
AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
JULIAN DATE OF J,TH FERTILIZATION(JFDAY)
138 204 234 ____ ____ ____ ____ ____ ____ ____
AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
60 60 60 ____ ____ ____ ____ ____ ____ ____
DEPTH OF INCORPORATION OF J,TH FERTILIZATION
(DFERT(J);CM,SURFACE APPLIED =1)
10 0 0 ____ ____ ____ ____ ____ ____ ____
CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
M.NITRATE = 5)(IFTYPE(J)) 1

Table E.8 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG=EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
ZADOKS:			10	(13)		(30)		39		89
1	2	1	180	---	196	207	---	229	223	281
1	1	2	180	---	196	201	233	237	235	300
1	3	3	180	---	196	207	234	237	236	293
1	4	4	180	---	196	201	---	229	228	286
2	1	1	180	---	196	201	232	237	235	287
2	3	2	180	---	194	207	234	238	237	294
2	2	3	180	---	196	201	---	229	223	281
2	4	4	180	---	196	207	---	229	228	287

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF LGTH CM	3RD LAST LEAF WDTH MM	LEAF NO.	SHOOT WTS.(G) AT MATURITY STOVER	SHOOT WTS.(G) AT MATURITY GRAIN	KERNEL WT MG	KERNEL N %
1	2	1	59.3	90	_____	116.4	150.15	336	1.87
1	1	2	71.6	105	_____	201.3	238.90	417	1.34
1	3	3	70.1	102	_____	298.2	208.35	343	2.14
1	4	4	65.9	103	_____	175.4	199.25	338	1.63
2	1	1	66.2	105	_____	251.7	305.95	403	1.68
2	3	2	61.0	94	_____	348.5	241.75	327	2.13
2	2	3	61.9	109	_____	188.2	162.15	305	1.79
2	4	4	59.6	92	_____	234.1	230.25	360	1.30

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 347.

GENERAL OBSERVATIONS
****

Table E.9 Maize data from Kuiaha Experiment Site, 17 h photoperiod treatment.

```
                INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                    MAIZE GENETIC COEFFICIENT NURSERIES


INSTITUTE
    NAME(INNAME):                    IBSNAT
    ID (INSTID):                     IB

RESEARCHER (S)
    NAME(RENAME):                    R.OGOSHI
    ID (RESID):                      RO

EXPERIMENT
    NAME (EXNAME):                   MAIZE 17H (P3) DAYLENGTH STUDY
    ID (EXPN):                       IDSM88K3

LOCATION
    NAME:                            KUIAHA
    ID (LOC):                        KU

SEEDING
    YEAR (IYR)                                   1988
    DATE (ISOW;JULIAN DATE)                       174
    SEED DEPTH (SDEPTH;CM)                          4
    ESTABLISHED PLANT POPULATION (PLANTS;M-2)    6.67
    ROW WIDTH (ROW;CM)                             75

PHOTOPERIOD (HOURS)                              17

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
   138  204  234 ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
    60   60   60 ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)
    10    0    0 ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J)) 1
```

Table E.9 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG= EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
ZADOKS:			10	(13)		(30)		39		89
1	3	1	180	---	196	201	256	263	264	329
1	4	2	180	---	196	207	229	235	232	278
1	2	3	180	---	196	207	---	229	228	277
1	1	4	180	---	196	207	242	246	246	317
2	3	1	180	---	194	201	261	263	281	330
2	2	2	180	---	196	201	---	229	228	282
2	1	3	180	---	196	201	239	243	242	308
2	4	4	180	---	196	207	231	237	235	286

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF LGTH CM	3RD LAST LEAF WDTH MM	LEAF NO.	SHOOT WTS.(G) AT MATURITY STOVER	SHOOT WTS.(G) AT MATURITY GRAIN	KERNEL WT MG	KERNEL N %
1	3	1	73.8	101		682.1	159.9	373	2.10
1	4	2	70.2	91		177.9	178.20	340	1.65
1	2	3	63.2	100		187.2	172.10	329	1.66
1	1	4	62.7	91		254.2	243.0	407	1.30
2	3	1	72.5	104		774.0	87.3	425	2.17
2	2	2	69.4	105		157.5	119.90	350	1.76
2	1	3	67.5	101		321.3	294.4	408	1.40
2	4	4	71.8	104		215.7	208.40	371	1.62

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 347.

GENERAL OBSERVATIONS
****

2/3/1 Low grain weight due to barren ears.

Table E.10 Maize data from Kuiaha Experiment Site, 20 h photoperiod treatment.

```
              INFORMATION REQUIRED FOR DETAILED DATA ANALYSIS

                  MAIZE GENETIC COEFFICIENT NURSERIES


INSTITUTE
    NAME(INNAME):                    IBSNAT
    ID (INSTID):                     IB

RESEARCHER (S)
    NAME(RENAME):                    R.OGOSHI
    ID (RESID):                      RO

EXPERIMENT
    NAME (EXNAME):                   MAIZE 20H (P4) DAYLENGTH STUDY
    ID (EXPN):                       IDSM88K4

LOCATION
    NAME:                            KUIAHA
    ID (LOC):                        KU

SEEDING
    YEAR (IYR)                                   1988
    DATE (ISOW;JULIAN DATE)                       174
    SEED DEPTH (SDEPTH;CM)                          4
    ESTABLISHED PLANT POPULATION (PLANTS;M-2)    6.67
    ROW WIDTH (ROW;CM)                             75

PHOTOPERIOD (HOURS)                              20

IRRIGATION.
  JULIAN DATE OF J,TH IRRIGATION (JDAY(J))
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____
  AMOUNT OF WATER ADDED FOR J,TH IRRIGTION (AIRR(J);MM)
  ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

NITROGEN FERTILIZATION
  JULIAN DATE OF J,TH  FERTILIZATION(JFDAY)
   174  204  234 ____ ____ ____ ____ ____ ____ ____
  AMMOUNT OF NITROGEN ADDED FOR J,TH FERTILIZATION (AFERT;KG N/HA)
    60   60   60 ____ ____ ____ ____ ____ ____ ____
  DEPTH OF INCORPORATION OF J,TH FERTILIZATION
  (DFERT(J);CM,SURFACE APPLIED =1)
    10    0    0 ____ ____ ____ ____ ____ ____ ____
  CODE NUMBER OF FERTILIZER TYPE FOR J,TH FERTILIZATION (UREA = 1;
       AMMONIUM NITRATE = 2;ANHYDRANE =3;CA AMMONIUM NITRATE = 4;
       M.NITRATE = 5)(IFTYPE(J)) 1
```

Table E.10 (continued)

PLOTDATA - PHENOLOGY
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. ZADOKS SCALES IN BRACKETS ARE APPROXIMATIONS. EMRG= EMERGENCE; LF5=LF.5; A=APPEARANCE; FE=FULLY EXPANDED; APX1=APEX AT 1 CM FROM CROWN; TA=TASSEL APPEARANCE; LSLFFE=LAST LEAF FULLY EXPANDED; MTUR =BLACK LAYER APPEARANCE.

REP	ENT	PLT	EMRG	LF5A	LF5FE	APX1	TA	LSLFFE	SILK	MTUR
ZADOKS:			10	(13)		(30)		39		89
1	4	1	180	---	196	201	232	237	236	292
1	2	2	180	---	196	207	229	230	230	279
1	1	3	180	---	196	207	246	250	249	317
1	3	4	180	---	194	201	256	263	286	337
2	4	1	180	---	196	201	233	238	238	301
2	1	2	180	---	196	207	243	246	246	317
2	3	3	180	---	194	207	256	263	279	337
2	2	4	180	---	196	201	229	232	230	277

PLOTDATA - LEAF,SHOOT AND KERNEL MEASUREMENTS
****

LEAF DIMENSIONS FROM REPRESENTATIVE LEAF AT ANTHESIS. OTHER MEASUREMENTS ON 10 PLANTS HARVESTED AT RANDOM FROM THE PLOTS AT MATURITY.

REP	ENT	PLT	3RD LAST LEAF LGTH CM	3RD LAST LEAF WDTH MM	LEAF NO.	SHOOT WTS.(G) AT MATURITY STOVER	SHOOT WTS.(G) AT MATURITY GRAIN	KERNEL WT MG	KERNEL N %
1	4	1	73.3	102	_____	291.0	229.00	373	1.71
1	2	2	64.7	92	_____	185.8	167.00	313	1.90
1	1	3	75.4	98	_____	208.5	189.9	400	1.34
1	3	4	77.9	99	_____	449.0	29.9	422	2.29
2	4	1	79.8	92	_____	201.3	174.70	304	1.58
2	1	2	67.6	102	_____	289.9	275.0	393	1.35
2	3	3	87.8	86	_____	636.0	66.8	406	2.16
2	2	4	65.9	103	_____	141.3	128.20	328	1.88

Ent. no.: 1=Pioneer hybrid 3165; 2=Pioneer hybrid 3790;
3=Pioneer hybrid X304C; 4=Pioneer hybrid 347.

GENERAL OBSERVATIONS
****

1/3/4 and 2/3/3 Low grain weight due to barren ears.

APPENDIX F

Maize data, winter 1988

Table F.1 Maize data from Haleakala Experiment Station, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                 PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;WINTER;MAIZE 1989
         ID:             IDWM89H0

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                     Dec. 28, 1988

      PLANT DENSITY (PLANTS/M2)         6.67

      ORGANISATION
         NO.OF ROWS (#):                2
         ROW LENGTH (M):                3
         ROW SPACING (CM):              75
         ORIENTATION OF ROWS:           E-W
         ALONG OR ACROSS DRAINS:        n.a.
         SPACE BETWEEN PLOTS (CM):      0
         GROSS AREA (M 2):              4.5

      HARVEST
         NO.OF ROWS:                    1
         ROW LENGTH (M):                2
         AREA (M 2):                    1.5
         METHOD:                        hand

      RANDOMIZATION/REPLICATION
         DESIGN:                        RCB
         NO.OF REPS.-SOWN:              2
                    -HARVESTED:         2

PROBLEMS
********
```

Table F.1 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*******************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  5 |  1 |    6|  19|  36|  37|  47|  66|  80|  84|  85|  85| 153| 160|
| 1 |  4 |  2 |    6|  19|  37|  37|  46|  65|  77|  80|  83|  82| 142| 153|
| 1 |  3 |  3 |    6|  25|  40|  41|  51|  73|  93|  96|  97|  95| 181| 184|
| 1 |  1 |  4 |    6|  23|  37|  38|  48|  72|  90|  97|  95|  96| 170| 175|
| 1 |  2 |  5 |    6|  19|  41|  41|  48|  68|  75|  80|  82|  80| 142| 153|
---------------------------------------------------------------------------
| 2 |  1 |  1 |    6|  26|  40|  41|  46|  68|  90|  95|  93|  94| 164| 170|
| 2 |  5 |  2 |    6|  19|  37|  37|  46|  66|  84|  86|  87|  87| 161| 164|
| 2 |  4 |  3 |    6|  20|  40|  41|  48|  67|  79|  81|  83|  82| 153| 154|
| 2 |  3 |  4 |    6|  20|  37|  38|  48|  72|  90|  98|  97|  96| 170| 179|
| 2 |  2 |  5 |    6|  20|  37|  38|  48|  70|  76|  79|  80|  80| 142| 150|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
************************************
   LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION    |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  5 |  1 |72.5| 9.8|17.4| 170| 173| 356|1.54|____|____|____|____|____|
| 1 |  4 |  2 |64.5|10.2|15.2| 108| 138| 284|1.31|____|____|____|____|____|
| 1 |  3 |  3 |79.0|10.2|17.6|95.1| 112| 297|1.56|____|____|____|____|____|
| 1 |  1 |  4 |75.1|11.8|18.2| 148| 154| 289|1.16|____|____|____|____|____|
| 1 |  2 |  5 |56.0| 9.0|13.0|84.3|99.1| 298|1.41|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  1 |  1 |84.0|11.5|18.4| 151| 132| 248|1.19|____|____|____|____|____|
| 2 |  5 |  2 |68.5| 9.9|17.4| 135| 174| 340|1.48|____|____|____|____|____|
| 2 |  4 |  3 |63.5| 9.1|15.4| 105| 140| 303|1.27|____|____|____|____|____|
| 2 |  3 |  4 |69.0|10.2|17.6| 119| 117| 288|1.96|____|____|____|____|____|
| 2 |  2 |  5 |58.0| 8.5|13.2|69.3| 101| 288|1.38|____|____|____|____|____|
---------------------------------------------------------------------------
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3165
| 2 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3790
| 3 | __ | __ | __ | __ | __ | __ | Pioneer hybrid X304C
| 4 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3475
| 5 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3324
```

Table F.2 Maize data from Haleakala Experiment Station, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;WINTER;MAIZE 1989
         ID:             IDWM89H1

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     1

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                   Dec. 28, 1988

      PLANT DENSITY (PLANTS/M2)       6.67

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              2
         AREA (M 2):                  1.5
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table F.2 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
---------------------------------------------------------------------------
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  5 |  1 |   6|  20|  37|  37|  47|  65|  83|  88|  87|  87| 153| 161|
| 1 |  1 |  2 |   6|  19|  37|  37|  48|  66|  90|  94|  93|  93| 170| 174|
| 1 |  2 |  3 |   6|  19|  37|  37|  48|  66|  72|  76|  79|  78| 142| 150|
| 1 |  3 |  4 |   6|  25|  37|  41|  48|  70|  96| 101| 101| 100| 188| 192|
| 1 |  4 |  5 |   6|  23|  37|  40|  51|  70|  81|  87|  84|  85| 142| 154|
---------------------------------------------------------------------------
| 2 |  3 |  1 |   6|  22|  37|  38|  41|  66|  89| 112|  93|  94| 170| 172|
| 2 |  5 |  2 |   6|  19|  37|  37|  46|  65|  83|  88|  86|  87| 159| 161|
| 2 |  2 |  3 |   6|  19|  38|  39|  46|  65|  74|  77|  77|  79| 142| 145|
| 2 |  1 |  4 |   6|  19|  37|  41|  48|  70|  93| 100|  96|  97| 164| 170|
| 2 |  4 |  5 |   6|  19|  37|  37|  48|  67|  79|  81|  84|  82| 152| 154|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION    |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  5 |  1 |69.5|10.1|17.2| 161| 183| 329|1.39|____|____|____|____|____|
| 1 |  1 |  2 |78.2|11.6|17.8| 152| 132| 301|1.33|____|____|____|____|____|
| 1 |  2 |  3 |57.4| 8.5|13.2|64.1|96.8| 269|1.36|____|____|____|____|____|
| 1 |  3 |  4 |79.0|11.5|18.2| 123| 152| 314|1.77|____|____|____|____|____|
| 1 |  4 |  5 |62.6| 8.0|15.4| 119| 140| 305|1.33|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  3 |  1 |80.0|10.2|18.6| 186| 153| 297|1.68|____|____|____|____|____|
| 2 |  5 |  2 |69.9| 9.9|17.0| 145| 158| 289|1.32|____|____|____|____|____|
| 2 |  2 |  3 |56.5| 7.5|13.6|59.2|97.1| 271|1.35|____|____|____|____|____|
| 2 |  1 |  4 |73.8|10.6|18.0| 151| 151| 282|1.07|____|____|____|____|____|
| 2 |  4 |  5 |65.5|10.6|15.0|99.4| 126| 285|1.32|____|____|____|____|____|
---------------------------------------------------------------------------
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3165
| 2 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3790
| 3 | __ | __ | __ | __ | __ | __ | Pioneer hybrid X304C
| 4 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3475
| 5 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3324
```

Table F.3 Maize data from Kuiaha Experiment Site, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;WINTER;MAIZE 1989
         ID:            IDWM89K0

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    0

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                   Dec. 29, 1988

      PLANT DENSITY (PLANTS/M2)       6.67

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              2
         AREA (M 2):                  1.5
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                   -HARVESTED:        2

PROBLEMS
********
```

Table F.3 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 |   4|  20|  34|  39|  41|  60|  80|  82|  83|  84| 154| 161|
| 1 |  5 |  2 |   4|  17|  34|  38|  45|  62|  74|  76|  77|  80| 138| 140|
| 1 |  2 |  3 |   4|  17|  37|  38|  45|  60|  61|  66|  68|  68| 118| 126|
| 1 |  4 |  4 |   4|  17|  38|  39|  46|  61|  66|  69|  72|  72| 118| 126|
| 1 |  1 |  5 |   4|  17|  32|  33|  41|  60|  76|  79|  81|  80| 142| 150|
---------------------------------------------------------------------------
| 2 |  1 |  1 |   4|  19|  34|  38|  41|  58|  77|  80|  82|  79| 134| 134|
| 2 |  3 |  2 |   4|  19|  32|  38|  40|  58|  79|  82|  82|  81| 142| 150|
| 2 |  4 |  3 |   4|  17|  34|  38|  41|  58|  66|  69|  73|  72| 118| 131|
| 2 |  2 |  4 |   4|  16|  34|  34|  41|  58|  60|  66|  67|  67| 121| 130|
| 2 |  5 |  5 |   4|  17|  30|  30|  40|  58|  71|  75|  74|  73| 131| 134|
---------------------------------------------------------------------------
PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION     |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 |63.0| 6.8|18.4| 116| 124| 344|1.90|____|____|____|____|____|
| 1 |  5 |  2 |64.0|10.4|16.4|70.6| 107| 331|1.56|____|____|____|____|____|
| 1 |  2 |  3 |43.0| 6.3|12.4|28.0|45.0| 224|1.29|____|____|____|____|____|
| 1 |  4 |  4 |57.2| 7.1|13.4|49.0|68.4| 253|1.19|____|____|____|____|____|
| 1 |  1 |  5 |71.5|12.0|18.2| 133| 148| 365|1.96|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  1 |  1 |74.0| 9.7|17.8|92.1| 133| 318|1.10|____|____|____|____|____|
| 2 |  3 |  2 |65.8| 9.8|18.4| 219| 129| 335|2.21|____|____|____|____|____|
| 2 |  4 |  3 |56.6| 7.9|15.2|62.0|92.4| 245|1.27|____|____|____|____|____|
| 2 |  2 |  4 |51.7| 8.4|13.4|52.9|81.9| 242|1.33|____|____|____|____|____|
| 2 |  5 |  5 |65.3|10.9|16.2|89.5| 109| 326|1.56|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3165
| 2 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3790
| 3 | __ | __ | __ | __ | __ | __ | Pioneer hybrid X304C
| 4 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3475
| 5 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3324
```

Table F.4 Maize data from Kuiaha Experiment Site, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;WINTER;MAIZE 1989
         ID:             IDWM89K1

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     1

      LOCATION
         NAME:           KUIAHA

PLOTS
*****
      PLANTING DATE                    Dec. 29, 1988

      PLANT DENSITY (PLANTS/M2)        6.67

      ORGANISATION
         NO.OF ROWS (#):               2
         ROW LENGTH (M):               3
         ROW SPACING (CM):             75
         ORIENTATION OF ROWS:          E-W
         ALONG OR ACROSS DRAINS:       n.a.
         SPACE BETWEEN PLOTS (CM):     0
         GROSS AREA (M 2):             4.5

      HARVEST
         NO.OF ROWS:                   1
         ROW LENGTH (M):               2
         AREA (M 2):                   1.5
         METHOD:                       hand

      RANDOMIZATION/REPLICATION
         DESIGN:                       RCB
         NO.OF REPS.-SOWN:             2
                    -HARVESTED:        2

PROBLEMS
********
```

Table F.4 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*****************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 |   4|  17|  30|  38|  41|  60|  79|  81|  83|  81| 154| 160|
| 1 |  5 |  2 |   4|  15|  30|  30|  41|  60|  70|  74|  76|  72| 131| 134|
| 1 |  1 |  3 |   4|  17|  30|  30|  41|  60|  74|  79|  81|  79| 134| 134|
| 1 |  2 |  4 |   4|  16|  30|  33|  40|  58|  61|  65|  66|  66| 121| 126|
| 1 |  4 |  5 |   4|  17|  32|  33|  39|  58|  66|  67|  70|  68| 121| 126|
---------------------------------------------------------------------------
| 2 |  4 |  1 |   4|  17|  32|  33|  38|  58|  68|  72|  74|  71| 116| 121|
| 2 |  2 |  2 |   4|  17|  31|  30|  37|  58|  59|  65|  66|  66| 117| 121|
| 2 |  1 |  3 |   4|  18|  30|  32|  34|  58|  74|  79|  81|  79| 142| 142|
| 2 |  3 |  4 |   4|  18|  30|  38|  34|  59|  77|  80|  82|  80| 153| 154|
| 2 |  5 |  5 |   4|  17|  30|  30|  39|  58|  70|  72|  74|  72| 122| 126|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION    |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 |71.0|10.2|18.6|90.6| 206| 353|1.88|____|____|____|____|____|
| 1 |  5 |  2 |56.2| 9.5|16.2|86.3| 120| 304|1.47|____|____|____|____|____|
| 1 |  1 |  3 |65.8| 9.9|17.8| 126| 174| 352|1.16|____|____|____|____|____|
| 1 |  2 |  4 |51.1| 9.5|14.0|56.2|88.8| 246|1.57|____|____|____|____|____|
| 1 |  4 |  5 |60.0| 9.2|16.0|69.4| 109| 280|1.30|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  4 |  1 |56.6| 9.7|15.4|62.5| 110| 268|1.22|____|____|____|____|____|
| 2 |  2 |  2 |64.0| 8.8|14.8|75.8| 108| 271|1.60|____|____|____|____|____|
| 2 |  1 |  3 |71.5|11.0|19.0| 115| 168| 299|1.10|____|____|____|____|____|
| 2 |  3 |  4 |66.0| 8.5|18.2| 119| 147| 328|1.20|____|____|____|____|____|
| 2 |  5 |  5 |69.0|10.5|16.8|94.6| 154| 346|1.50|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3165
| 2 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3790
| 3 | __ | __ | __ | __ | __ | __ | Pioneer hybrid X304C
| 4 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3475
| 5 | __ | __ | __ | __ | __ | __ | Pioneer hybrid 3324
```

APPENDIX G

Maize data, summer 1989

Table G.1 Maize data from Haleakala Experiment Station, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:             IDSM89H0

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                    Sep. 9, 1989

      PLANT DENSITY (PLANTS/M2)        6.67

      ORGANISATION
         NO.OF ROWS (#):               2
         ROW LENGTH (M):               3
         ROW SPACING (CM):             75
         ORIENTATION OF ROWS:          E-W
         ALONG OR ACROSS DRAINS:       n.a.
         SPACE BETWEEN PLOTS (CM):     75
         GROSS AREA (M 2):             4.5

      HARVEST
         NO.OF ROWS:                   1
         ROW LENGTH (M):               2
         AREA (M 2):                   1.5
         METHOD:                       hand

      RANDOMIZATION/REPLICATION
         DESIGN:                       RCB
         NO.OF REPS.-SOWN:             2
                    -HARVESTED:        2

PROBLEMS
********
```

Table G.1 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS

****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.

GROWTH STAGE			10		(13)	(30)				39				
ASPECT			EMRG	LF5A	LF5E	APX1	L10A	L10E	TA	LSLE	ANTH	SILK	MLDS	BLYR
REP	ENT	PLT												
1	2	1	258	269	282	276	290	310	332	338	334	335	25	36
1	5	2	258	268	282	275	290	305	310	316	313	315	12	15
1	1	3	258	268	280	277	287	308	328	335	330	332	54	55
1	3	4	258	269	280	277	289	289	325	335	327	328	25	37
1	4	5	259	269	282	278	291	309	319	329	322	324	21	24
2	3	1	258	269	280	276	289	304	323	335	325	328	31	37
2	5	2	258	268	282	275	291	305	310	316	313	315	13	16
2	2	3	258	268	282	277	291	310	331	335	333	335	31	37
2	1	4	258	270	280	278	290	308	327	335	331	333	51	55
2	4	5	259	269	282	277	291	310	318	326	320	323	25	27

PLOTDATA - GROWTH CHARACTERISTICS

****

LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.

ASPECT			MXLL	MXBL	LFNO	SHWM	GRWT	_KW_	_KN_					
CONVERSION														
REP	ENT	PLT												
1	2	1	80.3	10.3	18.2	51.3	48.6	160	1.22					
1	5	2	68.7	7.9	13.2	48.9	67.1	242	1.24					
1	1	3	87.0	8.4	18.6	134	114	256	1.44					
1	3	4	86.0	11.9	17.4	92.5	128	305	1.09					
1	4	5	77.0	10.3	15.8	83.6	81.6	238	1.22					
2	3	1	77.5	12.5	18.0	95.6	129	301	1.23					
2	5	2	77.0	8.7	13.8	54.2	74.3	245	1.18					
2	2	3	78.8	9.1	18.6	72.6	62.1	195	1.18					
2	1	4	92.3	10.8	18.0	92.2	109	264	1.35					
2	4	5	76.3	9.6	16.0	67.6	76.7	233	1.20					

KEY POSITIONS AND NAMES/PEDIGREES

****

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							X304C
2							PIO-3165
3							PIO-3324
4							PIO-3475
5							PIO-3790

Table G.2 Maize data from Haleakala Experiment Station, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:             IDSM89H1

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     1

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                    Sep. 9, 1989

      PLANT DENSITY (PLANT/M2)         6.67

      ORGANISATION
         NO.OF ROWS (#):               2
         ROW LENGTH (M):               3
         ROW SPACING (CM):             75
         ORIENTATION OF ROWS:          E-W
         ALONG OR ACROSS DRAINS:       n.a.
         SPACE BETWEEN PLOTS (CM):     0
         GROSS AREA (M 2):             4.5

      HARVEST
         NO.OF ROWS:                   1
         ROW LENGTH (M):               2
         AREA (M 2):                   1.5
         METHOD:                       hand

      RANDOMIZATION/REPLICATION
         DESIGN:                       RCB
         NO.OF REPS.-SOWN:             2
                    -HARVESTED:        2

PROBLEMS
********
```

Table G.2 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
******************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 | 257| 269| 283| 276| 289| 310| 331| 338| 333| 335|  32|  36|
| 1 |  4 |  2 | 258| 268| 283| 278| 290| 303| 318| 325| 320| 322|  19|  17|
| 1 |  5 |  3 | 258| 268| 282| 276| 290| 304| 313| 321| 317| 318|  21|  24|
| 1 |  3 |  4 | 258| 268| 280| 276| 291| 307| 327| 335| 328| 328|  36|  43|
| 1 |  1 |  5 | 258| 269| 282| 277| 290| 307| 332| 340| 335| 338|  51|  53|
---------------------------------------------------------------------------
| 2 |  4 |  1 | 258| 268| 283| 275| 287| 303| 316| 321| 318| 320|  23|  27|
| 2 |  5 |  2 | 258| 268| 282| 275| 289| 304| 311| 319| 314| 315|  19|  17|
| 2 |  2 |  3 | 258| 270| 283| 276| 291| 310| 333| 340| 335| 338|  31|  36|
| 2 |  1 |  4 | 258| 269| 280| 278| 287| 307| 331| 338| 333| 335|  51|  54|
| 2 |  3 |  5 | 258| 269| 282| 275| 290| 307| 325| 334| 328| 329|  24|  33|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*************************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION    |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 |76.5|11.4|19.0|61.8|43.1| 162|1.32|____|____|____|____|____|
| 1 |  4 |  2 |75.0| 9.6|16.4|64.2|70.3| 195|1.22|____|____|____|____|____|
| 1 |  5 |  3 |75.4| 8.3|14.4|46.2|77.9| 234|1.18|____|____|____|____|____|
| 1 |  3 |  4 |85.6|12.2|18.4|90.1| 103| 274|1.20|____|____|____|____|____|
| 1 |  1 |  5 |86.1|10.2|19.0| 141| 127| 268|1.46|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  4 |  1 |80.1|10.0|17.6|78.3|83.1| 226|1.24|____|____|____|____|____|
| 2 |  5 |  2 |70.4| 8.5|14.2|55.8|74.8| 221|1.19|____|____|____|____|____|
| 2 |  2 |  3 |81.5| 9.7|19.0|65.1|29.7| 150|1.44|____|____|____|____|____|
| 2 |  1 |  4 | 101|10.5|20.0| 211| 117| 286|1.67|____|____|____|____|____|
| 2 |  3 |  5 |81.3|12.4|18.4|76.7|76.3| 228|1.32|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*************************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table G.3 Maize data from Haleakala Experiment Station, 14 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:            IDSM89H2

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    1

      LOCATION
         NAME:          HALEAKALA

PLOTS
*****
      PLANTING DATE                  June 15, 1989

      PLANT DENSITY (PLANTS/M2)      6.67

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             2
         AREA (M 2):                 1.5
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table G.3 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  4 |  1 | 172| 182| 194| 188| 199| 216| 229| 235| 231| 233| 296| 301|
| 1 |  3 |  2 | 172| 180| 193| 187| 205| 218| 236| 243| 239| 240| 303| 311|
| 1 |  5 |  3 | 172| 180| 198| 186| 205| 218| 226| 233| 228| 229| 291| 296|
| 1 |  1 |  4 | 172| 182| 193| 191| 200| 216| 249| 256| 252| 254| 328| 329|
| 1 |  2 |  5 | 172| 182| 198| 191| 201| 220| 241| 248| 243| 244| 313| 319|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 172| 182| 194| 191| 200| 216| 249| 256| 253| 254| 338| 341|
| 2 |  5 |  2 | 171| 180| 196| 186| 202| 219| 228| 235| 231| 233| 292| 296|
| 2 |  4 |  3 | 172| 180| 196| 187| 200| 216| 231| 238| 233| 235| 299| 304|
| 2 |  2 |  4 | 171| 182| 198| 191| 204| 220| 242| 250| 244| 245| 313| 315|
| 2 |  3 |  5 | 171| 180| 196| 186| 202| 217| 237| 244| 239| 241| 301| 313|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION     |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  4 |  1 |86.4|12.8|17.4| 154| 151| 314|1.36|____|____|____|____|____|
| 1 |  3 |  2 |93.5|13.4|18.4| 147| 160| 322|1.33|____|____|____|____|____|
| 1 |  5 |  3 |72.5|10.2|15.2|98.5| 112| 285|1.19|____|____|____|____|____|
| 1 |  1 |  4 | 113|10.6|24.2| 334| 172| 338|1.80|____|____|____|____|____|
| 1 |  2 |  5 |98.2|13.0|20.2| 154| 154| 264|1.04|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 108|10.8|24.4| 360| 211| 342|1.87|____|____|____|____|____|
| 2 |  5 |  2 |74.5|10.5|15.2| 107| 121| 318|1.44|____|____|____|____|____|
| 2 |  4 |  3 |84.7|12.4|17.4| 168| 176| 341|1.32|____|____|____|____|____|
| 2 |  2 |  4 | 102|12.5|20.4| 206| 154| 294|1.19|____|____|____|____|____|
| 2 |  3 |  5 |95.8|12.1|18.0| 169| 176| 313|1.38|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table G.4 Maize data from Haleakala Experiment Station, 17 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:             IDSM89H3

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     1

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                   June 15, 1989

      PLANT DENSITY (PLANTS/M2)       6.67

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              2
         AREA (M 2):                  1.5
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                   -HARVESTED:        2

PROBLEMS
********
```

Table G.4 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 | 173| 183| 193| 192| 198| 214| 264| 269| 268| 269| 342| 356|
| 1 |  4 |  2 | 172| 182| 198| 188| 201| 216| 233| 242| 237| 238| 298| 305|
| 1 |  2 |  3 | 172| 182| 198| 192| 202| 220| 248| 260| 250| 251| 319| 322|
| 1 |  5 |  4 | 171| 181| 195| 187| 200| 217| 229| 235| 232| 233| 289| 293|
| 1 |  3 |  5 | 172| 180| 193| 186| 200| 216| 238| 244| 239| 240| 300| 305|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 172| 183| 194| 193| 201| 216| 269| 273| 273| 275| 340| 343|
| 2 |  4 |  2 | 171| 181| 195| 186| 200| 216| 235| 242| 236| 237| 300| 304|
| 2 |  3 |  3 | 171| 180| 192| 186| 198| 215| 237| 242| 239| 241| 299| 312|
| 2 |  2 |  4 | 171| 182| 195| 192| 200| 219| 250| 257| 252| 254| 319| 324|
| 2 |  5 |  5 | 172| 180| 198| 186| 201| 218| 229| 235| 232| 234| 291| 294|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION     |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 | 118|11.1|27.6| 342| 150| 337|1.74|____|____|____|____|____|
| 1 |  4 |  2 |88.3|11.3|18.6| 169| 157| 291|1.28|____|____|____|____|____|
| 1 |  2 |  3 | 109|12.5|22.0| 154| 135| 254|1.03|____|____|____|____|____|
| 1 |  5 |  4 |81.9| 9.8|16.2| 131| 139| 318|1.28|____|____|____|____|____|
| 1 |  3 |  5 |89.7|12.9|19.4| 151| 157| 293|1.29|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 117|10.9|28.0| 450| 152| 346|1.79|____|____|____|____|____|
| 2 |  4 |  2 |92.9|10.9|18.8| 162| 175| 294|1.35|____|____|____|____|____|
| 2 |  3 |  3 |91.3|10.5|19.4| 183| 187| 318|1.37|____|____|____|____|____|
| 2 |  2 |  4 | 112|12.6|22.2| 184| 167| 273|1.18|____|____|____|____|____|
| 2 |  5 |  5 |82.9|11.2|16.6| 138| 143| 320|1.15|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table G.5 Maize data from Haleakala Experiment Station, 20 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:             IDSM89H4

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     1

      LOCATION
         NAME:           HALEAKALA

PLOTS
*****
      PLANTING DATE                   June 15, 1989

      PLANT DENSITY (PLANTS/M2)       6.67

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              2
         AREA (M 2):                  1.5
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table G.5 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.

GROWTH STAGE			10		(13)	(30)				39				
ASPECT			EMRG	LF5A	LF5E	APX1	L10A	L10E	TA	LSLE	ANTH	SILK	MLDS	BLYR
REP	ENT	PLT												
1	2	1	172	183	198	191	202	221	251	258	253	254	325	333
1	5	2	172	181	198	191	203	219	231	241	233	235	291	294
1	3	3	171	182	196	192	202	219	242	249	244	247	300	318
1	4	4	172	182	198	192	205	220	238	245	241	244	312	314
1	1	5	172	183	196	193	201	216	270	279	275	277	342	363
2	5	1	171	180	194	186	198	216	231	236	232	234	291	296
2	2	2	171	183	198	191	200	219	252	261	254	254	325	335
2	3	3	171	180	193	188	200	216	242	248	244	245	312	315
2	4	4	172	181	195	187	200	216	237	244	240	241	300	304
2	1	5	172	183	196	193	201	217	273	279	276	278	341	363

PLOTDATA - GROWTH CHARACTERISTICS
****

LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.

ASPECT			MXLL	MXBL	LFNO	SHWM	GRWT	_KW_	_KN_					
CONVERSION														
REP	ENT	PLT												
1	2	1	106	13.3	21.6	176	149	266	1.13					
1	5	2	83.4	11.1	16.4	143	134	308	1.13					
1	3	3	94.9	12.0	19.0	167	159	302	1.26					
1	4	4	93.5	12.0	18.6	117	147	249	1.29					
1	1	5	125	11.5	27.4	291	120	312	1.53					
2	5	1	89.4	11.2	17.0	141	154	314	1.28					
2	2	2	109	11.4	22.4	221	168	294	1.16					
2	3	3	93.7	13.6	19.8	184	171	300	1.45					
2	4	4	99.4	12.6	19.2	143	153	269	1.21					
2	1	5	120	11.2	27.2	378	59.2	318	1.74					

KEY POSITIONS AND NAMES/PEDIGREES
****

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1							X304C
2							PIO-3165
3							PIO-3324
4							PIO-3475
5							PIO-3790

Table G.6 Maize data from Kuiaha Experiment Site, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:            IDSM89K0

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    0

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                    Sep. 8, 1989

      PLANT DENSITY (PLANTS/M2)        6.67

      ORGANISATION
         NO.OF ROWS (#):               2
         ROW LENGTH (M):               3
         ROW SPACING (CM):             75
         ORIENTATION OF ROWS:          E-W
         ALONG OR ACROSS DRAINS:       n.a.
         SPACE BETWEEN PLOTS (CM):     0
         GROSS AREA (M 2):             4.5

      HARVEST
         NO.OF ROWS:                   1
         ROW LENGTH (M):               2
         AREA (M 2):                   1.5
         METHOD:                       hand

      RANDOMIZATION/REPLICATION
         DESIGN:                       RCB
         NO.OF REPS.-SOWN:             2
                    -HARVESTED:        2

PROBLEMS
********
```

Table G.6 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 | 256| 264| 276| 272| 282| 298| 314| 321| 317| 319|  31|  34|
| 1 |  3 |  2 | 256| 263| 275| 271| 283| 296| 310| 314| 311| 312|   4|  10|
| 1 |  2 |  3 | 256| 266| 277| 272| 280| 299| 316| 321| 318| 319|  16|  17|
| 1 |  5 |  4 | 256| 263| 275| 270| 280| 293| 299| 308| 302| 304| 359| 363|
| 1 |  4 |  5 | 256| 265| 276| 271| 281| 296| 304| 310| 307| 308| 359| 363|
---------------------------------------------------------------------------
| 2 |  5 |  1 | 256| 264| 275| 270| 280| 292| 300| 307| 303| 304| 359| 363|
| 2 |  2 |  2 | 256| 266| 277| 272| 282| 296| 314| 321| 317| 319| 363|   4|
| 2 |  3 |  3 | 257| 265| 275| 271| 282| 294| 308| 313| 310| 311| 363|   4|
| 2 |  4 |  4 | 257| 264| 276| 271| 282| 296| 305| 311| 307| 308| 359| 363|
| 2 |  1 |  5 | 257| 265| 275| 272| 281| 296| 312| 318| 315| 317|  25|  28|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
   LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION    |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 |82.8| 9.9|18.6| 113| 143| 317|1.70|____|____|____|____|____|
| 1 |  3 |  2 |75.2|10.6|16.8| 105|77.6| 294|1.37|____|____|____|____|____|
| 1 |  2 |  3 |81.8|11.0|18.6|49.8|37.9| 209|1.07|____|____|____|____|____|
| 1 |  5 |  4 |65.1| 9.6|14.6|32.0|64.2| 215|1.36|____|____|____|____|____|
| 1 |  4 |  5 |76.7| 9.0|15.0|91.9|57.3| 263|1.44|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  5 |  1 |70.5| 9.2|14.6|37.6|97.2| 242|1.32|____|____|____|____|____|
| 2 |  2 |  2 |78.0|10.1|18.8|64.9|34.5| 230|1.35|____|____|____|____|____|
| 2 |  3 |  3 |80.9|10.5|17.0|77.4|81.2| 310|1.36|____|____|____|____|____|
| 2 |  4 |  4 |80.5| 9.0|15.4|90.1|64.5| 253|1.47|____|____|____|____|____|
| 2 |  1 |  5 |84.5|10.0|19.0|97.3| 112| 305|1.63|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table G.7 Maize data from Kuiaha Experiment Site, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:            IDSM89K1

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    1

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                  Sep. 8, 1989

      PLANT DENSITY (PLANTS/M2)      6.67

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             2
         AREA (M 2):                 1.5
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table G.7 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 | 256| 265| 277| 272| 282| 298| 314| 321| 317| 319|  32|  34|
| 1 |  4 |  2 | 256| 265| 276| 271| 282| 296| 304| 312| 307| 308| 363|   3|
| 1 |  5 |  3 | 256| 264| 275| 271| 280| 296| 301| 307| 303| 304| 352| 355|
| 1 |  3 |  4 | 256| 265| 275| 270| 282| 296| 310| 313| 311| 312|   2|   9|
| 1 |  2 |  5 | 256| 266| 277| 270| 283| 298| 316| 324| 318| 321| -- |  11|
---------------------------------------------------------------------------
| 2 |  5 |  1 | 256| 265| 275| 270| 282| 294| 301| 308| 303| 304| 353| 356|
| 2 |  3 |  2 | 257| 264| 275| 269| 282| 294| 309| 313| 311| 312| 363|   4|
| 2 |  2 |  3 | 257| 266| 277| 271| 282| 298| 314| 322| 317| 319| -- |  11|
| 2 |  4 |  4 | 257| 265| 276| 271| 282| 296| 304| 312| 307| 308| 359| 363|
| 2 |  1 |  5 | 257| 265| 275| 271| 280| 296| 312| 320| 315| 317|  24|  27|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION     |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 |94.7| 8.8|18.6|81.0|97.4| 296|1.66|____|____|____|____|____|
| 1 |  4 |  2 |84.2| 8.8|16.0|52.5|57.5| 207|1.43|____|____|____|____|____|
| 1 |  5 |  3 |66.3| 9.1|14.2|49.1|41.1| 196|1.53|____|____|____|____|____|
| 1 |  3 |  4 |73.0|10.2|16.6|56.9|63.1| 273|1.29|____|____|____|____|____|
| 1 |  2 |  5 |74.5| 9.7|18.4|54.1| 0.0| -- | -- |____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  5 |  1 |73.4| 9.6|14.0|59.1|68.3| 240|1.33|____|____|____|____|____|
| 2 |  3 |  2 |71.9| 9.9|17.0|81.0|44.3| 284|1.66|____|____|____|____|____|
| 2 |  2 |  3 |71.2| 9.5|18.2|45.6| 0.0| -- | -- |____|____|____|____|____|
| 2 |  4 |  4 |79.0| 8.5|16.4|61.5|58.5| 252|1.44|____|____|____|____|____|
| 2 |  1 |  5 |81.8| 8.7|18.8| 101| 109| 295|1.63|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table G.8 Maize data from Kuiaha Experiment Site, 14 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:             IDSM89K2

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     1

      LOCATION
         NAME:           KUIAHA

PLOTS
*****
      PLANTING DATE                   June 15, 1989

      PLANT DENSITY                   6.67

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              2
         AREA (M 2):                  1.5
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table G.8 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*******************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
----------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
----------------------------------------------------------------------------
| 1 |  4 |  1 | 172| 179| 191| 186| 194| 207| 221| 223| 223| 223| 271| 278|
| 1 |  1 |  2 | 173| 180| 191| 188| 194| 208| 230| 235| 232| 234| 296| 299|
| 1 |  2 |  3 | 171| 180| 190| 186| 195| 210| 227| 232| 228| 229| 289| 293|
| 1 |  5 |  4 | 171| 178| 190| 185| 194| 208| 213| 222| 216| 216| 268| 272|
| 1 |  3 |  5 | 171| 178| 190| 185| 195| 210| 224| 235| 226| 227| 283| 287|
----------------------------------------------------------------------------
| 2 |  3 |  1 | 171| 178| 189| 185| 194| 206| 223| 227| 226| 223| 279| 285|
| 2 |  1 |  2 | 173| 180| 191| 188| 194| 208| 231| 235| 233| 234| 284| 291|
| 2 |  2 |  3 | 171| 179| 190| 187| 195| 210| 227| 235| 228| 229| 289| 292|
| 2 |  4 |  4 | 171| 179| 190| 185| 194| 209| 218| 222| 220| 220| 275| 279|
| 2 |  5 |  5 | 171| 178| 189| 184| 194| 206| 213| 219| 216| 217| 268| 272|
----------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
   LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
----------------------------------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION    |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
----------------------------------------------------------------------------
| 1 |  4 |  1 |84.1|10.3|17.4| 127| 137| 300|1.15|____|____|____|____|____|
| 1 |  1 |  2 |96.4| 9.6|20.6| 202| 185| 318|1.41|____|____|____|____|____|
| 1 |  2 |  3 |85.6|10.7|19.0| 137| 190| 341|1.01|____|____|____|____|____|
| 1 |  5 |  4 |76.1|10.9|14.4|87.2| 114| 324|1.51|____|____|____|____|____|
| 1 |  3 |  5 |87.7|10.3|18.2| 157| 137| 357|1.41|____|____|____|____|____|
----------------------------------------------------------------------------
| 2 |  3 |  1 |83.2|11.6|18.6| 152| 156| 367|1.65|____|____|____|____|____|
| 2 |  1 |  2 |98.6|10.7|21.2| 224| 203| 344|1.41|____|____|____|____|____|
| 2 |  2 |  3 |91.3|12.1|19.2| 194| 194| 340|1.01|____|____|____|____|____|
| 2 |  4 |  4 |85.2|10.4|17.6| 123| 153| 330|1.30|____|____|____|____|____|
| 2 |  5 |  5 |80.0|10.8|15.4| 118| 130| 343|1.66|____|____|____|____|____|
----------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
----------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table G.9 Maize data from Kuiaha Experiment Site, 17 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:            IDSM89K3

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    1

      LOCATION
         NAME:          KUIAHA

PLOTS
*****
      PLANTING DATE                 June 15, 1989

      PLANT DENSITY (PLANTS/M2)     6.67

      ORGANISATION
         NO.OF ROWS (#):            2
         ROW LENGTH (M):            3
         ROW SPACING (CM):          75
         ORIENTATION OF ROWS:       E-W
         ALONG OR ACROSS DRAINS:    n.a.
         SPACE BETWEEN PLOTS (CM):  0
         GROSS AREA (M 2):          4.5

      HARVEST
         NO.OF ROWS:                1
         ROW LENGTH (M):            2
         AREA (M 2):                1.5
         METHOD:                    hand

      RANDOMIZATION/REPLICATION
         DESIGN:                    RCB
         NO.OF REPS.-SOWN:          2
                   -HARVESTED:      2

PROBLEMS
********
```

Table G.9 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*****************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 | 172| 179| 191| 188| 195| 210| 254| 263| 258| 261| 335| 342|
| 1 |  2 |  2 | 171| 181| 191| 188| 196| 213| 238| 244| 240| 241| 300| 306|
| 1 |  4 |  3 | 171| 179| 191| 186| 197| 210| 224| 229| 227| 228| 283| 287|
| 1 |  5 |  4 | 171| 179| 190| 186| 196| 211| 218| 224| 222| 223| 277| 286|
| 1 |  3 |  5 | 171| 179| 190| 186| 197| 210| 230| 235| 232| 233| 289| 292|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 172| 180| 191| 188| 195| 210| 258| 266| 263| 264| 330| 333|
| 2 |  2 |  2 | 171| 179| 191| 186| 195| 211| 239| 244| 240| 242| 300| 311|
| 2 |  5 |  3 | 171| 179| 190| 186| 197| 212| 226| 234| 232| 233| 285| 287|
| 2 |  3 |  4 | 171| 179| 191| 186| 197| 210| 221| 227| 225| 226| 277| 285|
| 2 |  4 |  5 | 171| 179| 190| 186| 195| 210| 229| 234| 232| 233| 290| 293|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
***********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION     |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 | 114|10.5|27.6| 342| 120| 280|1.56|____|____|____|____|____|
| 1 |  2 |  2 | 105|12.6|21.8| 181| 147| 314|0.98|____|____|____|____|____|
| 1 |  4 |  3 |87.8|12.0|18.0| 168| 120| 295|1.35|____|____|____|____|____|
| 1 |  5 |  4 |90.2|10.3|16.2| 117| 129| 308|1.44|____|____|____|____|____|
| 1 |  3 |  5 |91.8|12.2|18.8| 176| 154| 346|1.43|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 128|11.1|29.0| 295| 106| 294|1.54|____|____|____|____|____|
| 2 |  2 |  2 | 112|11.1|22.0| 194| 170| 306|0.99|____|____|____|____|____|
| 2 |  5 |  3 |87.9|11.9|18.6| 149| 157| 293|1.15|____|____|____|____|____|
| 2 |  3 |  4 |79.1| 9.4|16.6| 113| 129| 322|1.47|____|____|____|____|____|
| 2 |  4 |  5 |92.4| 9.9|19.2| 209| 155| 370|1.40|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
***********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table G.10 Maize data from Kuiaha Experiment Site, 20 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1989
         ID:             IDSM89K4

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     1

      LOCATION
         NAME:           KUIAHA

PLOTS
*****
      PLANTING DATE                   June 15, 1989

      PLANT DENSITY (PLANT/M2)        6.67

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              2
         AREA (M 2):                  1.5
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table G.10 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*******************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    | 39 |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 171| 179| 189| 186| 196| 210| 230| 234| 232| 234| 290| 293|
| 1 |  4 |  2 | 171| 179| 192| 187| 198| 213| 227| 234| 231| 233| 290| 293|
| 1 |  2 |  3 | 171| 180| 191| 188| 196| 211| 237| 244| 239| 241| 310| 313|
| 1 |  1 |  4 | 172| 179| 191| 188| 195| 210| 257| 267| 263| 277| 335| 343|
| 1 |  5 |  5 | 171| 179| 190| 186| 195| 210| 221| 225| 223| 225| 276| 285|
---------------------------------------------------------------------------
| 2 |  5 |  1 | 171| 179| 190| 186| 197| 210| 222| 227| 224| 226| 276| 280|
| 2 |  3 |  2 | 171| 179| 190| 186| 195| 210| 231| 236| 233| 234| 290| 294|
| 2 |  4 |  3 | 171| 179| 191| 186| 195| 210| 227| 234| 231| 233| 286| 287|
| 2 |  1 |  4 | 172| 179| 191| 188| 194| 210| 258| 267| 264| 279| 335| 342|
| 2 |  2 |  5 | 171| 180| 191| 186| 196| 211| 242| 251| 244| 248| 304| 307|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
************************************
   LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|____|____|____|____|____|
CONVERSION     |____|____|____|____|____|____|____|____|____|____|____|____|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 |92.3|12.4|19.2| 176| 134| 344|1.51|____|____|____|____|____|
| 1 |  4 |  2 |90.6|12.6|18.6| 183| 144| 303|1.28|____|____|____|____|____|
| 1 |  2 |  3 | 105|12.0|22.0| 212| 156| 308|1.25|____|____|____|____|____|
| 1 |  1 |  4 | 119| 9.1|26.2| 853|60.0| 374|2.02|____|____|____|____|____|
| 1 |  5 |  5 |81.6|10.4|16.6| 110| 112| 300|1.54|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  5 |  1 |84.6|10.0|16.6| 125| 127| 294|1.53|____|____|____|____|____|
| 2 |  3 |  2 |95.2|12.4|19.2| 166| 168| 363|1.40|____|____|____|____|____|
| 2 |  4 |  3 |94.6|11.9|19.4| 180| 166| 311|1.28|____|____|____|____|____|
| 2 |  1 |  4 | 113| 9.8|29.6| 584|50.9| 357|1.88|____|____|____|____|____|
| 2 |  2 |  5 | 113|13.2|22.0| 182| 117| 276|1.25|____|____|____|____|____|
---------------------------------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
************************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

APPENDIX H

Maize data, summer 1990

Table H.1 Maize data from Haleakala Experiment Station, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:      Richard Ogoshi
         INSTITUTION:     IBSNAT

      EXPERIMENT
         TITLE:           IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:              IDSM90H0

      TREATMENTS
         GENOTYPES:       5
         MANAGEMENT:      0

      LOCATION
         NAME:            Haleakala Experiment Station

PLOTS
*****
      PLANTING DATE                    May 17, 1990

      PLANTING DENSITY (PLANTS/M2)     6.67

      ORGANISATION
         NO.OF ROWS (#):               2
         ROW LENGTH (M):               3
         ROW SPACING (CM):             75
         ORIENTATION OF ROWS:          E-W
         ALONG OR ACROSS DRAINS:       n.a.
         SPACE BETWEEN PLOTS (CM):     0
         GROSS AREA (M 2):             4.5

      HARVEST
         NO.OF ROWS:                   1
         ROW LENGTH (M):               2
         AREA (M 2):                   1.5
         METHOD:                       hand

      RANDOMIZATION/REPLICATION
         DESIGN:                       RCB
         NO.OF REPS.-SOWN:             2
                   -HARVESTED:         2

PROBLEMS
********
```

Table H.1 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  5 |  1 | 143| 151| 169| 163| 177| 193| 200| 210| 204| 205| 254| 260|
| 1 |  1 |  2 | 143| 153| 164| 164| 176| 192| 218| 223| 219| 220| 292| 302|
| 1 |  2 |  3 | 143| 154| 169| 168| 178| 193| 214| 220| 215| 215| 278| 288|
| 1 |  4 |  4 | 143| 153| 169| 164| 172| 190| 204| 209| 208| 207| 262| 271|
| 1 |  3 |  5 | 143| 151| 164| 164| 177| 192| 211| 215| 212| 212| 263| 271|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 144| 153| 163| 164| 174| 191| 218| 223| 219| 220| 292| 302|
| 2 |  3 |  2 | 143| 153| 164| 163| 174| 189| 212| 219| 214| 213| 267| 275|
| 2 |  5 |  3 | 143| 151| 167| 165| 176| 192| 200| 208| 204| 204| 255| 261|
| 2 |  4 |  4 | 143| 153| 166| 166| 178| 191| 204| 213| 208| 207| 263| 270|
| 2 |  2 |  5 | 143| 154| 169| 165| 177| 193| 215| 221| 218| 218| 276| 281|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
-------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION    | cm | mm |____| g  | g  | mg |____|
 REP  ENT  PLT
-------------------------------------------------
| 1 |  5 |  1 |71.0| 106|13.8| 175| 127| 299|____|
| 1 |  1 |  2 |94.4| 106|21.2| 321| 187| 324|____|
| 1 |  2 |  3 |96.8| 121|19.4| 258| 210| 368|____|
| 1 |  4 |  4 |77.1| 114|16.6| 235| 185| 326|____|
| 1 |  3 |  5 |86.1| 122|18.4| 235| 171| 334|____|
-------------------------------------------------
| 2 |  1 |  1 |104.| 122|12.2| 197| 197| 331|____|
| 2 |  3 |  2 |87.2| 130|18.8| 180| 180| 315|____|
| 2 |  5 |  3 |72.4| 105|14.0| 135| 135| 275|____|
| 2 |  4 |  4 |85.2| 120|16.0| 201| 201| 347|____|
| 2 |  2 |  5 |96.5| 130|19.8|____|____|____|____|
-------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table H.2 Maize data from Haleakala Experiment Station, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:             IDSM90H1

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           Haleakala Experiment Station

PLOTS
*****
      PLANTING DATE                 May 17, 1990

      PLANT DENSITY (PLANTS/M2)     6.67

      ORGANISATION
         NO.OF ROWS (#):            2
         ROW LENGTH (M):            3
         ROW SPACING (CM):          75
         ORIENTATION OF ROWS:       E-W
         ALONG OR ACROSS DRAINS:    n.a.
         SPACE BETWEEN PLOTS (CM):  0
         GROSS AREA (M 2):          4.5

      HARVEST
         NO.OF ROWS:                1
         ROW LENGTH (M):            2
         AREA (M 2):                1.5
         METHOD:                    hand

      RANDOMIZATION/REPLICATION
         DESIGN:                    RCB
         NO.OF REPS.-SOWN:          2
                   -HARVESTED:      2

PROBLEMS
********
```

Table H.2 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*****************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  4 |  1 | 143| 153| 165| 162| 170| 188| 200| 208| 204| 204| 256| 267|
| 1 |  1 |  2 | 144| 153| 163| 163| 171| 188| 217| 222| 219| 220| 281| 299|
| 1 |  3 |  3 | 143| 153| 163| 162| 173| 189| 209| 220| 210| 210| 268| 276|
| 1 |  5 |  4 | 143| 152| 169| 161| 173| 191| 196| 204| 200| 199| 257| 262|
| 1 |  2 |  5 | 143| 154| 170| 164| 176| 193| 214| 222| 215| 215| 278| 289|
---------------------------------------------------------------------------
| 2 |  1 |  1 | 144| 153| 162| 162| 172| 188| 215| 222| 219| 220| 278| 293|
| 2 |  3 |  2 | 143| 153| 164| 162| 173| 188| 209| 215| 210| 209| 262| 268|
| 2 |  5 |  3 | 143| 153| 164| 160| 174| 190| 197| 204| 200| 200| 254| 260|
| 2 |  4 |  4 | 143| 153| 165| 162| 174| 191| 200| 208| 204| 204| 257| 264|
| 2 |  2 |  5 | 143| 153| 166| 166| 174| 191| 215| 221| 215| 216| 277| 283|
---------------------------------------------------------------------------
```

```
PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
--------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION    | cm | mm |____| g  | g  | mg |____|
 REP  ENT  PLT
--------------------------------------------------
| 1 |  4 |  1 |82.4| 127|15.8| 223| 171| 299|____|
| 1 |  1 |  2 |106.| 117|20.8| 417| 190| 347|____|
| 1 |  3 |  3 |89.4| 122|18.8| 248| 176| 324|____|
| 1 |  5 |  4 |73.9| 109|13.6| 164| 111| 268|____|
| 1 |  2 |  5 |95.6| 131|19.6| 285| 191| 320|____|
--------------------------------------------------
| 2 |  1 |  1 |102.| 111|22.8| 258|____|____|____|
| 2 |  3 |  2 |83.8| 130|18.2| 213| 182| 338|____|
| 2 |  5 |  3 |75.7| 116|14.4| 179| 136| 293|____|
| 2 |  4 |  4 |89.5| 118|15.0| 247| 209| 341|____|
| 2 |  2 |  5 |94.7| 117|19.8| 303| 207| 357|____|
--------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table H.3 Maize data from Haleakala Experiment Station, 14 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:            IDSM90H2

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    0

      LOCATION
         NAME:          Haleakala Experiment Station

PLOTS
*****
      PLANTING DATE                     May 17, 1990

      PLANT DENSITY (PLANTS/M2)         6.67

      ORGANISATION
         NO.OF ROWS (#):                2
         ROW LENGTH (M):                3
         ROW SPACING (CM):              75
         ORIENTATION OF ROWS:           E-W
         ALONG OR ACROSS DRAINS:        n.a.
         SPACE BETWEEN PLOTS (CM):      0
         GROSS AREA (M 2):              4.5

      HARVEST
         NO.OF ROWS:                    1
         ROW LENGTH (M):                2
         AREA (M 2):                    1.5
         METHOD:                        hand

      RANDOMIZATION/REPLICATION
         DESIGN:                        RCB
         NO.OF REPS.-SOWN:              2
                    -HARVESTED:         2

PROBLEMS
********
```

Table H.3 (continued)

PLOTDATA - PHENOLOGICAL CHARACTERISTICS
****

NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.

GROWTH STAGE			10		(13)	(30)								
ASPECT			EMRG	LF5A	LF5E	APX1	L10A	L10E	TA	LSLE	ANTH	SILK	MLDS	BLYR
REP	ENT	PLT												
1	1	1	144	154	162	162	170	187	215	220	216	218	278	296
1	4	2	143	153	166	164	174	188	203	210	204	205	264	271
1	5	3	143	153	169	162	174	191	198	206	204	204	260	267
1	2	4	143	155	171	169	176	194	215	228	216	218	288	297
1	3	5	143	153	166	166	173	192	211	220	213	212	269	278
2	4	1	143	153	165	162	173	187	200	208	204	204	260	268
2	5	2	143	153	164	161	174	187	197	204	199	199	255	261
2	2	3	143	155	169	166	173	192	211	220	213	214	277	281
2	1	4	144	153	162	163	170	187	218	227	222	221	278	291
2	3	5	143	153	163	162	172	188	208	214	209	209	263	278

PLOTDATA - GROWTH CHARACTERISTICS
****

LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.

ASPECT			MXLL	MXBL	LFNO	SHWM	GRWT	_KW_	_KN_
CONVERSION			cm	mm	____	g	g	mg	____
REP	ENT	PLT							
1	1	1	110.	118	21.2	289	184	318	____
1	4	2	80.9	124	16.2	233	189	316	____
1	5	3	73.5	111	14.0	178	125	285	____
1	2	4	96.4	133	19.8	311	211	352	____
1	3	5	86.4	143	18.4	223	173	333	____
2	4	1	86.4	119	16.8	208	178	300	____
2	5	2	73.0	120	14.2	209	149	304	____
2	2	3	87.2	129	19.4	274	196	365	____
2	1	4	106.	119	23.4	293	180	341	____
2	3	5	86.5	120	18.0	217	171	313	____

KEY POSITIONS AND NAMES/PEDIGREES
****

KEY	RP1	RP2	RP3	RP4	RP5	RP6	NAME/PEDIGREE
1	__	__	__	__	__	__	X304C
2	__	__	__	__	__	__	PIO-3165
3	__	__	__	__	__	__	PIO-3324
4	__	__	__	__	__	__	PIO-3475
5	__	__	__	__	__	__	PIO-3790

Table H.4 Maize data from Haleakala Experiment Station, 17 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:            IDSM90H3

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    0

      LOCATION
         NAME:          Haleakala Experiment Station

PLOTS
*****
      PLANTING DATE                  May 17, 1990

      PLANT DENSITY (PLANTS/M2)      6.67

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             2
         AREA (M 2):                 1.5
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table H.4 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*******************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  4 |  1 | 143| 153| 166| 163| 172| 190| 208| 214| 210| 211| 271| 278|
| 1 |  3 |  2 | 143| 153| 162| 162| 174| 192| 212| 220| 214| 215| 276| 281|
| 1 |  5 |  3 | 143| 153| 169| 165| 178| 193| 207| 209| 209| 209| 256| 267|
| 1 |  2 |  4 | 143| 155| 169| 169| 176| 194| 226| 230| 229| 229| 288| 304|
| 1 |  1 |  5 | 143| 154| 166| 166| 171| 190| 243| 249| 244| 244| 317| 321|
---------------------------------------------------------------------------
| 2 |  2 |  1 | 143| 155| 169| 170| 174| 192| 222| 228| 223| 223| 281| 292|
| 2 |  1 |  2 | 144| 154| 164| 164| 171| 188| 240| 249| 243| 243| 317| 321|
| 2 |  5 |  3 | 143| 153| 166| 162| 173| 192| 204| 212| 206| 206| 257| 263|
| 2 |  4 |  4 | 143| 153| 169| 163| 174| 190| 210| 219| 212| 211| 270| 278|
| 2 |  3 |  5 | 143| 153| 166| 164| 173| 191| 214| 222| 215.| 216| 271| 278|
---------------------------------------------------------------------------
```

```
PLOTDATA - GROWTH CHARACTERISTICS
**********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
-------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION     | cm | mm |____| g  | g  | mg |____|
 REP  ENT  PLT
-------------------------------------------------
| 1 |  4 |  1 |94.5| 126|18.2| 221| 166| 276|____|
| 1 |  3 |  2 |90.0| 116|19.0| 253| 160| 324|____|
| 1 |  5 |  3 |81.1| 113|15.2| 155| 122| 276|____|
| 1 |  2 |  4 |104.| 132|22.0| 315|____|____|____|
| 1 |  1 |  5 |117.| 106|27.4| 367|  91| 331|____|
-------------------------------------------------
| 2 |  2 |  1 |96.6| 144|22.0| 252| 164| 311|____|
| 2 |  1 |  2 |107.| 114|27.4| 407| 102| 353|____|
| 2 |  5 |  3 |81.3| 122|15.6| 185| 129| 253|____|
| 2 |  4 |  4 |89.5| 119|18.6| 230| 152| 262|____|
| 2 |  3 |  5 |96.1| 127|19.0| 233| 160| 297|____|
-------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
**********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
-------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table H.5 Maize data from Haleakala Experiment Station, 20 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:             IDSM90H4

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           Haleakala Experiment Station

PLOTS
*****
      PLANTING DATE                    May 17, 1990

      PLANT DENSITY (PLANTS/M2)        6.67

      ORGANISATION
         NO.OF ROWS (#):               2
         ROW LENGTH (M):               3
         ROW SPACING (CM):             75
         ORIENTATION OF ROWS:          E-W
         ALONG OR ACROSS DRAINS:       n.a.
         SPACE BETWEEN PLOTS (CM):     0
         GROSS AREA (M 2):             4.5

      HARVEST
         NO.OF ROWS:                   1
         ROW LENGTH (M):               2
         AREA (M 2):                   1.5
         METHOD:                       hand

      RANDOMIZATION/REPLICATION
         DESIGN:                       RCB
         NO.OF REPS.-SOWN:             2
                    -HARVESTED:        2

PROBLEMS
********
```

Table H.5 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*******************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  1 |  1 | 143| 155| 166| 167| 172| 190| 248| 255| 254| 257| 327| 335|
| 1 |  5 |  2 | 143| 153| 169| 164| 173| 191| 208| 215| 209| 211| 257| 263|
| 1 |  3 |  3 | 143| 153| 169| 164| 178| 194| 219| 226| 222| 221| 281| 290|
| 1 |  2 |  4 | 143| 156| 171| 170| 178| 196| 229| 236| 229| 230| 292| 306|
| 1 |  4 |  5 | 143| 153| 169| 164| 177| 194| 216| 222| 218| 220| 275| 281|
---------------------------------------------------------------------------
| 2 |  3 |  1 | 143| 153| 162| 162| 173| 190| 214| 220| 215| 216| 277| 282|
| 2 |  5 |  2 | 143| 153| 166| 164| 174| 191| 208| 215| 209| 209| 257| 263|
| 2 |  1 |  3 | 144| 154| 167| 167| 176| 194| 249| 255| 251| 260| 317| 327|
| 2 |  2 |  4 | 143| 156| 169| 170| 177| 196| 229| 236| 229| 230| 292| 299|
| 2 |  4 |  5 | 143| 153| 167| 164| 176| 193| 214| 222| 215| 217| 276| 286|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
   LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
--------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION     | cm | mm |____| g  | g  | mg |____|
 REP  ENT  PLT
--------------------------------------------------
| 1 |  1 |  1 |121.|  96|27.6| 363|49.6| 308|____|
| 1 |  5 |  2 |86.6| 111|16.6| 229| 123| 278|____|
| 1 |  3 |  3 |88.2| 120|19.4| 250| 180| 300|____|
| 1 |  2 |  4 |98.7| 125|22.0| 359| 208| 330|____|
| 1 |  4 |  5 |95.5| 128|18.6| 231| 186| 283|____|
--------------------------------------------------
| 2 |  3 |  1 |97.8| 140|19.6| 259|____|____|____|
| 2 |  5 |  2 |80.6| 112|16.2| 178| 128| 264|____|
| 2 |  1 |  3 |110.| 114|27.0| 519|80.9| 302|____|
| 2 |  2 |  4 |106.| 135|21.8| 291| 164| 280|____|
| 2 |  4 |  5 |96.1| 112|19.0| 216| 162| 246|____|
--------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
--------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table H.6 Maize data from Kuiaha Experiment Site, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:            IDSM90K0

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    0

      LOCATION
         NAME:          Kuiaha Experimental Site

PLOTS
*****
      PLANTING DATE                  May 17, 1990

      PLANT DENSITY (PLANTS/M2)      6.67

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             2
         AREA (M 2):                 1.5
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table H.6 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
****************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  5 |  1 | 142| 150| 165| 160| 170| 185| 190| 199| 192| 194| 243| 251|
| 1 |  4 |  2 | 142| 153| 164| 164| 174| 188| 206| 223| 208| 208| 263| 273|
| 1 |  2 |  3 | 142| 152| 162| 162| 170| 184| 193| 200| 196| 197| 250| 254|
| 1 |  1 |  4 | 142| 152| 161| 163| 173| 184| 205| 214| 208| 207| 267| 274|
| 1 |  3 |  5 | 142| 150| 159| 157| 168| 181| 197| 204| 198| 197| 255| 263|
---------------------------------------------------------------------------
| 2 |  2 |  1 | 142| 153| 163| 164| 173| 187| 205| 223| 207| 207| 263| 271|
| 2 |  5 |  2 | 142| 150| 162| 159| 170| 184| 190| 199| 192| 193| 243| 251|
| 2 |  3 |  3 | 142| 151| 164| 164| 169| 188| 202| 207| 204| 205| 255| 263|
| 2 |  4 |  4 | 142| 153| 162| 160| 173| 184| 194| 200| 197| 197| 247| 251|
| 2 |  1 |  5 | 142| 150| 159| 163| 170| 184| 204| 214| 205| 207| 256| 263|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
----------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION     | cm | mm |____|  g |  g | mg |____|
 REP  ENT  PLT
----------------------------------------------
| 1 |  5 |  1 |70.7|  92|14.2| 161| 114| 295|____|
| 1 |  4 |  2 |88.6| 107|18.6| 243| 181| 343|____|
| 1 |  2 |  3 |74.6| 113|15.2| 190| 145| 313|____|
| 1 |  1 |  4 |93.8| 100|19.8| 262| 155| 307|____|
| 1 |  3 |  5 |83.5| 124|18.2| 252| 186| 343|____|
----------------------------------------------
| 2 |  2 |  1 |87.5| 121|18.8| 259| 193| 315|____|
| 2 |  5 |  2 |75.3| 111|14.0| 159| 130| 314|____|
| 2 |  3 |  3 |74.7| 110|17.2| 211| 163| 353|____|
| 2 |  4 |  4 |74.6| 106|15.4| 179| 133| 288|____|
| 2 |  1 |  5 |102.| 106|20.0| 336| 171| 292|____|
----------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table H.7 Maize data from Kuiaha Experiment Site, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                 PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:             IDSM90K1

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           Kuiaha Experimental Site

PLOTS
*****
      PLANTING DATE                  May 17, 1990

      PLANT DENSITY (PLANTS/M2)      6.67

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 1
         ROW LENGTH (M):             2
         AREA (M 2):                 1.5
         METHOD:                     hand

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       2

PROBLEMS
********
```

Table H.7 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  4 |  1 | 142| 151| 162| 160| 169| 183| 192| 197| 195| 195| 240| 250|
| 1 |  1 |  2 | 142| 150| 159| 160| 166| 181| 204| 208| 206| 205| 262| 271|
| 1 |  5 |  3 | 142| 150| 162| 157| 166| 181| 189| 194| 191| 190| 239| 244|
| 1 |  3 |  4 | 142| 149| 160| 160| 169| 182| 198| 204| 199| 199| 248| 255|
| 1 |  2 |  5 | 142| 151| 161| 162| 169| 183| 200| 206| 204| 204| 254| 263|
---------------------------------------------------------------------------
| 2 |  4 |  1 | 143| 151| 163| 160| 174| 183| 196| 198| 198| 197| 248| 254|
| 2 |  5 |  2 | 142| 151| 162| 159| 170| 183| 191| 197| 193| 193| 240| 243|
| 2 |  2 |  3 | 142| 153| 162| 162| 170| 183| 204| 208| 206| 205| 261| 271|
| 2 |  3 |  4 | 142| 150| 160| 160| 170| 184| 198| 205| 200| 199| 247| 250|
| 2 |  1 |  5 | 143| 150| 160| 164| 169| 183| 205| 213| 208| 209| 263| 272|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
--------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION     | cm | mm |____| g  | g  | mg |____|
 REP  ENT  PLT
--------------------------------------------------
| 1 |  4 |  1 |80.6| 118|16.2| 206| 161| 302|____|
| 1 |  1 |  2 |89.5| 106|19.4| 266| 170| 303|____|
| 1 |  5 |  3 |78.8| 101|15.6| 197| 117| 311|____|
| 1 |  3 |  4 |85.0| 125|17.6| 226| 186| 350|____|
| 1 |  2 |  5 |98.5| 130|18.6| 303| 195| 351|____|
--------------------------------------------------
| 2 |  4 |  1 |78.4| 111|15.6| 171| 138| 265|____|
| 2 |  5 |  2 |76.0| 111|14.8| 196| 135| 302|____|
| 2 |  2 |  3 |85.6| 127|19.6| 273| 213| 343|____|
| 2 |  3 |  4 |78.5| 116|17.0| 238| 171| 329|____|
| 2 |  1 |  5 |90.3| 124|20.2| 303| 186| 299|____|
--------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
--------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table H.8 Maize data from Kuiaha Experiment Site, 14 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:             IDSM90K2

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           Kuiaha Experimental Site

PLOTS
*****
      PLANTING DATE                   May 17, 1990

      PLANT DENSITY (PLANTS/M2)       6.67

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              2
         AREA (M 2):                  1.5
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table H.8 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
*******************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
-------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
-------------------------------------------------------------------------
| 1 |  1 |  1 | 142| 150| 160| 162| 168| 182| 204| 214| 207| 208| 257| 271|
| 1 |  3 |  2 | 142| 149| 160| 159| 166| 182| 197| 204| 198| 198| 249| 263|
| 1 |  4 |  3 | 142| 151| 162| 159| 166| 184| 191| 198| 194| 195| 247| 250|
| 1 |  2 |  4 | 142| 153| 163| 163| 170| 184| 202| 208| 204| 204| 261| 271|
| 1 |  5 |  5 | 142| 151| 162| 158| 166| 181| 189| 196| 191| 190| 239| 243|
-------------------------------------------------------------------------
| 2 |  2 |  1 | 143| 151| 162| 159| 171| 185| 204| 208| 206| 205| 262| 274|
| 2 |  5 |  2 | 142| 150| 162| 158| 166| 182| 189| 196| 193| 192| 240| 247|
| 2 |  3 |  3 | 142| 149| 160| 160| 166| 183| 197| 204| 198| 198| 250| 256|
| 2 |  1 |  4 | 143| 151| 159| 160| 166| 182| 204| 208| 207| 206| 263| 277|
| 2 |  4 |  5 | 143| 149| 162| 159| 166| 181| 193| 197| 194| 195| 243| 251|
-------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
************************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION     | cm | mm |____| g  | g  | mg |____|
 REP  ENT  PLT
------------------------------------------------
| 1 |  1 |  1 |96.9| 106|19.2| 279| 181| 317|____|
| 1 |  3 |  2 |90.1| 121|17.2| 209| 170| 326|____|
| 1 |  4 |  3 |89.2| 118|16.8| 248| 170| 289|____|
| 1 |  2 |  4 |93.1| 130|19.2| 294| 215| 337|____|
| 1 |  5 |  5 |77.7| 112|15.0| 168| 124| 306|____|
------------------------------------------------
| 2 |  2 |  1 |90.9| 112|18.8| 250| 200| 322|____|
| 2 |  5 |  2 |75.0| 104|14.4| 172| 126| 309|____|
| 2 |  3 |  3 |86.8| 126|17.2| 249| 189| 337|____|
| 2 |  1 |  4 |96.4| 110|19.6| 338| 191| 310|____|
| 2 |  4 |  5 |72.7| 117|17.2| 174| 153| 270|____|
------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
************************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table H.9 Maize data from Kuiaha Experiment Site, 17 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:             IDSM90K3

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           Kuiaha Experimental Site

PLOTS
*****
      PLANTING DATE                   May 17, 1990

      PLANT DENSITY (PLANTS/M2)       6.67

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              2
         AREA (M 2):                  1.5
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table H.9 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
****************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 | 142| 153| 162| 162| 172| 187| 214| 219| 215| 216| 274| 281|
| 1 |  1 |  2 | 143| 153| 160| 161| 166| 183| 228| 240| 237| 242| 292| 306|
| 1 |  5 |  3 | 142| 151| 162| 159| 166| 182| 192| 200| 195| 195| 243| 248|
| 1 |  4 |  4 | 142| 151| 162| 159| 166| 181| 197| 206| 204| 202| 250| 255|
| 1 |  3 |  5 | 142| 151| 160| 160| 170| 184| 203| 214| 205| 204| 260| 265|
---------------------------------------------------------------------------
| 2 |  2 |  1 | 143| 153| 162| 164| 169| 185| 214| 220| 215| 215| 263| 276|
| 2 |  5 |  2 | 143| 151| 162| 162| 166| 182| 195| 199| 198| 197| 242| 251|
| 2 |  3 |  3 | 142| 149| 160| 162| 170| 183| 204| 223| 206| 205| 254| 262|
| 2 |  4 |  4 | 143| 150| 162| 161| 168| 184| 199| 206| 204| 204| 251| 256|
| 2 |  1 |  5 | 142| 151| 159| 162| 169| 181| 228| 236| 233| 233| 278| 283|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
   LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
---------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION     | cm | mm |____| g  | g  | mg |____|
 REP  ENT  PLT
---------------------------------------------------
| 1 |  2 |  1 |94.4| 121|21.8| 401| 176| 333|____|
| 1 |  1 |  2 |114.| 108|28.0| 495|25.2| 330|____|
| 1 |  5 |  3 |86.9| 110|15.8| 184| 124| 284|____|
| 1 |  4 |  4 |95.7| 124|17.6| 272| 176| 327|____|
| 1 |  3 |  5 |87.9| 120|18.0| 325| 176| 334|____|
---------------------------------------------------
| 2 |  2 |  1 |106.| 140|21.8| 282| 171| 292|____|
| 2 |  5 |  2 |83.3| 110|15.8| 150| 125| 278|____|
| 2 |  3 |  3 |88.2| 126|18.2| 249| 151| 320|____|
| 2 |  4 |  4 |88.7| 123|18.2| 227| 167| 267|____|
| 2 |  1 |  5 |129.| 109|28.4| 551|60.8| 315|____|
---------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table H.10 Maize data from Kuiaha Experiment Site, 20 h photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;SUMMER;MAIZE 1990
         ID:            IDSM90K4

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    0

      LOCATION
         NAME:          Kuiaha Experimental Site

PLOTS
*****

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  1
         ROW LENGTH (M):              2
         AREA (M 2):                  4.5
         METHOD:                      hand

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       2

PROBLEMS
********
```

Table H.10 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
----------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
----------------------------------------------------------------------------
| 1 |  4 |  1 | 143| 151| 162| 162| 166| 182| 204| 214| 207| 206| 260| 267|
| 1 |  1 |  2 | 143| 152| 159| 163| 169| 183| 230| 241| 237| 257| 288| 299|
| 1 |  2 |  3 | 142| 153| 162| 164| 169| 183| 215| 221| 215| 217| 278| 285|
| 1 |  5 |  4 | 142| 150| 162| 160| 168| 182| 196| 204| 197| 198| 243| 250|
| 1 |  3 |  5 | 142| 149| 160| 162| 166| 182| 204| 214| 206| 206| 257| 270|
----------------------------------------------------------------------------
| 2 |  1 |  1 | 143| 151| 160| 163| 169| 183| 228| 241| 237| 240| 288| 306|
| 2 |  5 |  2 | 143| 151| 161| 160| 166| 184| 196| 204| 197| 198| 243| 249|
| 2 |  3 |  3 | 142| 150| 160| 160| 160| 187| 204| 215| 206| 205| 260| 267|
| 2 |  2 |  4 | 142| 151| 162| 163| 170| 183| 214| 220| 215| 215| 263| 277|
| 2 |  4 |  5 | 143| 151| 162| 162| 169| 183| 200| 208| 205| 205| 255| 262|
----------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
   LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
-----------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION    | cm | mm |____| g  | g  | mg |____|
 REP  ENT  PLT
-----------------------------------------------------
| 1 |  4 |  1 |96.8| 115|18.2| 224| 145| 256|____|
| 1 |  1 |  2 |131.| 100|28.2| 382| 8.7| 313|____|
| 1 |  2 |  3 |105.| 130|22.4| 287| 138| 313|____|
| 1 |  5 |  4 |80.8| 116|16.0| 149| 109| 277|____|
| 1 |  3 |  5 |95.9| 130|19.2| 261| 177| 329|____|
-----------------------------------------------------
| 2 |  1 |  1 |131.| 115|28.0| 379|67.8| 363|____|
| 2 |  5 |  2 |82.1| 101|16.6| 193| 125| 268|____|
| 2 |  3 |  3 |90.5| 124|17.8| 242| 163| 303|____|
| 2 |  2 |  4 |105.| 140|22.0| 317| 190| 326|____|
| 2 |  4 |  5 |81.7| 109|18.4| 224| 171| 270|____|
-----------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
-----------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

APPENDIX I

Maize data, winter 1990

Table I.1 Maize data from Haleakala Experiment Station, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;WINTER;MAIZE 1990
         ID:             IDWM90H0

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           Haleakala Experiment Station

PLOTS
*****
      PLANTING DATE                    Jan. 12, 1991

      PLANTING DENSITY                 6.67

      ORGANISATION
         NO.OF ROWS (#):               2
         ROW LENGTH (M):               3
         ROW SPACING (CM):             75
         ORIENTATION OF ROWS:          E-W
         ALONG OR ACROSS DRAINS:       n.a.
         SPACE BETWEEN PLOTS (CM):     0
         GROSS AREA (M 2):             4.5

      HARVEST
         NO.OF ROWS:                   ________________
         ROW LENGTH (M):               ________________
         AREA (M 2):                   ________________
         METHOD:                       ________________

      RANDOMIZATION/REPLICATION
         DESIGN:                       RCB
         NO.OF REPS.-SOWN:             2
                    -HARVESTED:        _

PROBLEMS
********
```

Table I.1 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
----------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
----------------------------------------------------------------------------
| 1 |  3 |  1 | 19 | 32 | 50 | 46 |____|____|____|____|____|____|____|____|
| 1 |  4 |  2 | 19 | 35 | 50 | 47 |____|____|____|____|____|____|____|____|
| 1 |  5 |  3 | 19 | 33 | 51 | 49 |____|____|____|____|____|____|____|____|
| 1 |  2 |  4 | 19 | 36 | 50 | 50 |____|____|____|____|____|____|____|____|
| 1 |  1 |  5 | 20 | 36 | 51 | 50 |____|____|____|____|____|____|____|____|
----------------------------------------------------------------------------
| 2 |  4 |  1 | 19 | 33 | 50 | 46 |____|____|____|____|____|____|____|____|
| 2 |  2 |  2 | 19 | 34 | 51 | 52 |____|____|____|____|____|____|____|____|
| 2 |  5 |  3 | 19 | 33 | 52 | 46 |____|____|____|____|____|____|____|____|
| 2 |  3 |  4 | 19 | 32 | 50 | 48 |____|____|____|____|____|____|____|____|
| 2 |  1 |  5 | 20 | 35 | 51 | 50 |____|____|____|____|____|____|____|____|
----------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
--------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION    |____|____|____|____|____|____|____|
 REP  ENT  PLT
--------------------------------------------------
| 1 |  3 |  1 |____|____|____|____|____|____|____|
| 1 |  4 |  2 |____|____|____|____|____|____|____|
| 1 |  5 |  3 |____|____|____|____|____|____|____|
| 1 |  2 |  4 |____|____|____|____|____|____|____|
| 1 |  1 |  5 |____|____|____|____|____|____|____|
--------------------------------------------------
| 2 |  4 |  1 |____|____|____|____|____|____|____|
| 2 |  2 |  2 |____|____|____|____|____|____|____|
| 2 |  5 |  3 |____|____|____|____|____|____|____|
| 2 |  3 |  4 |____|____|____|____|____|____|____|
| 2 |  1 |  5 |____|____|____|____|____|____|____|
--------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
----------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table I.2 Maize data from Haleakala Experiment Station, natural photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                 PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:    Richard Ogoshi
         INSTITUTION:   IBSNAT

      EXPERIMENT
         TITLE:         IBSNAT DAYLENGTH;WINTER;MAIZE 1990
         ID:            IDWM90H1

      TREATMENTS
         GENOTYPES:     5
         MANAGEMENT:    0

      LOCATION
         NAME:          Haleakala Experiment Station

PLOTS
*****
      PLANTING DATE                  Jan. 12, 1991

      PLANT DENSITY (PLANTS/M2)      6.67

      ORGANISATION
         NO.OF ROWS (#):             2
         ROW LENGTH (M):             3
         ROW SPACING (CM):           75
         ORIENTATION OF ROWS:        E-W
         ALONG OR ACROSS DRAINS:     n.a.
         SPACE BETWEEN PLOTS (CM):   0
         GROSS AREA (M 2):           4.5

      HARVEST
         NO.OF ROWS:                 ________________
         ROW LENGTH (M):             ________________
         AREA (M 2):                 ________________
         METHOD:                     ________________

      RANDOMIZATION/REPLICATION
         DESIGN:                     RCB
         NO.OF REPS.-SOWN:           2
                   -HARVESTED:       _

PROBLEMS
********
```

Table I.2 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
******************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 | 19 | 35 | 51 | 50 |____|____|____|____|____|____|____|____|
| 1 |  4 |  2 | 19 | 34 | 50 | 45 |____|____|____|____|____|____|____|____|
| 1 |  1 |  3 | 19 | 35 | 50 | 50 |____|____|____|____|____|____|____|____|
| 1 |  3 |  4 | 19 | 33 | 50 | 46 |____|____|____|____|____|____|____|____|
| 1 |  5 |  5 | 19 | 33 | 51 | 44 |____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  4 |  1 | 19 | 33 | 50 | 46 |____|____|____|____|____|____|____|____|
| 2 |  2 |  2 | 19 | 35 | 50 | 51 |____|____|____|____|____|____|____|____|
| 2 |  3 |  3 | 19 | 32 | 50 | 45 |____|____|____|____|____|____|____|____|
| 2 |  1 |  4 | 19 | 36 | 50 | 50 |____|____|____|____|____|____|____|____|
| 2 |  5 |  5 | 19 | 33 | 52 | 46 |____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
   LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
-----------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION    |____|____|____|____|____|____|____|
 REP  ENT  PLT
-----------------------------------------------
| 1 |  2 |  1 |____|____|____|____|____|____|____|
| 1 |  4 |  2 |____|____|____|____|____|____|____|
| 1 |  1 |  3 |____|____|____|____|____|____|____|
| 1 |  3 |  4 |____|____|____|____|____|____|____|
| 1 |  5 |  5 |____|____|____|____|____|____|____|
-----------------------------------------------
| 2 |  4 |  1 |____|____|____|____|____|____|____|
| 2 |  2 |  2 |____|____|____|____|____|____|____|
| 2 |  3 |  3 |____|____|____|____|____|____|____|
| 2 |  1 |  4 |____|____|____|____|____|____|____|
| 2 |  5 |  5 |____|____|____|____|____|____|____|
-----------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table I.3 Maize data from Kuiaha Experiment Site, control photoperiod treatment.

```
     IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                 PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;WINTER;MAIZE 1990
         ID:             IDWM90K0

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           Kuiaha Experimental Site

PLOTS
*****
      PLANTING DATE                    Jan. 12, 1991

      PLANT DENSITY (PLANTS/M2)        6.67

      ORGANISATION
         NO.OF ROWS (#):               2
         ROW LENGTH (M):               3
         ROW SPACING (CM):             75
         ORIENTATION OF ROWS:          E-W
         ALONG OR ACROSS DRAINS:       n.a.
         SPACE BETWEEN PLOTS (CM):     0
         GROSS AREA (M 2):             4.5

      HARVEST
         NO.OF ROWS:                   ________________
         ROW LENGTH (M):               ________________
         AREA (M 2):                   ________________
         METHOD:                       ________________

      RANDOMIZATION/REPLICATION
         DESIGN:                       RCB
         NO.OF REPS.-SOWN:             2
                   -HARVESTED:         _

PROBLEMS
********
```

Table I.3 (continued)

```
PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE   | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT         |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  2 |  1 | 18 | 32 | 43 | 44 |____|____|____|____|____|____|____|____|
| 1 |  1 |  2 | 18 | 32 | 43 | 45 |____|____|____|____|____|____|____|____|
| 1 |  3 |  3 | 18 | 30 | 42 | 43 |____|____|____|____|____|____|____|____|
| 1 |  5 |  4 | 18 | 28 | 43 | 42 |____|____|____|____|____|____|____|____|
| 1 |  4 |  5 | 18 | 32 | 43 | 43 |____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  3 |  1 | 18 | 30 | 46 | 47 |____|____|____|____|____|____|____|____|
| 2 |  1 |  2 | 18 | 32 | 42 | 49 |____|____|____|____|____|____|____|____|
| 2 |  2 |  3 | 18 | 32 | 51 | 52 |____|____|____|____|____|____|____|____|
| 2 |  5 |  4 | 18 | 30 | 46 | 46 |____|____|____|____|____|____|____|____|
| 2 |  4 |  5 | 18 | 32 | 44 | 43 |____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
    LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
--------------------------------------------------
ASPECT         |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION     |____|____|____|____|____|____|____|
 REP  ENT  PLT
--------------------------------------------------
| 1 |  2 |  1 |____|____|____|____|____|____|____|
| 1 |  1 |  2 |____|____|____|____|____|____|____|
| 1 |  3 |  3 |____|____|____|____|____|____|____|
| 1 |  5 |  4 |____|____|____|____|____|____|____|
| 1 |  4 |  5 |____|____|____|____|____|____|____|
--------------------------------------------------
| 2 |  3 |  1 |____|____|____|____|____|____|____|
| 2 |  1 |  2 |____|____|____|____|____|____|____|
| 2 |  2 |  3 |____|____|____|____|____|____|____|
| 2 |  5 |  4 |____|____|____|____|____|____|____|
| 2 |  4 |  5 |____|____|____|____|____|____|____|
--------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

Table I.4 Maize data from Kuiaha Experiment Site, natural photoperiod treatment.

```
      IBSNAT REDUCED DATA SET FOR MODELLING CROP GROWTH AND DEVELOPMENT
                 PLOTDATA REQUIRED FOR FIELD EXPERIMENTS

GENERAL
*******

      PERSONNEL
         RESEARCHER:     Richard Ogoshi
         INSTITUTION:    IBSNAT

      EXPERIMENT
         TITLE:          IBSNAT DAYLENGTH;WINTER;MAIZE 1990
         ID:             IDWM90K1

      TREATMENTS
         GENOTYPES:      5
         MANAGEMENT:     0

      LOCATION
         NAME:           Kuiaha Experimental Site

PLOTS
*****

      ORGANISATION
         NO.OF ROWS (#):              2
         ROW LENGTH (M):              3
         ROW SPACING (CM):            75
         ORIENTATION OF ROWS:         E-W
         ALONG OR ACROSS DRAINS:      n.a.
         SPACE BETWEEN PLOTS (CM):    0
         GROSS AREA (M 2):            4.5

      HARVEST
         NO.OF ROWS:                  ________________
         ROW LENGTH (M):              ________________
         AREA (M 2):                  ________________
         METHOD:                      ________________

      RANDOMIZATION/REPLICATION
         DESIGN:                      RCB
         NO.OF REPS.-SOWN:            2
                    -HARVESTED:       _

PROBLEMS
********
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Table I.4 (continued)

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PLOTDATA - PHENOLOGICAL CHARACTERISTICS
***************************************
 NOTES TAKEN WHEN 50% OF PLANTS ARE AT THE APPROPRIATE STAGE. DATES AS DAYS
FROM JANUARY 1. GROWTH SCALES IN BRACKETS ARE APPROXIMATIONS.
---------------------------------------------------------------------------
GROWTH STAGE  | 10 |    |(13)|(30)|    |    |    |    |    |    |    |    |
ASPECT        |EMRG|LF5A|LF5E|APX1|L10A|L10E| TA |LSLE|ANTH|SILK|MLDS|BLYR|
 REP  ENT  PLT
---------------------------------------------------------------------------
| 1 |  3 |  1 | 18 | 31 | 44 | 42 |____|____|____|____|____|____|____|____|
| 1 |  2 |  2 | 18 | 32 | 44 | 42 |____|____|____|____|____|____|____|____|
| 1 |  4 |  3 | 18 | 31 | 43 | 43 |____|____|____|____|____|____|____|____|
| 1 |  5 |  4 | 18 | 30 | 44 | 42 |____|____|____|____|____|____|____|____|
| 1 |  1 |  5 | 18 | 31 | 43 | 42 |____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------
| 2 |  2 |  1 | 18 | 33 | 51 | 52 |____|____|____|____|____|____|____|____|
| 2 |  3 |  2 | 18 | 30 | 43 | 42 |____|____|____|____|____|____|____|____|
| 2 |  1 |  3 | 18 | 31 | 42 | 43 |____|____|____|____|____|____|____|____|
| 2 |  5 |  4 | 18 | 30 | 46 | 43 |____|____|____|____|____|____|____|____|
| 2 |  4 |  5 | 18 | 32 | 46 | 44 |____|____|____|____|____|____|____|____|
---------------------------------------------------------------------------

PLOTDATA - GROWTH CHARACTERISTICS
*********************************
   LEAF DIMENSIONS FROM REPRESENTATIVE AT ANTHESIS. OTHERS FROM 10 PLANTS
TAKEN AT RANDOM AT MATURITY. CONVERSIONS IF UNITS NOT: CM;G/PLANT;MG/K;%.
--------------------------------------------------
ASPECT        |MXLL|MXBL|LFNO|SHWM|GRWT|_KW_|_KN_|
CONVERSION    |____|____|____|____|____|____|____|
 REP  ENT  PLT
--------------------------------------------------
| 1 |  3 |  1 |____|____|____|____|____|____|____|
| 1 |  2 |  2 |____|____|____|____|____|____|____|
| 1 |  4 |  3 |____|____|____|____|____|____|____|
| 1 |  5 |  4 |____|____|____|____|____|____|____|
| 1 |  1 |  5 |____|____|____|____|____|____|____|
--------------------------------------------------
| 2 |  2 |  1 |____|____|____|____|____|____|____|
| 2 |  3 |  2 |____|____|____|____|____|____|____|
| 2 |  1 |  3 |____|____|____|____|____|____|____|
| 2 |  5 |  4 |____|____|____|____|____|____|____|
| 2 |  4 |  5 |____|____|____|____|____|____|____|
--------------------------------------------------
KEY POSITIONS AND NAMES/PEDIGREES
*********************************
 KEY  RP1  RP2  RP3  RP4  RP5  RP6   NAME/PEDIGREE
---------------------------------------------------------------------------
| 1 | __ | __ | __ | __ | __ | __ | X304C
| 2 | __ | __ | __ | __ | __ | __ | PIO-3165
| 3 | __ | __ | __ | __ | __ | __ | PIO-3324
| 4 | __ | __ | __ | __ | __ | __ | PIO-3475
| 5 | __ | __ | __ | __ | __ | __ | PIO-3790
```

APPENDIX J
Weather Data

Table J.1 Weather data from Haleakala Experiment Station, 1988 to 1991.

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	1	1.44	18.1	14.0	105.0
88	2	8.93	16.5	14.1	51.0
88	3	13.77	18.5	14.2	4.0
88	4	12.74	20.7	13.3	0.0
88	5	12.85	24.0	12.7	16.0
88	6	14.09	20.5	15.9	3.0
88	7	16.69	23.4	12.2	0.0
88	8	14.41	24.2	10.6	0.0
88	9	10.97	20.8	16.0	54.0
88	10	7.00	23.2	16.8	9.0
88	11	9.99	24.7	15.1	0.0
88	12	12.15	26.1	15.3	0.0
88	13	14.76	25.5	14.6	0.0
88	14	12.98	25.8	14.3	0.0
88	15	8.06	22.7	13.8	0.0
88	16	12.37	23.8	16.6	1.0
88	17	12.08	25.8	15.9	0.0
88	18	9.55	24.3	17.2	1.0
88	19	14.94	25.4	14.6	0.0
88	20	14.68	24.7	13.1	0.0
88	21	12.80	25.8	13.3	0.0
88	22	11.35	25.6	14.1	0.0
88	23	13.83	23.3	15.0	0.0
88	24	15.60	22.7	14.6	0.0
88	25	12.70	22.0	16.8	0.0
88	26	5.49	17.1	15.5	111.0
88	27	12.73	19.3	16.0	34.0
88	28	10.35	20.3	16.3	32.0
88	29	15.28	23.3	13.9	10.0
88	30	18.66	23.4	12.4	0.0
88	31	18.88	22.6	11.9	0.0
88	32	16.29	24.6	12.5	0.0
88	33	14.84	24.6	12.9	0.0
88	34	15.84	24.4	11.9	0.0
88	35	12.05	24.2	13.6	3.0
88	36	16.78	25.5	12.6	0.0
88	37	12.85	25.2	13.3	0.0
88	38	12.05	21.8	14.7	1.0
88	39	14.90	23.7	16.3	0.0
88	40	14.27	24.0	15.8	0.0
88	41	15.67	23.4	15.0	0.0
88	42	20.45	22.2	15.7	0.0
88	43	20.45	23.0	16.2	6.0
88	44	15.85	23.9	14.8	2.0
88	45	16.09	21.7	16.8	4.0
88	46	17.70	23.7	16.7	2.0
88	47	17.71	22.8	15.9	9.0

Table J.1 (continued)

Year	Day	Solar Radiation ($MJ\ m^{-2}$)	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	48	17.83	22.8	16.2	1.0
88	49	14.37	23.6	14.1	0.0
88	50	7.87	22.0	12.9	4.0
88	51	14.85	24.8	13.3	0.0
88	52	13.63	25.0	14.3	0.0
88	53	8.33	22.4	16.1	4.0
88	54	9.79	25.4	14.5	1.0
88	55	16.44	25.0	14.6	0.0
88	56	10.13	18.6	15.7	70.0
88	57	11.97	21.4	15.4	1.0
88	58	18.74	21.6	14.7	0.0
88	59	22.51	21.1	15.4	0.0
88	60	19.72	22.1	13.0	0.0
88	61	15.02	24.7	11.6	0.0
88	62	16.68	22.9	15.2	0.0
88	63	18.30	23.7	14.4	0.0
88	64	22.55	23.3	15.7	1.0
88	65	17.19	22.9	16.0	1.0
88	66	10.24	22.7	14.6	0.0
88	67	14.96	23.3	15.7	0.0
88	68	12.42	23.3	15.4	0.0
88	69	11.83	24.1	14.3	0.0
88	70	21.85	24.0	13.0	0.0
88	71	22.67	24.2	13.9	0.0
88	72	20.11	26.4	12.3	0.0
88	73	21.99	24.5	11.9	3.0
88	74	10.34	17.7	14.9	73.0
88	75	15.36	18.7	14.7	5.0
88	76	14.92	24.1	13.4	0.0
88	77	14.49	24.3	13.8	3.0
88	78	17.62	22.9	17.0	7.0
88	79	16.89	24.3	16.6	0.0
88	80	21.11	24.7	14.5	0.0
88	81	17.50	24.7	15.0	0.0
88	82	17.50	24.7	15.0	0.0
88	83	17.50	24.7	15.0	0.0
88	84	14.30	24.7	15.9	0.0
88	85	15.15	24.3	16.2	0.0
88	86	15.07	23.4	15.1	3.0
88	87	17.23	25.5	14.8	0.0
88	88	16.88	25.1	16.2	0.0
88	89	18.00	23.5	16.5	0.0
88	90	19.16	22.1	16.9	13.0
88	91	20.71	22.4	16.6	7.0
88	92	20.40	23.0	17.0	0.0
88	93	20.40	23.0	17.0	0.0
88	94	20.40	23.0	17.0	0.0
88	95	20.40	23.0	17.0	0.0
88	96	20.40	23.0	17.0	0.0
88	97	20.40	23.0	17.0	0.0
88	98	20.40	23.0	17.0	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	99	20.40	23.0	17.0	0.0
88	100	20.40	23.0	17.0	0.0
88	101	20.40	23.0	17.0	0.0
88	102	20.40	23.0	17.0	0.0
88	103	20.40	23.0	17.0	0.0
88	104	20.40	23.0	17.0	0.0
88	105	20.40	23.0	17.0	0.0
88	106	20.40	23.0	17.0	0.0
88	107	20.40	23.0	17.0	0.0
88	108	20.40	23.0	17.0	0.0
88	109	20.40	23.0	17.0	0.0
88	110	20.40	23.0	17.0	0.0
88	111	20.11	24.2	17.4	0.0
88	112	21.09	24.9	16.3	0.0
88	113	24.15	24.0	16.5	0.0
88	114	20.34	24.2	16.9	0.0
88	115	23.83	22.6	16.0	0.0
88	116	26.91	23.6	16.2	0.0
88	117	21.23	21.8	15.6	0.0
88	118	21.02	21.1	15.5	0.0
88	119	16.19	21.1	15.9	0.0
88	120	18.68	22.9	15.8	0.0
88	121	20.54	25.3	17.1	0.0
88	122	13.00	25.2	18.5	0.0
88	123	14.84	26.2	15.9	0.0
88	124	13.50	23.0	15.2	0.0
88	125	13.50	23.0	15.2	0.0
88	126	13.50	23.0	15.2	0.0
88	127	13.50	23.0	15.2	0.0
88	128	13.50	23.0	15.2	0.0
88	129	13.50	23.0	15.2	0.0
88	130	13.50	23.0	15.2	0.0
88	131	12.52	20.2	14.7	6.0
88	132	18.85	22.8	17.2	24.0
88	133	22.09	22.9	17.7	8.0
88	134	26.85	25.2	16.9	0.0
88	135	27.37	25.9	15.9	0.0
88	136	27.16	24.9	17.8	0.0
88	137	21.32	25.5	17.4	0.0
88	138	12.25	24.2	18.0	0.0
88	139	18.00	24.5	18.0	0.0
88	140	18.00	24.5	18.0	0.0
88	141	18.00	24.5	18.0	0.0
88	142	18.00	24.5	18.0	0.0
88	143	18.00	24.5	18.0	0.0
88	144	18.00	24.5	18.0	0.0
88	145	25.00	24.9	18.1	0.0
88	146	25.34	26.1	16.7	0.0
88	147	23.10	24.8	15.2	0.0
88	148	24.94	24.5	16.3	2.0
88	149	20.59	23.8	17.3	7.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	150	19.74	26.2	15.7	0.0
88	151	22.44	26.1	16.5	0.0
88	152	25.34	26.1	17.6	0.0
88	153	17.83	26.3	18.2	0.0
88	154	16.46	25.8	17.4	0.0
88	155	25.42	26.5	17.3	0.0
88	156	24.35	26.4	16.2	0.0
88	157	23.56	27.7	17.3	0.0
88	158	25.17	26.4	17.6	0.0
88	159	20.54	25.8	17.0	3.0
88	160	24.50	25.9	15.8	1.0
88	161	24.43	25.6	16.7	0.0
88	162	24.82	27.1	17.3	0.0
88	163	21.08	25.8	15.8	0.0
88	164	19.05	26.3	15.7	0.0
88	165	25.25	25.9	16.0	0.0
88	166	21.03	25.5	17.4	0.0
88	167	26.37	25.8	16.7	0.0
88	168	23.60	26.2	15.4	0.0
88	169	16.03	24.8	15.6	0.0
88	170	25.61	26.7	15.5	0.0
88	171	22.51	26.6	17.0	0.0
88	172	24.97	25.9	17.1	0.0
88	173	24.73	28.1	16.4	0.0
88	174	23.61	27.5	18.5	0.0
88	175	25.14	26.8	17.0	1.0
88	176	25.17	25.7	17.0	0.0
88	177	25.15	27.1	16.3	0.0
88	178	25.28	26.4	17.7	1.0
88	179	26.32	26.6	18.5	0.0
88	180	26.10	26.9	18.1	0.0
88	181	25.30	27.5	17.6	0.0
88	182	21.80	28.7	16.6	0.0
88	183	25.68	28.0	15.8	0.0
88	184	22.74	25.6	16.3	0.0
88	185	21.16	27.6	17.6	0.0
88	186	26.16	27.6	16.3	0.0
88	187	25.39	26.7	18.0	0.0
88	188	23.79	24.9	18.7	28.0
88	189	25.03	26.8	18.6	3.0
88	190	24.05	25.6	18.9	8.0
88	191	21.67	26.2	18.3	0.0
88	192	22.20	26.9	17.1	0.0
88	193	25.59	26.9	18.7	0.0
88	194	24.98	25.8	19.3	1.0
88	195	23.34	27.5	17.7	0.0
88	196	24.06	26.4	19.0	0.0
88	197	22.51	26.8	16.8	0.0
88	198	24.62	28.5	15.4	0.0
88	199	21.19	26.2	16.7	0.0
88	200	25.24	26.7	17.1	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	201	21.34	26.2	18.2	0.0
88	202	25.83	25.6	17.8	0.0
88	203	17.68	25.9	17.9	0.0
88	204	23.57	26.8	16.6	0.0
88	205	25.21	27.8	15.7	0.0
88	206	20.78	26.8	14.7	0.0
88	207	14.13	26.1	16.1	1.0
88	208	25.11	26.2	16.9	0.0
88	209	20.24	25.8	19.1	2.0
88	210	24.05	24.3	18.6	1.0
88	211	25.29	26.5	18.4	5.0
88	212	25.43	25.6	18.5	4.0
88	213	25.51	26.2	17.1	0.0
88	214	22.15	25.9	18.0	0.0
88	215	20.02	27.4	17.1	8.0
88	216	16.77	27.3	19.4	0.0
88	217	25.16	27.6	17.7	3.0
88	218	23.47	26.1	18.3	0.0
88	219	20.54	25.9	19.0	0.0
88	220	13.43	28.4	19.7	0.0
88	221	18.45	27.5	19.0	0.0
88	222	24.62	27.8	18.3	0.0
88	223	21.85	27.5	18.3	7.0
88	224	10.87	25.6	17.8	3.0
88	225	23.23	27.1	19.5	0.0
88	226	23.51	26.2	18.7	0.0
88	227	21.98	27.3	17.9	0.0
88	228	23.98	27.2	18.6	0.0
88	229	20.87	26.4	18.9	0.0
88	230	23.92	27.3	18.1	1.0
88	231	23.41	26.7	18.4	0.0
88	232	23.81	27.1	19.3	0.0
88	233	20.35	24.6	18.4	2.0
88	234	22.37	24.9	17.8	2.0
88	235	24.01	26.5	17.9	0.0
88	236	22.66	27.9	15.7	0.0
88	237	22.64	28.0	14.8	0.0
88	238	16.53	27.2	14.6	0.0
88	239	21.54	26.8	16.1	0.0
88	240	21.81	27.4	14.6	0.0
88	241	22.75	26.9	18.7	0.0
88	242	22.16	27.5	18.1	0.0
88	243	22.34	27.5	18.3	0.0
88	244	23.57	26.9	19.3	0.0
88	245	21.50	28.3	19.5	0.0
88	246	21.74	27.9	17.0	0.0
88	247	14.75	27.8	16.7	0.0
88	248	17.83	29.7	16.2	0.0
88	249	18.87	27.3	17.1	0.0
88	250	15.21	29.1	18.3	0.0
88	251	17.69	27.8	17.3	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	252	22.23	27.6	16.9	0.0
88	253	11.60	27.5	15.9	0.0
88	254	10.75	25.5	16.3	3.0
88	255	13.66	25.0	16.9	0.0
88	256	20.73	26.9	15.3	0.0
88	257	19.47	27.4	16.3	0.0
88	258	15.53	27.3	15.4	0.0
88	259	16.35	29.0	17.3	0.0
88	260	19.47	27.4	17.4	0.0
88	261	22.33	28.6	18.7	0.0
88	262	19.57	26.3	18.3	3.0
88	263	20.81	27.6	18.0	0.0
88	264	18.31	25.6	18.5	1.0
88	265	21.24	26.2	18.3	1.0
88	266	21.58	26.5	18.5	5.0
88	267	18.43	25.7	18.3	4.0
88	268	17.67	26.0	17.7	0.0
88	269	17.65	26.6	16.8	0.0
88	270	16.09	28.2	18.1	11.0
88	271	13.30	28.4	18.4	5.0
88	272	13.99	26.2	18.3	0.0
88	273	15.77	27.9	17.5	0.0
88	274	20.44	30.2	16.7	0.0
88	275	20.30	30.0	15.5	0.0
88	276	18.28	29.6	15.1	0.0
88	277	17.64	28.2	15.1	0.0
88	278	16.55	29.6	14.7	0.0
88	279	19.81	26.5	16.9	0.0
88	280	17.63	25.8	18.1	0.0
88	281	18.28	26.0	19.3	1.0
88	282	17.56	28.0	17.5	0.0
88	283	13.91	27.8	16.4	0.0
88	284	14.13	27.9	15.4	0.0
88	285	15.77	27.6	16.5	0.0
88	286	16.03	27.6	18.3	18.0
88	287	18.63	27.0	19.1	0.0
88	288	13.00	27.0	16.9	0.0
88	289	12.20	27.4	16.7	0.0
88	290	10.22	25.7	17.9	1.0
88	291	11.04	21.1	17.3	0.0
88	292	9.67	23.5	17.0	0.0
88	293	10.06	23.3	17.0	0.0
88	294	14.03	26.6	15.6	0.0
88	295	14.30	25.4	17.2	0.0
88	296	11.90	27.9	16.2	0.0
88	297	7.58	27.8	16.4	3.0
88	298	9.70	26.7	16.2	27.0
88	299	12.19	25.3	15.2	0.0
88	300	8.93	23.8	17.4	1.0
88	301	12.62	25.1	17.4	0.0
88	302	11.09	24.9	17.4	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	303	12.24	25.5	15.6	0.0
88	304	10.72	27.3	17.6	0.0
88	305	12.58	25.5	18.1	0.0
88	306	11.86	25.8	18.4	0.0
88	307	9.98	25.3	15.6	0.0
88	308	9.36	26.5	15.4	0.0
88	309	1.15	22.0	16.2	78.0
88	310	4.42	25.6	18.2	5.0
88	311	8.54	26.8	18.3	0.0
88	312	11.71	27.5	17.9	0.0
88	313	9.84	25.4	18.9	0.0
88	314	7.58	22.0	18.3	5.0
88	315	11.86	24.0	18.3	0.0
88	316	10.51	25.1	18.2	1.0
88	317	10.90	25.0	17.1	0.0
88	318	10.75	23.2	18.5	17.0
88	319	10.56	23.9	17.4	6.0
88	320	6.43	23.6	15.7	0.0
88	321	6.91	25.5	15.6	0.0
88	322	12.10	26.0	15.9	1.0
88	323	14.86	26.4	16.9	4.0
88	324	14.95	25.0	16.9	0.0
88	325	18.06	23.2	18.3	8.0
88	326	17.45	22.2	18.1	5.0
88	327	14.60	21.6	17.9	11.0
88	328	17.19	22.2	17.9	10.0
88	329	18.92	23.2	16.9	6.0
88	330	12.53	24.0	15.5	0.0
88	331	11.32	24.8	15.4	12.0
88	332	10.97	23.5	16.6	0.0
88	333	10.63	25.6	16.5	0.0
88	334	12.96	25.3	17.0	0.0
88	335	15.47	26.5	16.5	0.0
88	336	19.09	25.3	15.7	0.0
88	337	14.08	25.0	14.7	0.0
88	338	11.92	24.9	15.3	0.0
88	339	17.11	24.6	15.2	0.0
88	340	13.22	24.3	15.8	0.0
88	341	1.55	21.8	16.2	124.0
88	342	11.15	24.7	16.2	9.0
88	343	14.77	26.5	15.4	3.0
88	344	11.84	24.6	15.5	0.0
88	345	18.32	23.1	15.4	0.0
88	346	17.11	22.6	16.9	5.0
88	347	13.31	24.0	15.6	0.0
88	348	9.33	23.6	14.6	0.0
88	349	14.08	24.3	14.2	0.0
88	350	12.44	24.2	14.9	0.0
88	351	1.55	19.4	14.5	98.0
88	352	12.01	20.4	11.5	0.0
88	353	13.56	22.3	10.9	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	354	11.92	24.9	15.4	0.0
88	355	13.82	23.6	17.7	0.0
88	356	18.75	23.6	16.9	0.0
88	357	11.66	23.7	14.9	0.0
88	358	10.02	23.5	14.7	0.0
88	359	14.43	23.0	17.1	0.0
88	360	14.95	23.1	15.4	1.0
88	361	11.58	22.5	16.2	0.0
88	362	13.56	23.1	17.0	0.0
88	363	11.40	22.6	16.6	2.0
88	364	9.76	20.3	17.3	49.0
88	365	10.80	19.0	16.6	35.0
88	366	16.16	21.3	16.9	22.0
89	1	13.68	21.8	11.9	0.0
89	2	12.40	24.8	11.5	2.0
89	3	14.56	25.1	14.0	5.0
89	4	17.55	21.1	14.0	3.0
89	5	17.66	19.9	13.8	16.0
89	6	12.96	19.6	15.3	44.0
89	7	12.46	19.4	15.8	38.0
89	8	15.36	19.0	13.7	51.0
89	9	11.13	17.8	14.5	68.0
89	10	6.30	18.4	16.1	103.0
89	11	7.09	22.0	15.6	3.0
89	12	9.72	23.7	14.7	9.0
89	13	7.43	20.2	16.6	34.0
89	14	15.52	18.9	15.9	18.0
89	15	15.69	19.6	15.2	12.0
89	16	14.63	22.4	14.0	5.0
89	17	17.35	21.5	14.6	0.0
89	18	18.67	21.6	13.9	0.0
89	19	13.12	22.3	15.0	0.0
89	20	11.63	23.3	13.1	0.0
89	21	12.65	22.9	13.0	0.0
89	22	17.57	21.3	14.9	0.0
89	23	13.02	24.2	14.4	0.0
89	24	13.71	25.2	13.3	0.0
89	25	17.53	23.2	14.4	2.0
89	26	18.00	22.2	11.7	1.0
89	27	15.72	24.7	11.3	0.0
89	28	17.81	24.9	12.4	5.0
89	29	6.43	21.8	14.3	15.0
89	30	10.88	21.9	13.1	0.0
89	31	5.47	19.9	12.9	1.0
89	32	14.79	24.1	12.7	0.0
89	33	17.06	24.5	13.0	34.0
89	34	5.53	16.6	14.3	19.0
89	35	2.61	17.0	13.7	152.0
89	36	9.43	21.5	14.1	2.0
89	37	13.08	24.0	14.1	8.0
89	38	10.06	21.8	16.0	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	39	14.75	25.0	16.0	0.0
89	40	12.40	24.4	15.3	5.0
89	41	10.05	21.8	16.2	3.0
89	42	6.78	22.3	13.0	32.0
89	43	14.51	24.1	13.9	0.0
89	44	15.53	25.9	12.7	0.0
89	45	19.16	26.1	12.4	0.0
89	46	16.00	25.2	12.8	0.0
89	47	15.78	25.0	12.1	0.0
89	48	15.57	25.5	12.9	0.0
89	49	20.44	23.8	14.5	0.0
89	50	17.47	22.8	13.2	0.0
89	51	21.14	22.3	12.2	0.0
89	52	20.24	23.3	13.0	0.0
89	53	12.75	21.1	13.9	0.0
89	54	18.59	20.9	15.1	10.0
89	55	21.70	19.3	14.4	15.0
89	56	20.43	19.7	13.7	3.0
89	57	20.57	24.1	12.7	0.0
89	58	9.62	22.7	11.6	0.0
89	59	6.11	21.4	15.0	21.0
89	60	10.50	22.8	14.7	6.0
89	61	14.61	23.4	18.8	1.0
89	62	18.22	23.7	19.0	0.0
89	63	7.19	22.1	15.4	0.0
89	64	8.97	20.9	15.3	0.0
89	65	19.16	22.8	16.5	0.0
89	66	19.72	21.4	14.2	0.0
89	67	21.51	19.3	12.7	0.0
89	68	20.93	21.0	12.2	0.0
89	69	17.57	21.5	11.7	0.0
89	70	16.87	23.0	10.8	0.0
89	71	15.63	22.5	12.6	0.0
89	72	17.02	24.5	11.0	0.0
89	73	24.95	22.9	14.1	0.0
89	74	16.82	23.8	12.9	0.0
89	75	15.69	26.1	12.4	0.0
89	76	13.56	25.8	13.2	0.0
89	77	17.32	24.6	13.4	0.0
89	78	15.90	24.6	12.7	0.0
89	79	13.02	25.7	13.2	0.0
89	80	24.30	25.7	13.6	0.0
89	81	23.80	25.8	13.5	0.0
89	82	25.16	24.3	16.1	0.0
89	83	24.61	25.9	17.0	0.0
89	84	10.36	25.5	15.9	0.0
89	85	17.05	26.8	13.9	0.0
89	86	19.21	24.9	13.9	0.0
89	87	22.25	25.9	13.7	0.0
89	88	26.29	24.3	14.6	1.0
89	89	20.42	21.9	15.9	7.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	90	15.97	20.9	16.0	49.0
89	91	22.29	22.0	15.9	31.0
89	92	20.06	22.7	15.4	57.0
89	93	10.81	24.2	13.0	32.0
89	94	19.83	24.8	14.2	0.0
89	95	6.98	16.4	13.7	121.0
89	96	7.77	17.2	13.6	37.0
89	97	2.16	15.1	13.6	220.0
89	98	5.78	17.2	14.2	90.0
89	99	14.27	19.7	14.0	56.0
89	100	14.51	20.3	13.1	1.0
89	101	27.72	23.3	11.5	0.0
89	102	18.35	23.5	13.0	6.0
89	103	12.45	20.2	15.9	101.0
89	104	16.73	18.2	14.0	57.0
89	105	17.63	17.3	13.5	2.0
89	106	14.18	19.0	13.1	0.0
89	107	19.79	19.3	13.5	0.0
89	108	22.94	19.4	13.7	1.0
89	109	26.68	22.1	14.3	0.0
89	110	16.96	20.1	15.2	11.0
89	111	20.46	22.1	15.7	2.0
89	112	21.47	22.7	15.6	0.0
89	113	15.51	21.8	16.0	56.0
89	114	25.14	24.3	15.0	0.0
89	115	24.20	22.6	13.5	1.0
89	116	19.97	23.4	12.3	1.0
89	117	18.70	20.8	12.5	10.0
89	118	14.12	20.7	15.4	13.0
89	119	12.57	19.3	15.6	65.0
89	120	17.17	22.0	15.1	8.0
89	121	20.38	22.1	14.2	0.0
89	122	15.57	21.9	13.5	0.0
89	123	13.72	19.1	12.5	0.0
89	124	23.00	21.7	13.5	1.0
89	125	21.25	21.9	13.9	0.0
89	126	18.02	22.6	12.8	0.0
89	127	20.78	23.4	13.9	0.0
89	128	20.50	23.8	14.4	0.0
89	129	13.77	23.6	15.1	0.0
89	130	26.86	24.5	14.9	0.0
89	131	22.76	24.6	14.6	1.0
89	132	28.14	24.6	15.0	0.0
89	133	23.93	23.2	17.0	1.0
89	134	19.06	23.8	15.1	4.0
89	135	19.25	24.4	16.7	4.0
89	136	18.51	24.9	15.3	0.0
89	137	27.19	23.1	15.8	0.0
89	138	26.58	23.5	15.9	0.0
89	139	26.09	21.7	15.8	2.0
89	140	28.82	23.8	15.8	1.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	141	27.53	23.8	14.2	0.0
89	142	20.41	23.2	16.7	23.0
89	143	23.78	22.4	16.4	20.0
89	144	25.24	23.3	16.8	5.0
89	145	27.93	24.1	16.4	2.0
89	146	27.12	26.7	15.5	0.0
89	147	16.49	26.9	16.3	0.0
89	148	25.12	25.9	18.0	0.0
89	149	25.03	24.0	16.7	4.0
89	150	21.43	22.6	16.4	12.0
89	151	12.20	23.3	16.7	1.0
89	152	14.29	24.5	15.4	11.0
89	153	19.98	24.7	13.6	1.0
89	154	28.97	24.7	16.5	2.0
89	155	16.30	21.8	17.1	16.0
89	156	26.23	23.7	17.2	19.0
89	157	28.07	23.2	16.6	5.0
89	158	20.24	22.5	15.9	2.0
89	159	20.57	24.1	16.7	0.0
89	160	28.61	24.4	15.7	0.0
89	161	23.18	23.1	15.6	0.0
89	162	24.62	23.8	15.6	1.0
89	163	23.41	22.5	16.7	3.0
89	164	29.48	24.6	15.5	2.0
89	165	25.60	22.7	15.4	3.0
89	166	22.11	23.1	16.3	0.0
89	167	18.55	24.7	15.9	2.0
89	168	19.93	22.7	16.8	3.0
89	169	29.82	24.7	16.3	0.0
89	170	28.20	25.2	16.9	0.0
89	171	20.08	23.3	16.1	1.0
89	172	19.12	26.1	15.9	0.0
89	173	15.45	26.9	14.0	0.0
89	174	15.11	26.1	15.1	0.0
89	175	26.86	25.6	15.5	0.0
89	176	21.04	24.1	15.3	0.0
89	177	15.32	25.4	14.1	1.0
89	178	21.75	25.3	14.4	0.0
89	179	28.12	25.1	17.7	1.0
89	180	23.56	23.7	16.8	2.0
89	181	22.48	23.9	16.8	7.0
89	182	29.30	23.9	17.0	1.0
89	183	27.50	24.5	17.1	0.0
89	184	20.10	23.1	16.7	6.0
89	185	24.16	24.2	16.8	4.0
89	186	28.40	24.3	17.5	36.0
89	187	25.30	22.2	17.3	24.0
89	188	28.13	24.7	16.5	0.0
89	189	25.27	25.2	15.6	1.0
89	190	23.53	25.4	16.0	0.0
89	191	22.80	24.2	18.4	14.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	192	27.74	25.5	18.0	1.0
89	193	20.79	22.1	17.4	8.0
89	194	23.23	21.9	17.8	19.0
89	195	25.61	23.9	17.6	3.0
89	196	24.70	26.4	18.1	0.0
89	197	27.19	25.3	17.9	1.0
89	198	24.49	24.5	18.3	1.0
89	199	25.90	24.2	17.1	7.0
89	200	23.43	22.7	17.4	22.0
89	201	4.19	22.3	19.5	3.0
89	202	21.03	27.2	18.7	0.0
89	203	5.61	21.8	19.3	58.0
89	204	21.64	25.4	17.1	1.0
89	205	28.68	24.5	16.2	1.0
89	206	24.35	24.4	17.0	1.0
89	207	20.84	24.8	17.2	0.0
89	208	28.66	25.0	17.8	0.0
89	209	24.38	22.7	17.6	15.0
89	210	26.73	23.6	17.0	8.0
89	211	26.69	24.2	17.2	0.0
89	212	28.17	25.8	14.9	0.0
89	213	27.67	24.8	16.8	11.0
89	214	27.22	24.7	17.5	3.0
89	215	23.19	24.9	14.8	0.0
89	216	23.35	24.6	17.1	0.0
89	217	18.13	25.8	16.4	4.0
89	218	26.01	24.0	16.7	1.0
89	219	17.99	28.0	16.3	1.0
89	220	21.64	29.7	15.9	0.0
89	221	20.56	28.6	14.5	0.0
89	222	17.62	25.1	15.4	0.0
89	223	14.30	25.7	15.2	0.0
89	224	26.53	29.3	15.6	0.0
89	225	20.38	26.7	15.1	0.0
89	226	14.28	24.5	17.1	0.0
89	227	19.97	25.5	15.8	0.0
89	228	23.39	25.2	17.2	0.0
89	229	25.40	25.5	16.5	0.0
89	230	20.85	24.2	16.9	1.0
89	231	22.03	24.3	16.1	5.0
89	232	13.08	22.2	18.5	109.0
89	233	13.04	24.8	17.2	1.0
89	234	25.44	24.3	16.4	0.0
89	235	18.53	24.7	16.5	0.0
89	236	26.63	25.5	17.0	0.0
89	237	27.54	25.3	16.1	0.0
89	238	27.54	25.7	14.5	0.0
89	239	27.01	26.6	14.3	0.0
89	240	24.70	27.7	14.6	0.0
89	241	20.60	28.1	14.3	0.0
89	242	26.01	24.9	15.3	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	243	20.95	23.8	17.3	2.0
89	244	21.14	22.9	17.3	16.0
89	245	20.51	23.2	17.7	3.0
89	246	20.85	23.4	17.1	15.0
89	247	23.74	23.2	16.7	0.0
89	248	11.01	23.8	15.9	4.0
89	249	10.34	23.6	14.0	13.0
89	250	25.94	24.8	16.3	1.0
89	251	21.04	25.0	16.7	0.0
89	252	22.51	23.7	17.0	7.0
89	253	24.85	23.4	16.9	1.0
89	254	24.12	24.8	17.2	0.0
89	255	15.66	26.0	15.3	9.0
89	256	18.61	25.5	16.3	0.0
89	257	25.79	24.5	17.2	0.0
89	258	21.60	24.9	16.6	0.0
89	259	14.15	24.8	14.5	2.0
89	260	22.94	25.4	16.6	0.0
89	261	18.08	24.2	14.8	0.0
89	262	15.73	22.1	17.1	4.0
89	263	23.85	24.1	15.0	0.0
89	264	20.88	23.6	14.9	1.0
89	265	24.04	23.9	16.9	1.0
89	266	24.53	25.5	16.5	0.0
89	267	25.10	25.6	16.6	1.0
89	268	21.42	25.2	17.5	0.0
89	269	20.23	24.9	17.5	0.0
89	270	17.80	24.8	15.5	0.0
89	271	11.48	23.6	14.7	0.0
89	272	19.68	24.9	15.0	0.0
89	273	15.36	28.1	14.3	10.0
89	274	13.82	28.0	16.3	0.0
89	275	13.90	26.6	15.9	1.0
89	276	8.79	27.0	18.3	9.0
89	277	12.15	26.6	17.7	0.0
89	278	11.65	26.9	16.9	11.0
89	279	9.05	26.2	17.9	13.0
89	280	13.22	26.1	16.4	4.0
89	281	10.11	26.3	15.3	11.0
89	282	11.39	26.8	16.8	20.0
89	283	14.38	27.8	18.0	0.0
89	284	15.69	27.1	16.0	0.0
89	285	15.71	27.4	14.1	0.0
89	286	11.07	25.4	15.1	6.0
89	287	17.45	28.2	15.6	0.0
89	288	9.76	27.4	16.5	8.0
89	289	17.71	27.5	15.5	0.0
89	290	12.91	26.9	14.8	0.0
89	291	12.08	26.1	16.3	7.0
89	292	20.56	24.9	15.1	1.0
89	293	21.44	25.2	17.6	1.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	294	15.12	23.9	16.3	0.0
89	295	15.54	24.4	14.7	0.0
89	296	13.43	24.4	16.4	23.0
89	297	11.27	23.8	17.1	7.0
89	298	13.56	23.0	17.7	0.0
89	299	16.38	23.5	16.3	0.0
89	300	20.56	24.4	13.9	0.0
89	301	19.80	26.5	13.7	6.0
89	302	9.96	24.6	16.0	0.0
89	303	14.52	27.7	16.1	0.0
89	304	15.32	25.7	15.1	0.0
89	305	14.64	23.6	14.6	0.0
89	306	16.75	23.8	13.1	0.0
89	307	13.29	25.6	12.8	0.0
89	308	15.96	28.7	15.2	0.0
89	309	17.40	24.4	15.9	0.0
89	310	19.45	23.9	17.0	0.0
89	311	19.59	24.3	15.8	0.0
89	312	16.32	23.8	14.1	0.0
89	313	15.20	27.3	13.1	0.0
89	314	13.53	26.5	14.3	0.0
89	315	13.00	27.2	13.5	0.0
89	316	9.89	26.9	16.5	0.0
89	317	13.80	29.7	17.3	0.0
89	318	7.44	26.5	16.7	18.0
89	319	11.26	25.5	17.0	26.0
89	320	3.78	17.7	14.9	16.0
89	321	15.81	20.3	14.6	0.0
89	322	19.17	21.2	14.6	0.0
89	323	9.61	20.8	15.2	5.0
89	324	14.08	21.7	15.4	0.0
89	325	16.52	24.0	16.3	1.0
89	326	17.25	22.4	15.9	0.0
89	327	17.40	24.5	11.5	0.0
89	328	16.16	26.1	12.4	0.0
89	329	10.79	24.1	13.9	0.0
89	330	17.69	25.3	13.6	0.0
89	331	18.22	25.0	12.9	0.0
89	332	13.77	25.6	13.0	0.0
89	333	16.72	25.0	15.2	1.0
89	334	7.31	23.7	16.7	0.0
89	335	16.78	23.2	14.6	0.0
89	336	15.26	25.0	14.1	0.0
89	337	7.29	23.1	13.6	0.0
89	338	9.54	25.2	13.4	0.0
89	339	13.15	25.4	13.7	0.0
89	340	15.52	25.9	13.3	0.0
89	341	14.32	26.1	14.4	0.0
89	342	14.96	27.1	14.4	0.0
89	343	1.01	20.6	15.2	48.0
89	344	20.13	20.0	11.8	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	345	9.33	18.8	12.0	2.0
89	346	4.73	18.4	11.1	6.0
89	347	4.80	16.4	13.2	50.0
89	348	13.68	19.6	11.9	0.0
89	349	17.89	20.8	11.9	0.0
89	350	21.53	22.1	8.5	0.0
89	351	15.80	22.7	9.7	0.0
89	352	20.29	23.6	8.3	0.0
89	353	20.83	26.6	13.8	0.0
89	354	10.47	21.3	16.6	18.0
89	355	8.48	21.3	16.0	5.0
89	356	12.56	23.8	13.4	1.0
89	357	14.46	24.7	12.9	0.0
89	358	18.46	25.6	12.3	0.0
89	359	11.99	23.4	13.8	0.0
89	360	16.64	24.9	12.3	0.0
89	361	15.34	24.5	12.1	0.0
89	362	15.63	25.2	13.6	0.0
89	363	17.42	23.7	14.2	1.0
89	364	20.44	20.6	14.0	10.0
89	365	16.20	22.1	15.5	64.0
90	1	5.06	18.5	16.1	21.0
90	2	17.84	20.5	16.5	18.0
90	3	18.10	21.8	15.0	3.0
90	4	20.40	22.6	13.3	1.0
90	5	18.76	22.9	14.8	0.0
90	6	19.69	24.4	11.3	0.0
90	7	18.09	24.7	11.0	0.0
90	8	10.54	21.8	13.5	31.0
90	9	19.57	18.0	14.7	12.0
90	10	18.49	19.7	12.8	0.0
90	11	21.29	19.5	13.7	6.0
90	12	18.95	22.0	14.2	1.0
90	13	15.01	23.8	13.0	0.0
90	14	15.93	23.8	12.3	0.0
90	15	3.02	17.0	15.0	32.0
90	16	11.50	20.2	14.9	45.0
90	17	8.11	19.3	15.4	103.0
90	18	11.12	21.4	15.3	14.0
90	19	3.38	19.9	16.7	30.0
90	20	5.59	21.9	16.1	11.0
90	21	17.25	26.1	13.9	0.0
90	22	4.03	21.0	15.4	23.0
90	23	6.91	22.0	14.2	10.0
90	24	10.28	22.7	13.8	0.0
90	25	9.71	23.5	15.9	0.0
90	26	10.43	23.8	16.6	0.0
90	27	13.88	23.0	16.8	1.0
90	28	15.54	21.4	15.1	0.0
90	29	23.39	21.7	15.7	3.0
90	30	20.98	19.1	15.3	10.0

Table J.1 (continued)

Year	Day	Solar Radiation ($MJ\ m^{-2}$)	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	31	21.25	21.2	15.5	18.0
90	32	19.86	22.0	16.5	34.0
90	33	20.21	19.7	16.4	41.0
90	34	20.61	20.8	16.4	28.0
90	35	20.06	21.0	16.0	2.0
90	36	19.09	23.5	16.0	2.0
90	37	25.18	22.3	14.9	9.0
90	38	18.02	17.8	13.4	10.0
90	39	20.70	18.3	13.0	4.0
90	40	24.19	20.1	13.5	3.0
90	41	25.90	20.2	13.3	6.0
90	42	15.71	20.9	10.8	0.0
90	43	18.16	22.3	9.8	0.0
90	44	26.89	23.0	10.4	0.0
90	45	16.48	22.4	11.8	0.0
90	46	21.05	25.3	11.5	0.0
90	47	24.00	23.3	12.8	1.0
90	48	12.21	19.8	14.1	47.0
90	49	6.48	15.7	11.0	12.0
90	50	15.33	18.3	10.4	5.0
90	51	22.33	18.9	11.2	3.0
90	52	14.53	20.1	9.2	0.0
90	53	15.11	21.8	11.2	0.0
90	54	16.20	23.9	11.2	0.0
90	55	8.09	22.4	13.3	18.0
90	56	6.70	21.5	16.3	41.0
90	57	10.55	18.2	13.5	57.0
90	58	9.85	17.0	13.5	7.0
90	59	6.37	15.7	12.8	9.0
90	60	6.51	16.4	12.5	73.0
90	61	19.34	18.7	11.8	23.0
90	62	14.35	18.2	13.8	9.0
90	63	15.57	18.4	13.9	2.0
90	64	9.41	18.3	14.4	4.0
90	65	20.56	21.5	15.1	9.0
90	66	13.32	18.6	15.3	49.0
90	67	13.74	17.7	14.6	20.0
90	68	20.85	20.8	15.6	1.0
90	69	28.91	23.9	13.9	0.0
90	70	26.20	22.3	14.2	0.0
90	71	26.52	22.9	12.7	0.0
90	72	24.67	25.6	12.3	0.0
90	73	25.20	24.2	13.0	0.0
90	74	7.70	15.8	13.2	23.0
90	75	30.77	18.7	12.5	1.0
90	76	26.51	19.8	9.5	0.0
90	77	23.97	23.4	11.4	0.0
90	78	27.60	23.8	12.2	0.0
90	79	17.34	23.8	15.0	16.0
90	80	19.55	24.2	11.7	0.0
90	81	14.88	23.3	12.7	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	82	21.64	24.5	13.1	0.0
90	83	17.56	24.7	14.2	0.0
90	84	17.10	24.4	12.7	0.0
90	85	31.46	23.7	13.2	0.0
90	86	26.22	23.0	15.7	0.0
90	87	29.80	24.0	13.6	5.0
90	88	31.67	20.2	13.9	4.0
90	89	28.25	20.7	13.9	1.0
90	90	28.01	21.0	13.8	4.0
90	91	28.20	21.7	14.2	0.0
90	92	22.10	22.7	12.7	0.0
90	93	20.74	21.2	12.7	2.0
90	94	20.72	21.5	12.1	1.0
90	95	15.80	23.2	11.8	0.0
90	96	23.74	25.6	11.5	0.0
90	97	14.93	23.9	12.7	0.0
90	98	16.49	24.7	11.8	0.0
90	99	20.47	22.9	12.7	0.0
90	100	11.60	24.2	14.4	0.0
90	101	20.76	27.4	13.6	0.0
90	102	30.23	27.4	14.7	0.0
90	103	29.19	25.1	14.9	2.0
90	104	23.66	24.6	16.9	0.0
90	105	26.89	25.3	14.4	0.0
90	106	21.98	24.8	12.9	0.0
90	107	25.48	23.7	13.5	0.0
90	108	26.86	23.7	14.0	0.0
90	109	24.61	23.5	14.1	0.0
90	110	29.18	23.2	16.5	0.0
90	111	31.86	23.1	16.3	3.0
90	112	29.11	23.2	15.4	0.0
90	113	15.68	23.3	13.9	2.0
90	114	14.24	25.4	14.9	0.0
90	115	15.89	26.1	15.5	0.0
90	116	17.31	26.1	14.8	0.0
90	117	20.69	26.7	15.1	0.0
90	118	14.05	25.6	15.8	0.0
90	119	14.87	25.7	15.0	0.0
90	120	16.93	24.5	14.6	0.0
90	121	24.70	23.8	14.6	0.0
90	122	24.48	25.2	13.1	0.0
90	123	9.83	21.3	14.1	32.0
90	124	25.54	21.7	13.4	14.0
90	125	17.20	20.1	14.8	30.0
90	126	24.78	21.0	14.8	5.0
90	127	28.01	22.3	14.3	2.0
90	128	24.78	21.4	15.3	5.0
90	129	30.21	22.7	13.6	0.0
90	130	15.86	23.1	13.9	2.0
90	131	23.50	24.0	14.8	0.0
90	132	23.18	23.5	14.9	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	133	25.10	23.6	15.0	0.0
90	134	20.04	24.3	14.8	0.0
90	135	24.68	22.6	15.5	0.0
90	136	24.29	23.2	14.6	1.0
90	137	25.35	23.5	16.2	5.0
90	138	25.68	22.7	16.1	18.0
90	139	21.02	22.2	15.5	20.0
90	140	14.42	20.2	16.0	67.0
90	141	21.46	21.0	15.9	1.0
90	142	23.93	23.5	15.3	0.0
90	143	26.91	22.9	14.1	0.0
90	144	19.02	22.0	15.6	9.0
90	145	26.14	22.5	15.3	1.0
90	146	23.79	22.8	16.4	2.0
90	147	21.75	23.1	17.1	5.0
90	148	24.09	27.8	15.7	0.0
90	149	26.17	24.7	14.5	0.0
90	150	26.29	23.8	15.7	0.0
90	151	26.39	26.2	15.9	0.0
90	152	27.72	25.1	16.1	0.0
90	153	27.53	24.2	16.3	0.0
90	154	25.34	25.1	16.1	1.0
90	155	25.62	25.3	17.1	0.0
90	156	19.61	24.4	17.2	2.0
90	157	19.43	24.3	16.9	1.0
90	158	19.21	25.4	16.4	2.0
90	159	26.40	24.0	16.8	1.0
90	160	27.14	24.8	15.1	0.0
90	161	25.63	23.8	14.5	0.0
90	162	19.75	26.0	15.0	0.0
90	163	22.94	24.4	16.6	0.0
90	164	26.03	25.1	16.5	0.0
90	165	24.24	24.0	16.8	11.0
90	166	16.74	22.0	16.8	27.0
90	167	15.45	20.2	16.7	56.0
90	168	19.23	21.4	16.0	11.0
90	169	20.62	21.2	16.0	24.0
90	170	22.26	23.4	15.9	13.0
90	171	15.33	22.9	16.7	2.0
90	172	23.41	24.0	17.3	0.0
90	173	24.49	22.5	16.5	1.0
90	174	20.47	23.7	16.2	0.0
90	175	23.25	22.5	15.9	4.0
90	176	21.92	22.5	16.1	1.0
90	177	25.43	23.2	16.2	0.0
90	178	26.53	25.9	15.4	0.0
90	179	26.41	24.2	17.5	0.0
90	180	23.39	23.8	17.5	2.0
90	181	21.38	24.4	17.2	1.0
90	182	25.16	23.8	17.4	1.0
90	183	24.92	24.0	17.5	3.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	184	26.10	24.9	17.2	0.0
90	185	26.37	24.8	16.6	0.0
90	186	24.74	23.6	15.8	1.0
90	187	26.45	25.4	12.3	0.0
90	188	27.04	25.0	13.4	0.0
90	189	14.50	24.7	13.8	31.0
90	190	22.67	27.4	15.7	0.0
90	191	25.89	25.5	17.1	0.0
90	192	27.26	24.5	16.6	1.0
90	193	19.82	23.5	17.1	1.0
90	194	24.61	25.1	14.7	0.0
90	195	15.63	27.0	16.5	0.0
90	196	17.96	26.0	15.2	0.0
90	197	25.19	23.8	17.4	0.0
90	198	26.25	26.1	17.7	6.0
90	199	24.91	24.4	18.1	4.0
90	200	24.34	24.9	16.2	0.0
90	201	15.48	23.4	16.5	1.0
90	202	9.95	24.8	16.2	6.0
90	203	21.89	25.1	17.8	0.0
90	204	28.02	26.6	16.4	2.0
90	205	24.17	23.7	17.2	6.0
90	206	23.26	23.1	16.8	0.0
90	207	24.13	24.0	17.0	4.0
90	208	13.73	25.4	18.5	17.0
90	209	22.54	26.6	18.3	0.0
90	210	14.82	27.7	16.7	0.0
90	211	12.58	25.0	16.3	0.0
90	212	21.58	26.6	18.5	0.0
90	213	17.14	26.5	15.9	0.0
90	214	22.57	25.6	17.9	0.0
90	215	14.65	24.1	15.6	0.0
90	216	21.98	25.8	17.1	0.0
90	217	21.22	25.2	17.1	1.0
90	218	21.81	26.1	17.4	5.0
90	219	25.77	26.5	17.6	0.0
90	220	25.77	25.7	18.2	0.0
90	221	19.37	26.5	17.6	0.0
90	222	26.45	25.2	16.2	0.0
90	223	25.66	26.0	17.1	7.0
90	224	18.88	24.3	16.2	1.0
90	225	20.38	28.2	18.0	0.0
90	226	26.04	27.8	17.2	0.0
90	227	26.02	27.5	18.9	0.0
90	228	20.91	26.3	17.9	0.0
90	229	25.76	25.5	16.4	1.0
90	230	18.69	23.4	17.6	9.0
90	231	15.04	26.1	15.7	1.0
90	232	21.28	28.4	16.6	0.0
90	233	25.59	26.6	15.3	0.0
90	234	23.79	25.4	15.7	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	235	21.82	27.6	17.2	0.0
90	236	23.79	27.1	17.7	3.0
90	237	22.68	25.6	18.8	1.0
90	238	20.58	23.9	18.2	14.0
90	239	20.73	24.6	17.5	13.0
90	240	25.66	25.0	16.6	0.0
90	241	25.07	25.5	15.2	0.0
90	242	25.24	25.0	16.8	0.0
90	243	22.90	27.1	13.8	0.0
90	244	13.86	28.0	14.7	4.0
90	245	18.65	29.3	16.0	0.0
90	246	18.03	27.4	17.0	0.0
90	247	19.42	28.4	17.4	0.0
90	248	23.51	25.6	18.7	6.0
90	249	19.31	24.4	17.8	3.0
90	250	23.77	25.6	17.2	0.0
90	251	17.40	27.2	16.1	0.0
90	252	20.48	25.8	18.4	5.0
90	253	21.12	25.3	17.0	1.0
90	254	22.50	25.4	16.9	0.0
90	255	20.59	24.5	16.8	7.0
90	256	18.50	26.2	17.7	3.0
90	257	18.02	25.3	18.3	0.0
90	258	21.95	25.1	18.4	5.0
90	259	21.27	26.2	18.8	4.0
90	260	23.98	26.1	17.4	31.0
90	261	12.41	22.5	18.9	32.0
90	262	13.69	26.6	18.2	1.0
90	263	10.37	27.6	17.6	9.0
90	264	11.70	26.4	18.5	0.0
90	265	19.81	24.5	16.2	1.0
90	266	16.73	26.2	17.4	1.0
90	267	18.60	26.4	17.4	0.0
90	268	22.29	25.4	15.2	0.0
90	269	16.49	25.6	15.6	0.0
90	270	19.38	25.5	17.0	0.0
90	271	19.71	24.5	16.6	1.0
90	272	11.56	21.9	17.9	38.0
90	273	19.58	24.4	17.9	10.0
90	274	16.50	24.4	16.9	4.0
90	275	19.63	27.9	15.7	0.0
90	276	15.90	26.2	16.8	5.0
90	277	22.34	26.4	18.9	3.0
90	278	20.27	25.1	17.6	3.0
90	279	20.33	25.1	18.1	0.0
90	280	18.79	26.1	15.7	0.0
90	281	18.70	26.7	16.0	0.0
90	282	20.74	25.8	16.9	0.0
90	283	14.16	23.5	17.3	25.0
90	284	15.54	22.3	17.5	26.0
90	285	19.92	23.1	17.0	1.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	286	20.61	25.6	17.3	1.0
90	287	19.74	24.0	17.2	2.0
90	288	21.34	24.8	16.4	0.0
90	289	13.92	26.1	15.9	3.0
90	290	20.86	24.6	18.0	6.0
90	291	12.90	26.2	15.3	2.0
90	292	14.07	29.2	18.8	0.0
90	293	11.12	27.8	17.1	0.0
90	294	13.11	27.6	16.4	0.0
90	295	15.73	26.9	14.9	0.0
90	296	14.17	25.6	16.7	0.0
90	297	20.74	24.6	17.6	3.0
90	298	20.25	23.9	16.8	0.0
90	299	14.05	24.2	14.1	0.0
90	300	17.68	24.9	16.1	0.0
90	301	19.96	24.8	17.0	0.0
90	302	14.53	23.8	17.3	1.0
90	303	12.70	23.7	17.2	2.0
90	304	14.42	25.9	15.6	0.0
90	305	12.89	29.0	15.7	0.0
90	306	11.81	28.0	16.8	0.0
90	307	18.28	25.3	15.7	0.0
90	308	16.07	26.0	13.6	0.0
90	309	9.98	24.2	17.8	0.0
90	310	16.83	28.0	16.2	0.0
90	311	10.73	28.2	16.1	0.0
90	312	11.59	27.0	16.5	0.0
90	313	15.50	28.6	13.7	0.0
90	314	16.17	27.9	13.1	0.0
90	315	13.52	29.2	15.4	0.0
90	316	4.18	23.1	18.9	18.0
90	317	15.49	25.4	18.1	4.0
90	318	15.26	21.0	17.3	26.0
90	319	13.20	23.1	15.4	3.0
90	320	7.57	23.6	16.6	1.0
90	321	4.93	22.6	16.3	22.0
90	322	2.96	18.6	16.1	85.0
90	323	11.46	24.1	17.1	60.0
90	324	1.50	20.9	18.4	53.0
90	325	11.59	27.1	16.7	0.0
90	326	13.61	28.5	17.1	0.0
90	327	4.25	21.5	16.2	57.0
90	328	14.21	21.8	14.5	10.0
90	329	5.35	19.7	14.6	3.0
90	330	6.94	21.9	15.2	0.0
90	331	8.00	26.5	16.2	1.0
90	332	15.11	26.2	17.0	1.0
90	333	9.87	24.7	16.2	0.0
90	334	14.07	25.5	15.5	0.0
90	335	15.27	24.5	15.8	0.0
90	336	9.54	25.0	14.4	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	337	13.75	23.3	15.6	6.0
90	338	12.46	22.5	14.4	2.0
90	339	17.16	22.5	15.6	6.0
90	340	17.98	23.5	15.2	3.0
90	341	14.63	25.3	14.1	4.0
90	342	9.47	22.3	15.9	53.0
90	343	11.42	18.1	15.7	99.0
90	344	17.51	20.9	15.2	2.0
90	345	16.35	22.2	15.4	0.0
90	346	11.43	20.8	15.8	17.0
90	347	7.58	17.6	15.3	18.0
90	348	10.67	18.0	14.9	11.0
90	349	16.22	25.2	12.8	0.0
90	350	13.53	26.3	13.4	0.0
90	351	11.16	24.8	13.1	0.0
90	352	6.67	19.3	16.3	19.0
90	353	2.68	17.4	15.6	17.0
90	354	7.80	19.0	15.6	2.0
90	355	3.71	20.8	17.3	4.0
90	356	5.19	23.8	17.0	10.0
90	357	5.11	24.5	14.6	34.0
90	358	7.27	22.5	14.6	32.0
90	359	17.09	22.7	11.0	0.0
90	360	3.40	20.0	15.2	3.0
90	361	16.59	22.5	15.4	1.0
90	362	14.54	21.4	14.9	5.0
90	363	13.80	21.4	13.0	0.0
90	364	16.24	21.3	11.8	7.0
90	365	15.04	20.4	12.2	5.0
91	1	17.37	20.0	11.7	0.0
91	2	14.21	20.7	9.1	1.0
91	3	9.23	19.8	12.1	0.0
91	4	7.33	19.4	13.8	1.0
91	5	9.44	18.9	12.7	2.0
91	6	12.77	19.7	14.4	5.0
91	7	11.61	21.2	14.0	0.0
91	8	15.77	26.0	13.3	0.0
91	9	17.49	24.1	12.6	0.0
91	10	16.76	21.1	15.5	25.0
91	11	14.31	23.3	13.7	0.0
91	12	16.64	26.5	12.3	0.0
91	13	10.67	25.8	14.4	0.0
91	14	11.49	25.5	16.2	0.0
91	15	14.66	25.8	14.1	0.0
91	16	15.39	24.0	13.0	0.0
91	17	11.18	25.5	14.5	0.0
91	18	12.89	25.5	13.9	0.0
91	19	8.06	19.8	14.4	0.0
91	20	18.40	18.7	13.6	0.0
91	21	15.15	20.0	13.9	0.0
91	22	12.03	17.7	13.8	0.0

Table J.1 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
91	23	12.77	18.4	14.3	0.0
91	24	14.05	21.6	12.5	0.0
91	25	11.20	22.7	12.0	0.0
91	26	16.96	21.9	14.1	0.0
91	27	6.32	25.7	14.1	0.0
91	28	19.82	23.0	12.7	0.0
91	29	20.07	22.4	12.0	0.0
91	30	20.41	22.2	10.1	0.0
91	31	20.13	22.3	16.5	0.0
91	32	18.37	24.6	12.7	0.0
91	33	19.63	22.6	15.8	0.0
91	34	7.89	23.6	15.9	0.0
91	35	18.02	23.7	14.2	0.0
91	36	20.40	26.2	17.3	0.0
91	37	19.30	27.0	13.5	0.0
91	38	21.00	24.8	13.3	0.0
91	39	20.80	25.0	13.4	0.0
91	40	13.30	23.9	14.8	0.0
91	41	12.60	24.9	13.1	0.0
91	42	16.54	25.6	14.1	0.0
91	43	15.80	23.8	14.0	0.0
91	44	11.42	19.0	15.6	0.0
91	45	16.18	22.6	16.0	0.0
91	46	20.15	21.7	13.0	0.0
91	47	14.50	24.8	11.6	0.0
91	48	19.13	26.5	13.6	0.0
91	49	12.90	23.3	13.4	0.0
91	50	20.34	22.2	14.9	0.0
91	51	12.03	21.9	16.8	0.0
91	52	15.81	23.3	14.8	0.0
91	53	21.29	27.4	13.2	0.0
91	54	14.35	28.2	12.6	0.0
91	55	14.85	21.9	13.3	0.0
91	56	21.12	22.6	12.4	0.0
91	57	21.59	23.3	10.7	0.0
91	58	22.32	21.8	10.1	0.0
91	59	14.76	23.0	14.1	0.0

Table J.2 Weather data from Kuiaha Experiment Site, 1988 to 1991.

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	1	1.05	19.6	15.9	163.0
88	2	8.77	17.8	15.9	60.0
88	3	13.20	20.9	16.0	0.0
88	4	16.83	21.5	16.6	1.0
88	5	12.06	26.3	15.6	4.0
88	6	11.25	22.5	17.9	5.0
88	7	19.12	22.9	17.2	0.0
88	8	17.32	23.3	17.7	0.0
88	9	4.71	20.7	18.3	78.0
88	10	8.67	25.0	18.9	19.0
88	11	12.89	23.9	18.1	0.0
88	12	18.49	24.6	18.9	0.0
88	13	14.76	27.5	17.1	0.0
88	14	18.74	24.7	18.5	0.0
88	15	13.29	23.7	18.6	16.0
88	16	14.03	24.0	18.9	10.0
88	17	15.04	25.6	18.5	0.0
88	18	13.46	27.1	18.6	0.0
88	19	18.73	24.6	17.8	0.0
88	20	18.76	27.8	15.9	0.0
88	21	13.73	26.5	17.1	0.0
88	22	14.38	27.5	16.6	0.0
88	23	19.13	24.2	19.2	0.0
88	24	19.75	24.1	17.8	1.0
88	25	14.32	23.1	18.6	0.0
88	26	4.00	19.1	17.0	97.0
88	27	7.81	19.0	17.2	78.0
88	28	8.84	19.7	17.8	57.0
88	29	15.85	25.4	16.0	17.0
88	30	21.85	27.3	15.3	0.0
88	31	20.34	24.3	15.5	0.0
88	32	20.53	26.9	14.8	0.0
88	33	17.99	27.8	15.6	0.0
88	34	18.23	27.6	14.8	0.0
88	35	16.49	24.1	17.7	36.0
88	36	19.62	28.3	15.8	0.0
88	37	17.04	25.1	15.4	2.0
88	38	11.50	22.1	19.0	6.0
88	39	19.50	23.5	19.0	0.0
88	40	21.20	24.5	18.7	0.0
88	41	19.82	24.0	18.4	0.0
88	42	19.65	23.5	18.3	0.0
88	43	20.53	24.3	18.2	2.0
88	44	22.95	23.7	18.8	4.0
88	45	18.61	23.3	18.3	3.0
88	46	19.49	24.0	18.7	9.0
88	47	20.08	23.6	18.1	6.0
88	48	20.22	23.5	18.5	9.0
88	49	22.33	24.0	17.6	0.0
88	50	12.45	24.2	16.6	2.0
88	51	21.94	25.0	16.8	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	52	19.26	27.9	16.4	0.0
88	53	11.74	26.5	18.4	4.0
88	54	15.75	25.6	19.4	1.0
88	55	23.19	27.6	16.9	0.0
88	56	6.37	20.2	17.0	40.0
88	57	15.68	21.6	17.1	0.0
88	58	22.99	22.9	18.2	0.0
88	59	24.44	23.0	17.6	0.0
88	60	22.93	23.2	17.1	0.0
88	61	22.67	24.1	18.2	0.0
88	62	22.13	24.2	18.6	1.0
88	63	22.95	24.7	17.9	1.0
88	64	23.34	24.5	18.7	1.0
88	65	22.49	23.7	18.3	4.0
88	66	15.20	23.7	18.4	5.0
88	67	20.54	24.5	18.5	0.0
88	68	22.17	24.3	18.9	0.0
88	69	24.24	25.1	18.4	1.0
88	70	25.55	24.4	18.0	0.0
88	71	25.71	24.3	18.1	0.0
88	72	25.83	25.2	16.5	0.0
88	73	25.21	26.3	15.3	1.0
88	74	6.51	19.4	16.5	23.0
88	75	12.09	18.7	16.2	47.0
88	76	25.76	24.4	16.0	5.0
88	77	15.10	27.1	16.2	0.0
88	78	17.57	23.5	18.4	22.0
88	79	23.11	24.4	18.8	7.0
88	80	26.16	24.7	18.7	0.0
88	81	24.61	24.5	19.1	4.0
88	82	25.56	24.3	18.7	6.0
88	83	17.55	23.8	18.7	16.0
88	84	13.72	24.5	19.7	0.0
88	85	12.42	27.0	18.0	0.0
88	86	21.85	27.6	17.0	0.0
88	87	21.55	27.8	17.1	0.0
88	88	24.88	25.8	19.3	0.0
88	89	24.67	24.9	19.5	1.0
88	90	19.47	23.4	18.3	15.0
88	91	21.79	23.1	18.8	8.0
88	92	20.25	22.9	18.0	7.0
88	93	21.57	23.1	18.1	13.0
88	94	4.96	19.4	17.3	87.0
88	95	19.14	23.1	18.0	17.0
88	96	22.40	23.8	18.4	6.0
88	97	20.02	23.9	18.6	9.0
88	98	27.30	24.2	18.8	2.0
88	99	27.96	25.6	17.6	0.0
88	100	22.94	24.1	18.6	2.0
88	101	19.70	24.0	18.4	12.0
88	102	26.86	23.2	17.9	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	103	26.24	23.8	17.5	0.0
88	104	22.16	24.4	17.8	0.0
88	105	20.84	25.6	18.8	0.0
88	106	25.27	25.9	16.5	0.0
88	107	28.46	25.5	16.9	0.0
88	108	28.58	25.7	18.7	0.0
88	109	26.69	25.1	19.4	1.0
88	110	27.79	24.7	19.6	0.0
88	111	26.18	24.8	18.8	0.0
88	112	20.21	24.2	18.3	5.0
88	113	26.38	25.1	18.9	1.0
88	114	22.75	24.6	19.2	10.0
88	115	23.23	24.2	18.4	7.0
88	116	28.12	24.2	18.0	6.0
88	117	19.07	23.5	17.7	21.0
88	118	20.42	23.2	17.8	3.0
88	119	21.19	23.2	17.9	8.0
88	120	22.08	24.3	18.2	2.0
88	121	25.46	24.3	19.3	2.0
88	122	23.61	24.7	19.6	2.0
88	123	25.57	25.8	19.9	2.0
88	124	16.55	26.5	18.7	0.0
88	125	24.55	26.2	20.3	0.0
88	126	24.51	25.1	19.9	0.0
88	127	28.20	25.4	18.6	0.0
88	128	17.89	25.2	19.0	0.0
88	129	27.49	25.3	19.2	0.0
88	130	25.96	24.7	18.7	0.0
88	131	12.22	22.9	16.4	8.0
88	132	13.96	21.0	18.6	39.0
88	133	18.06	21.3	18.8	30.0
88	134	26.47	24.8	19.5	24.0
88	135	27.13	24.9	19.4	6.0
88	136	28.34	25.4	19.7	1.0
88	137	29.12	25.7	19.2	1.0
88	138	15.28	25.1	20.2	8.0
88	139	27.24	26.8	20.0	0.0
88	140	26.82	25.6	19.7	0.0
88	141	27.16	24.8	19.3	3.0
88	142	24.55	25.4	18.9	14.0
88	143	27.23	25.3	19.2	9.0
88	144	24.25	24.6	19.8	10.0
88	145	24.34	24.8	19.6	4.0
88	146	28.96	25.4	19.3	0.0
88	147	24.55	24.9	18.9	1.0
88	148	27.92	24.8	19.1	4.0
88	149	23.72	24.4	19.2	11.0
88	150	27.65	25.6	19.3	0.0
88	151	22.93	25.4	19.9	0.0
88	152	28.68	25.8	20.3	2.0
88	153	20.57	26.0	20.1	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	154	20.80	25.7	20.4	3.0
88	155	22.96	25.2	20.1	1.0
88	156	25.53	25.0	19.7	2.0
88	157	29.57	26.1	20.0	4.0
88	158	28.27	25.2	19.4	0.0
88	159	21.84	25.3	19.9	11.0
88	160	27.41	24.9	19.3	10.0
88	161	28.70	25.5	19.5	3.0
88	162	28.59	26.1	19.7	1.0
88	163	28.52	26.1	19.3	0.0
88	164	26.04	26.2	19.8	0.0
88	165	28.83	26.3	19.9	0.0
88	166	22.98	25.5	20.0	1.0
88	167	29.94	26.0	19.7	0.0
88	168	26.73	26.0	19.4	0.0
88	169	26.52	26.5	19.7	0.0
88	170	29.59	26.5	20.1	0.0
88	171	29.15	25.9	19.8	1.0
88	172	21.11	24.8	19.7	4.0
88	173	24.74	26.0	19.9	1.0
88	174	25.53	26.8	20.8	4.0
88	175	27.31	25.6	20.2	5.0
88	176	27.45	25.9	19.3	3.0
88	177	28.36	26.3	20.0	3.0
88	178	25.13	25.6	20.3	4.0
88	179	27.75	26.0	20.6	1.0
88	180	29.87	26.0	20.3	3.0
88	181	25.67	26.5	20.5	1.0
88	182	29.18	27.1	20.3	0.0
88	183	28.49	27.0	20.3	0.0
88	184	25.29	25.2	19.8	0.0
88	185	28.30	26.1	20.4	0.0
88	186	28.13	26.5	20.1	4.0
88	187	28.58	26.1	20.3	3.0
88	188	27.04	25.4	20.3	21.0
88	189	28.06	26.1	20.1	11.0
88	190	23.26	25.6	20.3	6.0
88	191	24.59	25.0	20.1	4.0
88	192	28.50	25.8	19.7	5.0
88	193	21.59	25.7	20.5	5.0
88	194	21.60	27.2	19.6	9.0
88	195	28.88	26.4	20.5	1.0
88	196	27.97	25.7	20.2	1.0
88	197	27.17	25.8	20.3	2.0
88	198	26.28	26.3	20.3	0.0
88	199	26.72	26.4	20.7	1.0
88	200	22.06	25.5	20.7	2.0
88	201	27.74	26.3	20.3	1.0
88	202	27.53	25.6	20.0	0.0
88	203	26.06	26.9	19.5	21.0
88	204	28.06	26.5	20.5	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	205	29.26	26.9	20.2	0.0
88	206	29.79	26.6	19.1	0.0
88	207	22.12	26.5	20.1	2.0
88	208	26.08	26.7	21.2	0.0
88	209	23.25	27.6	21.0	0.0
88	210	24.85	25.6	20.9	2.0
88	211	22.63	26.5	20.6	3.0
88	212	28.06	26.2	21.2	2.0
88	213	27.02	26.5	20.9	0.0
88	214	25.58	26.6	20.0	0.0
88	215	13.95	25.5	18.5	18.0
88	216	22.03	27.3	21.6	0.0
88	217	27.87	27.5	20.8	3.0
88	218	25.56	26.6	20.5	0.0
88	219	16.96	24.6	20.6	4.0
88	220	19.81	26.7	20.7	0.0
88	221	25.56	27.5	21.5	0.0
88	222	28.49	28.0	20.9	0.0
88	223	24.90	27.2	20.0	7.0
88	224	8.97	26.3	20.4	2.0
88	225	26.31	26.7	21.4	4.0
88	226	27.53	26.8	20.8	0.0
88	227	26.60	27.0	20.3	0.0
88	228	28.63	27.5	20.7	4.0
88	229	26.99	27.1	19.8	4.0
88	230	27.63	26.8	19.3	6.0
88	231	25.03	26.6	20.8	0.0
88	232	25.43	26.7	20.9	3.0
88	233	21.32	26.0	20.5	6.0
88	234	24.57	25.4	19.5	10.0
88	235	27.82	26.2	19.7	4.0
88	236	28.85	26.3	19.3	0.0
88	237	28.53	26.6	16.7	0.0
88	238	28.82	27.4	17.6	0.0
88	239	28.30	26.3	19.9	0.0
88	240	28.05	26.9	19.4	2.0
88	241	28.31	26.2	20.1	0.0
88	242	24.00	26.3	20.7	2.0
88	243	26.65	26.9	20.1	3.0
88	244	26.36	26.5	21.2	0.0
88	245	26.61	26.9	21.1	1.0
88	246	25.30	27.3	20.8	0.0
88	247	25.31	27.6	21.2	0.0
88	248	27.26	27.7	21.0	0.0
88	249	20.68	26.9	21.1	4.0
88	250	24.61	28.6	21.9	0.0
88	251	24.99	28.1	21.5	0.0
88	252	27.09	27.6	20.1	0.0
88	253	26.64	28.5	18.7	0.0
88	254	13.00	28.0	19.7	7.0
88	255	15.01	26.2	21.0	5.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	256	26.71	27.3	20.9	0.0
88	257	26.83	27.7	20.6	0.0
88	258	24.98	27.6	18.9	0.0
88	259	24.27	28.2	21.3	0.0
88	260	24.21	27.8	20.7	4.0
88	261	25.08	27.9	20.7	1.0
88	262	23.63	27.7	20.0	0.0
88	263	23.92	27.2	20.4	0.0
88	264	19.40	26.7	20.7	1.0
88	265	24.41	27.5	20.3	0.0
88	266	24.23	27.4	20.7	2.0
88	267	19.24	26.5	20.3	6.0
88	268	22.56	26.5	19.8	0.0
88	269	21.20	27.0	20.7	0.0
88	270	18.40	27.0	20.9	32.0
88	271	10.18	26.7	21.9	15.0
88	272	16.38	26.8	21.6	1.0
88	273	19.93	27.9	21.0	0.0
88	274	23.27	27.4	19.1	0.0
88	275	23.28	27.3	18.8	0.0
88	276	22.71	27.1	18.3	0.0
88	277	23.20	26.6	19.2	0.0
88	278	22.96	27.5	18.3	0.0
88	279	21.97	27.0	20.8	0.0
88	280	20.03	26.5	21.4	3.0
88	281	20.12	26.6	21.4	5.0
88	282	22.69	27.0	20.8	0.0
88	283	18.85	27.0	19.9	0.0
88	284	19.92	28.0	18.7	0.0
88	285	21.04	27.4	18.7	21.0
88	286	18.24	26.7	20.0	16.0
88	287	20.95	26.9	21.2	0.0
88	288	12.55	26.6	20.0	0.0
88	289	14.83	31.5	19.5	0.0
88	290	10.26	28.1	19.2	0.0
88	291	6.53	24.6	20.2	53.0
88	292	11.96	26.3	19.5	4.0
88	293	10.50	27.6	19.1	0.0
88	294	12.66	26.9	19.7	0.0
88	295	14.98	27.3	19.6	0.0
88	296	19.50	27.0	18.9	0.0
88	297	16.99	27.1	18.7	0.0
88	298	15.98	27.0	20.3	0.0
88	299	20.56	26.1	20.2	0.0
88	300	10.71	24.1	20.2	4.0
88	301	15.02	25.3	19.8	0.0
88	302	19.04	25.4	20.3	6.0
88	303	20.70	25.9	19.7	0.0
88	304	16.71	25.3	20.6	0.0
88	305	15.84	25.7	20.5	0.0
88	306	19.22	26.0	19.7	2.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	307	18.26	25.9	19.6	0.0
88	308	13.93	29.0	18.6	0.0
88	309	1.93	23.7	19.2	60.0
88	310	6.85	28.0	19.9	3.0
88	311	17.17	26.9	20.6	0.0
88	312	19.28	26.3	21.3	1.0
88	313	15.05	25.6	20.6	3.0
88	314	10.60	23.8	20.5	8.0
88	315	15.22	25.0	20.5	1.0
88	316	19.69	25.1	20.4	6.0
88	317	19.10	25.7	20.8	3.0
88	318	12.19	23.6	20.3	41.0
88	319	15.86	24.5	20.1	8.0
88	320	12.61	25.0	20.0	0.0
88	321	13.78	25.7	19.3	1.0
88	322	12.70	26.3	20.1	13.0
88	323	15.59	26.3	20.7	4.0
88	324	18.45	25.6	20.6	0.0
88	325	15.10	25.2	20.2	6.0
88	326	14.96	24.7	20.1	4.0
88	327	9.95	23.2	20.0	9.0
88	328	13.54	23.3	20.1	16.0
88	329	13.04	24.7	19.4	7.0
88	330	14.13	25.9	19.6	0.0
88	331	14.03	25.8	20.2	0.0
88	332	11.88	25.4	20.4	0.0
88	333	11.80	26.2	20.4	1.0
88	334	14.19	25.3	19.9	0.0
88	335	17.77	25.7	20.1	0.0
88	336	15.80	25.0	19.7	0.0
88	337	16.21	27.1	17.6	0.0
88	338	10.58	29.1	17.5	0.0
88	339	16.52	29.8	17.9	0.0
88	340	13.17	27.7	17.6	0.0
88	341	1.78	23.8	18.1	107.0
88	342	10.73	25.2	19.0	11.0
88	343	14.42	26.9	17.8	0.0
88	344	17.37	26.1	19.7	0.0
88	345	12.28	24.1	19.8	3.0
88	346	13.64	23.7	18.7	5.0
88	347	17.18	24.9	19.8	0.0
88	348	9.96	24.9	17.8	4.0
88	349	12.57	27.5	16.4	0.0
88	350	10.23	28.0	17.5	0.0
88	351	1.20	21.7	16.2	124.0
88	352	11.74	24.4	14.7	2.0
88	353	12.90	23.7	13.7	1.0
88	354	13.67	25.1	17.9	0.0
88	355	13.43	25.1	19.9	0.0
88	356	14.65	23.9	20.2	2.0
88	357	15.91	24.7	19.4	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
88	358	17.59	24.6	19.6	4.0
88	359	13.91	24.1	19.2	9.0
88	360	15.95	23.9	18.9	23.0
88	361	15.60	24.3	18.4	3.0
88	362	14.42	24.3	19.0	9.0
88	363	9.93	23.6	19.5	9.0
88	364	5.75	21.3	18.7	50.0
88	365	6.89	20.7	18.3	32.0
88	366	9.54	22.8	19.0	12.0
89	1	15.88	22.6	18.6	8.0
89	2	15.03	24.0	17.6	1.0
89	3	17.53	24.6	18.7	4.0
89	4	17.55	23.5	18.3	0.0
89	5	12.90	22.7	16.9	8.0
89	6	11.63	22.8	18.2	26.0
89	7	12.26	22.1	18.6	29.0
89	8	13.90	22.8	17.3	19.0
89	9	10.45	21.1	17.3	33.0
89	10	6.01	22.1	18.3	54.0
89	11	6.57	24.1	19.0	23.0
89	12	12.87	25.0	18.6	22.0
89	13	5.98	21.3	18.9	21.0
89	14	9.63	20.3	18.7	19.0
89	15	12.28	21.2	18.3	19.0
89	16	16.43	23.2	18.5	5.0
89	17	18.29	23.5	18.3	2.0
89	18	16.53	23.3	18.1	0.0
89	19	17.41	23.4	18.3	26.0
89	20	16.20	24.0	17.9	2.0
89	21	16.22	23.7	17.5	2.0
89	22	18.15	23.6	18.0	1.0
89	23	12.23	23.7	18.4	0.0
89	24	17.61	27.9	16.4	0.0
89	25	16.25	24.9	16.6	0.0
89	26	18.44	23.8	17.6	1.0
89	27	18.56	24.5	16.7	0.0
89	28	18.46	28.3	14.6	0.0
89	29	5.49	24.3	17.3	17.0
89	30	10.13	24.1	16.0	0.0
89	31	6.85	23.3	16.9	0.0
89	32	14.69	27.5	15.8	0.0
89	33	17.45	27.3	16.4	12.0
89	34	5.03	19.7	16.5	51.0
89	35	2.53	19.2	15.7	178.0
89	36	15.06	24.7	17.1	0.0
89	37	12.45	25.3	17.7	3.0
89	38	11.75	26.6	18.6	1.0
89	39	18.39	27.8	18.7	0.0
89	40	16.71	28.0	16.3	3.0
89	41	8.98	23.2	19.3	1.0
89	42	7.17	24.9	15.5	21.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	43	12.60	27.8	16.7	0.0
89	44	18.08	29.2	16.2	0.0
89	45	17.65	25.0	16.3	0.0
89	46	15.76	26.0	16.3	0.0
89	47	20.69	25.2	15.4	0.0
89	48	21.75	25.2	17.4	0.0
89	49	21.45	24.6	18.6	0.0
89	50	21.29	24.1	17.6	1.0
89	51	20.82	24.2	17.5	0.0
89	52	21.39	24.3	17.9	3.0
89	53	13.35	22.3	18.3	2.0
89	54	12.73	22.6	18.5	14.0
89	55	18.64	22.8	17.2	2.0
89	56	21.40	22.3	16.9	3.0
89	57	23.01	23.1	16.9	0.0
89	58	9.31	26.5	15.4	0.0
89	59	5.45	23.2	17.7	8.0
89	60	10.20	26.7	17.3	5.0
89	61	17.27	27.0	21.9	3.0
89	62	17.04	28.2	22.0	4.0
89	63	6.08	24.4	19.0	50.0
89	64	7.94	21.4	18.5	6.0
89	65	6.74	20.9	18.7	27.0
89	66	17.07	23.3	16.9	17.0
89	67	16.99	22.1	15.9	0.0
89	68	19.09	22.9	14.3	0.0
89	69	22.31	23.4	16.5	0.0
89	70	20.37	23.6	14.0	0.0
89	71	19.06	24.2	18.1	4.0
89	72	24.85	24.4	16.8	0.0
89	73	25.32	23.9	17.9	0.0
89	74	14.79	24.5	18.9	0.0
89	75	17.90	27.8	16.8	0.0
89	76	18.54	28.3	16.3	0.0
89	77	21.42	27.2	16.6	0.0
89	78	16.92	26.3	17.4	0.0
89	79	21.13	26.1	16.6	0.0
89	80	25.00	25.6	18.9	0.0
89	81	25.46	25.0	19.2	0.0
89	82	25.69	24.8	19.2	0.0
89	83	24.17	25.3	19.2	3.0
89	84	23.03	26.9	19.4	0.0
89	85	17.46	27.6	17.7	0.0
89	86	26.26	25.5	16.8	0.0
89	87	25.14	25.7	19.4	1.0
89	88	23.43	24.8	19.1	8.0
89	89	17.16	23.6	19.2	1.0
89	90	15.77	23.4	18.7	37.0
89	91	22.75	24.0	18.7	13.0
89	92	19.58	24.7	18.6	25.0
89	93	15.09	26.7	16.9	7.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	94	15.12	28.0	16.2	2.0
89	95	6.18	19.5	16.2	149.0
89	96	7.22	19.0	16.1	91.0
89	97	1.84	17.5	15.9	224.0
89	98	3.86	19.0	16.5	131.0
89	99	14.26	21.9	16.5	127.0
89	100	15.43	23.2	15.6	2.0
89	101	23.30	23.8	15.3	0.0
89	102	13.27	23.5	17.9	6.0
89	103	10.03	22.3	18.5	21.0
89	104	8.39	18.8	16.6	54.0
89	105	8.00	19.8	16.3	0.0
89	106	6.43	20.5	17.1	0.0
89	107	12.73	21.8	16.9	0.0
89	108	19.97	22.6	17.2	0.0
89	109	24.86	23.7	17.7	1.0
89	110	14.60	20.6	17.9	52.0
89	111	19.30	23.5	18.3	3.0
89	112	25.42	24.3	18.7	4.0
89	113	11.51	22.1	19.3	33.0
89	114	23.55	25.1	19.6	1.0
89	115	21.32	23.5	17.8	8.0
89	116	22.78	24.7	16.1	6.0
89	117	11.59	22.2	17.5	22.0
89	118	9.71	21.8	18.2	35.0
89	119	8.11	20.7	17.8	71.0
89	120	12.01	23.5	17.5	6.0
89	121	20.72	24.9	16.5	0.0
89	122	14.95	24.2	16.8	0.0
89	123	11.22	21.8	15.4	4.0
89	124	19.28	23.2	17.2	0.0
89	125	22.73	23.2	18.4	0.0
89	126	19.63	24.8	18.3	1.0
89	127	22.04	24.6	18.8	2.0
89	128	23.17	25.2	19.2	0.0
89	129	13.11	23.9	20.2	0.0
89	130	24.33	25.6	19.7	1.0
89	131	22.20	25.3	19.4	1.0
89	132	26.43	25.6	19.7	1.0
89	133	21.21	24.9	19.7	6.0
89	134	15.77	23.4	19.7	8.0
89	135	20.68	25.0	19.7	12.0
89	136	20.56	24.5	19.5	1.0
89	137	22.39	24.3	19.7	0.0
89	138	26.87	25.4	18.7	2.0
89	139	20.19	23.6	19.1	6.0
89	140	24.55	25.2	19.7	7.0
89	141	23.51	25.7	19.6	6.0
89	142	15.26	24.1	18.8	46.0
89	143	19.47	24.8	19.7	15.0
89	144	21.67	25.0	19.9	6.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	145	14.99	23.9	19.8	2.0
89	146	23.73	25.6	20.0	1.0
89	147	25.24	26.6	21.0	3.0
89	148	21.52	25.4	20.4	0.0
89	149	17.77	24.7	19.7	3.0
89	150	19.12	24.3	19.2	35.0
89	151	13.29	24.5	19.3	3.0
89	152	27.72	26.4	19.3	0.0
89	153	28.67	26.3	18.9	0.0
89	154	27.12	26.0	20.6	10.0
89	155	18.04	24.5	20.2	5.0
89	156	22.72	25.0	19.5	8.0
89	157	20.36	24.7	20.1	4.0
89	158	19.06	24.6	19.7	1.0
89	159	19.59	25.2	19.8	2.0
89	160	25.82	25.2	20.5	0.0
89	161	14.22	24.7	19.9	0.0
89	162	23.38	24.8	19.0	2.0
89	163	15.55	22.3	19.7	11.0
89	164	25.07	25.0	18.6	4.0
89	165	20.60	24.5	19.2	0.0
89	166	18.49	24.5	19.6	11.0
89	167	16.06	25.3	20.2	16.0
89	168	12.48	23.2	19.9	27.0
89	169	26.88	25.9	20.0	2.0
89	170	25.62	26.2	19.9	1.0
89	171	17.96	24.7	20.1	6.0
89	172	25.88	26.7	19.4	0.0
89	173	27.26	26.7	19.1	0.0
89	174	27.98	25.9	19.8	0.0
89	175	24.77	25.7	19.7	0.0
89	176	25.46	24.9	19.4	1.0
89	177	19.92	26.1	18.6	0.0
89	178	22.80	25.5	19.8	0.0
89	179	25.15	25.8	19.7	3.0
89	180	22.32	25.5	19.8	3.0
89	181	22.08	25.2	19.9	11.0
89	182	22.05	25.2	19.9	4.0
89	183	25.40	25.6	19.7	3.0
89	184	22.28	25.4	19.6	8.0
89	185	25.52	25.3	19.8	19.0
89	186	27.45	25.8	19.5	26.0
89	187	19.00	24.5	19.5	21.0
89	188	27.54	25.7	19.9	0.0
89	189	26.12	25.6	20.1	1.0
89	190	22.26	26.1	20.6	4.0
89	191	21.91	25.9	20.6	23.0
89	192	25.85	25.9	20.3	4.0
89	193	21.28	25.3	20.1	7.0
89	194	17.99	24.2	19.9	39.0
89	195	23.54	25.3	20.3	9.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	196	26.71	26.8	21.0	1.0
89	197	23.64	26.1	21.1	2.0
89	198	19.87	25.7	20.7	3.0
89	199	18.68	25.3	19.7	7.0
89	200	14.13	23.0	19.6	33.0
89	201	5.91	25.4	21.5	5.0
89	202	18.28	26.8	21.9	0.0
89	203	5.21	23.1	21.7	53.0
89	204	22.76	26.4	21.2	3.0
89	205	27.88	25.4	20.7	0.0
89	206	26.82	25.5	19.9	1.0
89	207	23.73	26.2	19.6	0.0
89	208	25.93	25.8	20.7	5.0
89	209	22.70	25.2	20.3	20.0
89	210	24.40	24.6	20.3	13.0
89	211	26.17	25.5	20.1	1.0
89	212	26.41	25.9	20.1	0.0
89	213	23.14	25.4	19.9	11.0
89	214	24.99	25.7	19.9	10.0
89	215	21.67	25.6	19.4	3.0
89	216	19.93	25.8	20.6	11.0
89	217	21.91	26.1	19.7	4.0
89	218	24.36	25.9	20.4	5.0
89	219	27.56	27.6	20.4	0.0
89	220	24.72	27.5	21.2	0.0
89	221	25.71	26.5	20.3	0.0
89	222	27.40	26.8	20.2	0.0
89	223	22.75	26.0	20.6	1.0
89	224	27.08	26.8	20.6	0.0
89	225	26.54	26.9	20.8	1.0
89	226	19.36	26.8	20.9	2.0
89	227	24.90	26.3	20.9	2.0
89	228	25.96	26.2	20.5	1.0
89	229	23.86	25.0	20.1	5.0
89	230	23.23	26.0	19.8	0.0
89	231	11.78	25.8	21.0	14.0
89	232	6.50	23.1	21.4	41.0
89	233	13.27	26.6	21.5	7.0
89	234	25.07	26.2	20.6	0.0
89	235	20.10	26.0	20.1	6.0
89	236	25.03	26.1	20.3	1.0
89	237	26.28	25.8	20.0	0.0
89	238	26.74	26.3	19.8	0.0
89	239	22.41	26.9	19.9	0.0
89	240	26.01	26.8	18.8	0.0
89	241	21.00	26.9	18.0	0.0
89	242	24.65	25.9	19.8	4.0
89	243	19.25	25.3	20.3	8.0
89	244	16.19	25.0	19.5	41.0
89	245	19.74	25.3	20.6	8.0
89	246	18.48	25.2	19.9	18.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	247	24.35	25.2	19.9	5.0
89	248	16.04	25.6	19.7	1.0
89	249	18.13	27.8	17.0	1.0
89	250	23.71	27.1	19.8	1.0
89	251	20.41	25.8	20.9	0.0
89	252	21.78	25.5	20.3	2.0
89	253	23.35	25.3	19.8	5.0
89	254	23.92	25.9	20.3	15.0
89	255	-99.00	-99.0	-99.0	-99.0
89	256	-99.00	-99.0	-99.0	-99.0
89	257	-99.00	-99.0	-99.0	-99.0
89	258	-99.00	-99.0	-99.0	-99.0
89	259	-99.00	-99.0	-99.0	-99.0
89	260	-99.00	-99.0	-99.0	-99.0
89	261	-99.00	-99.0	-99.0	-99.0
89	262	18.58	25.4	19.2	2.0
89	263	24.11	25.9	20.1	1.0
89	264	22.92	26.6	19.3	1.0
89	265	21.23	25.9	19.7	14.0
89	266	23.58	25.8	20.1	2.0
89	267	23.61	26.3	19.9	3.0
89	268	22.56	26.2	20.3	2.0
89	269	22.12	25.8	20.6	1.0
89	270	18.69	26.1	20.2	1.0
89	271	17.40	26.6	19.6	0.0
89	272	18.99	26.2	20.3	0.0
89	273	20.10	26.3	17.5	0.0
89	274	17.54	28.2	20.5	0.0
89	275	14.77	29.5	19.2	0.0
89	276	10.01	28.6	21.0	1.0
89	277	13.22	27.3	20.7	0.0
89	278	12.70	29.8	19.7	13.0
89	279	11.10	28.8	20.5	3.0
89	280	14.65	27.6	18.6	0.0
89	281	8.81	28.0	18.5	18.0
89	282	12.45	28.3	19.2	14.0
89	283	16.28	26.3	21.9	0.0
89	284	20.56	25.8	21.0	0.0
89	285	16.97	28.4	18.0	0.0
89	286	11.56	29.1	18.1	0.0
89	287	18.94	31.1	18.8	0.0
89	288	10.59	30.0	20.0	1.0
89	289	21.31	26.7	19.5	0.0
89	290	18.53	26.9	20.8	0.0
89	291	16.84	26.2	21.1	1.0
89	292	13.83	24.7	20.6	6.0
89	293	21.52	25.9	20.1	3.0
89	294	20.67	25.7	19.6	1.0
89	295	20.54	25.7	20.0	0.0
89	296	12.00	23.8	20.5	26.0
89	297	10.96	24.0	20.6	11.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	298	16.26	25.0	20.2	1.0
89	299	19.20	25.3	20.3	0.0
89	300	18.81	25.3	19.0	3.0
89	301	20.89	25.8	17.7	23.0
89	302	10.77	25.9	19.2	0.0
89	303	17.30	29.9	18.6	0.0
89	304	12.15	27.0	18.4	0.0
89	305	13.24	26.5	17.9	1.0
89	306	18.39	26.6	16.2	0.0
89	307	16.12	26.5	17.5	0.0
89	308	16.95	28.1	19.4	0.0
89	309	19.44	25.5	20.9	0.0
89	310	17.17	24.6	20.5	0.0
89	311	18.82	24.8	19.0	1.0
89	312	14.26	24.3	19.4	5.0
89	313	14.61	28.4	17.1	1.0
89	314	15.56	28.4	17.7	0.0
89	315	11.69	27.6	17.6	0.0
89	316	9.54	27.5	19.7	0.0
89	317	10.78	27.6	20.1	0.0
89	318	8.40	27.4	19.4	12.0
89	319	9.28	27.2	19.4	35.0
89	320	3.71	20.9	17.6	12.0
89	321	14.56	22.9	17.9	1.0
89	322	17.73	23.8	17.9	0.0
89	323	7.38	22.4	17.8	1.0
89	324	13.34	23.7	18.2	3.0
89	325	15.89	24.0	19.2	5.0
89	326	16.95	24.1	19.9	0.0
89	327	18.34	24.5	19.3	0.0
89	328	18.41	24.5	19.1	0.0
89	329	12.95	24.2	16.9	0.0
89	330	17.34	25.2	16.3	0.0
89	331	18.57	24.5	17.3	1.0
89	332	14.64	27.9	15.1	0.0
89	333	16.09	28.7	16.7	4.0
89	334	7.39	27.6	18.4	28.0
89	335	16.91	23.5	16.5	0.0
89	336	15.69	25.3	16.6	0.0
89	337	9.31	25.2	17.1	0.0
89	338	16.23	25.2	16.1	0.0
89	339	12.95	27.2	16.3	0.0
89	340	16.96	25.4	15.2	0.0
89	341	16.89	26.0	19.9	0.0
89	342	12.53	26.7	17.0	0.0
89	343	1.05	22.6	16.9	59.0
89	344	14.95	22.4	14.1	0.0
89	345	9.58	23.5	15.0	1.0
89	346	7.67	23.8	16.2	4.0
89	347	3.55	19.7	16.6	31.0
89	348	12.46	22.9	14.6	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
89	349	14.35	23.5	13.5	0.0
89	350	17.09	24.4	12.9	0.0
89	351	12.52	24.2	13.8	0.0
89	352	15.32	24.0	13.4	0.0
89	353	17.12	28.6	14.8	0.0
89	354	8.67	23.3	18.3	21.0
89	355	6.95	25.2	17.8	6.0
89	356	9.32	26.9	16.2	0.0
89	357	15.14	27.4	15.6	0.0
89	358	10.82	27.8	16.3	0.0
89	359	12.76	25.3	17.8	0.0
89	360	15.63	24.7	16.2	0.0
89	361	16.05	27.2	16.3	0.0
89	362	13.04	27.3	16.1	0.0
89	363	9.56	23.9	17.2	1.0
89	364	12.49	22.9	18.6	2.0
89	365	11.36	23.1	18.5	21.0
90	1	3.49	20.9	18.1	19.0
90	2	13.26	22.7	18.3	8.0
90	3	12.20	22.9	19.0	2.0
90	4	10.06	22.9	18.9	6.0
90	5	16.33	23.6	19.5	1.0
90	6	16.88	24.0	18.2	0.0
90	7	16.43	26.9	16.2	0.0
90	8	-99.00	-99.0	-99.0	-99.0
90	9	-99.00	-99.0	-99.0	-99.0
90	10	-99.00	-99.0	-99.0	-99.0
90	11	-99.00	-99.0	-99.0	-99.0
90	12	-99.00	-99.0	-99.0	-99.0
90	13	-99.00	-99.0	-99.0	-99.0
90	14	-99.00	-99.0	-99.0	-99.0
90	15	-99.00	-99.0	-99.0	-99.0
90	16	-99.00	-99.0	-99.0	-99.0
90	17	-99.00	-99.0	-99.0	-99.0
90	18	-99.00	-99.0	-99.0	-99.0
90	19	-99.00	-99.0	-99.0	-99.0
90	20	-99.00	-99.0	-99.0	-99.0
90	21	-99.00	-99.0	-99.0	-99.0
90	22	-99.00	-99.0	-99.0	-99.0
90	23	-99.00	-99.0	-99.0	-99.0
90	24	-99.00	-99.0	-99.0	-99.0
90	25	-99.00	-99.0	-99.0	-99.0
90	26	-99.00	-99.0	-99.0	-99.0
90	27	-99.00	-99.0	-99.0	-99.0
90	28	-99.00	-99.0	-99.0	-99.0
90	29	-99.00	-99.0	-99.0	-99.0
90	30	-99.00	-99.0	-99.0	-99.0
90	31	-99.00	-99.0	-99.0	-99.0
90	32	-99.00	-99.0	-99.0	-99.0
90	33	-99.00	-99.0	-99.0	-99.0
90	34	-99.00	-99.0	-99.0	-99.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	35	-99.00	-99.0	-99.0	-99.0
90	36	-99.00	-99.0	-99.0	-99.0
90	37	-99.00	-99.0	-99.0	-99.0
90	38	-99.00	-99.0	-99.0	-99.0
90	39	-99.00	-99.0	-99.0	-99.0
90	40	-99.00	-99.0	-99.0	-99.0
90	41	-99.00	-99.0	-99.0	-99.0
90	42	-99.00	-99.0	-99.0	-99.0
90	43	-99.00	-99.0	-99.0	-99.0
90	44	-99.00	-99.0	-99.0	-99.0
90	45	-99.00	-99.0	-99.0	-99.0
90	46	-99.00	-99.0	-99.0	-99.0
90	47	19.32	24.1	17.7	3.0
90	48	6.32	21.9	16.2	30.0
90	49	9.21	21.5	13.7	2.0
90	50	14.41	22.6	13.3	5.0
90	51	15.71	21.7	13.2	3.0
90	52	13.99	22.6	12.9	0.0
90	53	15.91	25.7	13.7	0.0
90	54	17.99	25.6	14.5	0.0
90	55	7.10	23.0	16.3	18.0
90	56	6.06	24.3	17.7	50.0
90	57	5.58	19.3	15.5	79.0
90	58	5.29	17.8	15.4	24.0
90	59	2.73	15.8	14.5	56.0
90	60	3.70	16.7	14.1	119.0
90	61	13.31	21.1	14.4	19.0
90	62	9.64	21.1	17.3	0.0
90	63	9.77	21.5	17.3	0.0
90	64	4.10	19.7	17.2	27.0
90	65	13.18	21.9	17.4	51.0
90	66	8.24	20.6	17.5	30.0
90	67	8.43	20.8	17.1	22.0
90	68	15.08	21.9	17.9	5.0
90	69	22.86	23.3	18.9	0.0
90	70	15.96	22.6	18.3	1.0
90	71	22.54	22.8	18.1	1.0
90	72	15.89	27.1	17.9	1.0
90	73	24.31	27.0	15.6	0.0
90	74	4.59	17.9	16.0	24.0
90	75	21.40	21.2	15.9	0.0
90	76	24.30	21.5	16.0	0.0
90	77	24.03	23.2	17.0	0.0
90	78	20.58	27.4	15.0	0.0
90	79	10.72	26.4	16.0	10.0
90	80	12.30	23.1	15.5	1.0
90	81	16.84	24.3	16.2	0.0
90	82	21.98	24.7	17.9	0.0
90	83	20.84	24.8	18.7	2.0
90	84	18.52	27.3	16.5	0.0
90	85	23.53	25.3	15.8	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	86	19.76	24.0	18.0	5.0
90	87	24.82	24.0	17.9	0.0
90	88	20.63	22.6	16.5	0.0
90	89	20.49	22.6	16.6	2.0
90	90	18.41	22.5	16.5	1.0
90	91	22.68	23.7	17.2	1.0
90	92	18.02	23.7	17.7	3.0
90	93	14.40	21.4	17.2	5.0
90	94	22.19	23.8	17.3	0.0
90	95	24.21	23.9	16.6	0.0
90	96	21.07	26.2	14.6	0.0
90	97	18.31	25.0	15.1	0.0
90	98	20.06	27.6	14.7	0.0
90	99	12.77	25.6	15.6	0.0
90	100	11.37	26.8	17.0	0.0
90	101	21.61	28.3	16.4	0.0
90	102	25.71	27.4	17.1	0.0
90	103	23.98	26.2	17.5	2.0
90	104	22.21	25.0	20.1	4.0
90	105	18.18	24.5	18.9	0.0
90	106	22.90	24.2	18.4	0.0
90	107	19.24	24.5	19.2	1.0
90	108	20.77	24.5	18.6	0.0
90	109	13.64	23.1	18.6	5.0
90	110	20.57	23.8	19.2	3.0
90	111	19.28	23.1	18.3	18.0
90	112	23.47	23.9	18.4	6.0
90	113	15.04	24.2	18.2	1.0
90	114	17.15	25.3	19.6	1.0
90	115	22.40	25.9	20.3	0.0
90	116	21.45	27.1	18.7	0.0
90	117	22.65	28.7	17.9	0.0
90	118	11.04	26.3	18.6	0.0
90	119	26.09	27.2	18.2	0.0
90	120	27.31	25.7	19.4	0.0
90	121	22.35	25.0	19.5	1.0
90	122	26.24	25.7	19.0	0.0
90	123	11.05	22.5	16.9	19.0
90	124	21.87	23.2	16.4	5.0
90	125	19.78	22.9	17.2	7.0
90	126	19.28	23.4	17.6	4.0
90	127	20.30	23.0	18.8	9.0
90	128	21.15	24.3	17.9	36.0
90	129	27.66	24.3	18.4	0.0
90	130	16.15	24.1	19.0	2.0
90	131	23.75	25.9	18.1	0.0
90	132	27.17	24.8	18.3	0.0
90	133	18.22	26.0	17.1	2.0
90	134	22.04	24.1	18.4	4.0
90	135	25.03	24.1	18.9	1.0
90	136	26.63	24.4	18.1	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	137	25.72	24.7	18.8	9.0
90	138	24.15	24.3	18.4	8.0
90	139	20.45	24.0	19.0	10.0
90	140	16.85	23.0	18.4	16.0
90	141	17.37	23.4	18.9	3.0
90	142	24.56	24.0	18.5	0.0
90	143	26.05	25.1	19.2	1.0
90	144	21.75	24.4	18.2	8.0
90	145	22.36	23.7	18.6	3.0
90	146	17.05	23.3	18.5	5.0
90	147	21.96	24.3	19.2	19.0
90	148	26.00	25.4	18.8	5.0
90	149	23.97	25.0	19.4	1.0
90	150	22.17	24.7	19.6	1.0
90	151	25.08	25.6	19.7	1.0
90	152	24.11	25.5	19.5	4.0
90	153	21.02	24.8	20.0	0.0
90	154	13.34	23.5	19.7	3.0
90	155	26.55	25.7	20.3	3.0
90	156	19.06	25.1	19.9	4.0
90	157	25.33	25.5	19.7	4.0
90	158	24.93	25.8	19.7	5.0
90	159	20.87	25.0	19.7	8.0
90	160	26.22	25.0	19.5	0.0
90	161	22.74	24.6	19.1	2.0
90	162	25.78	25.7	19.5	0.0
90	163	19.61	25.0	19.5	3.0
90	164	26.39	25.0	19.4	2.0
90	165	22.01	24.9	18.9	18.0
90	166	21.81	24.4	19.4	20.0
90	167	13.21	22.8	18.8	45.0
90	168	21.75	24.6	18.4	17.0
90	169	19.25	22.8	18.9	6.0
90	170	19.51	24.1	18.5	16.0
90	171	14.97	23.6	18.7	36.0
90	172	23.82	24.9	19.2	2.0
90	173	24.60	24.2	19.3	3.0
90	174	21.45	24.2	18.2	5.0
90	175	19.72	24.5	18.7	6.0
90	176	24.75	24.4	18.6	2.0
90	177	26.40	24.6	19.3	0.0
90	178	27.32	26.0	19.4	0.0
90	179	24.26	25.6	19.6	1.0
90	180	17.71	24.4	19.2	11.0
90	181	17.56	24.6	19.2	6.0
90	182	19.68	25.1	19.8	3.0
90	183	18.72	25.0	19.7	7.0
90	184	23.55	25.0	20.1	0.0
90	185	25.79	24.7	19.2	0.0
90	186	21.09	25.2	18.7	1.0
90	187	24.91	25.4	16.2	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	188	24.60	25.9	17.4	0.0
90	189	15.49	23.4	19.3	1.0
90	190	26.83	26.2	20.0	1.0
90	191	25.39	25.5	20.3	1.0
90	192	25.21	25.2	19.6	4.0
90	193	21.77	25.4	19.3	7.0
90	194	25.19	25.2	19.7	0.0
90	195	23.07	25.8	19.3	1.0
90	196	24.03	26.0	20.2	5.0
90	197	15.35	24.5	19.8	3.0
90	198	24.24	26.1	20.2	3.0
90	199	25.74	25.9	20.7	7.0
90	200	15.42	24.7	20.4	3.0
90	201	16.02	24.2	19.8	0.0
90	202	12.72	25.4	19.7	1.0
90	203	25.91	26.3	20.5	0.0
90	204	25.05	26.5	20.0	2.0
90	205	20.32	25.2	20.2	6.0
90	206	19.68	24.7	19.0	6.0
90	207	18.50	25.2	20.2	13.0
90	208	21.69	26.7	20.6	15.0
90	209	17.70	25.5	20.6	4.0
90	210	26.39	27.0	20.1	0.0
90	211	18.42	26.5	21.0	1.0
90	212	24.96	26.4	21.3	4.0
90	213	24.54	26.3	20.6	0.0
90	214	25.43	26.5	20.4	1.0
90	215	17.21	24.4	19.9	6.0
90	216	23.63	25.6	20.5	2.0
90	217	12.44	24.7	20.2	4.0
90	218	20.05	25.8	19.5	6.0
90	219	23.24	26.2	20.1	3.0
90	220	25.15	26.1	21.4	0.0
90	221	20.91	25.8	20.5	0.0
90	222	25.12	25.8	19.8	0.0
90	223	25.76	25.9	19.8	2.0
90	224	19.00	25.6	19.7	1.0
90	225	23.89	26.8	21.2	1.0
90	226	23.63	27.3	21.6	0.0
90	227	20.66	26.7	20.7	5.0
90	228	22.20	26.2	21.0	1.0
90	229	24.98	26.4	19.3	2.0
90	230	22.71	26.1	19.7	18.0
90	231	20.64	26.6	20.1	21.0
90	232	25.38	26.9	19.6	0.0
90	233	25.91	27.0	20.6	0.0
90	234	24.98	26.4	20.5	2.0
90	235	25.41	27.0	20.6	6.0
90	236	20.19	27.1	21.1	4.0
90	237	21.32	26.9	20.7	0.0
90	238	14.29	24.8	20.2	10.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	239	14.49	25.6	19.8	3.0
90	240	23.11	26.5	20.3	0.0
90	241	25.87	26.6	20.2	0.0
90	242	25.38	26.3	19.7	0.0
90	243	25.64	27.3	17.8	0.0
90	244	21.80	27.9	18.3	0.0
90	245	24.54	27.6	21.9	0.0
90	246	21.70	27.2	21.5	0.0
90	247	22.14	28.0	-99.0	5.0
90	248	20.82	26.5	21.3	8.0
90	249	22.91	26.1	20.8	5.0
90	250	20.58	26.5	20.6	5.0
90	251	21.36	26.9	21.3	3.0
90	252	24.37	26.5	20.4	20.0
90	253	21.84	26.3	19.9	2.0
90	254	24.70	26.5	20.7	2.0
90	255	21.02	26.2	19.7	6.0
90	256	22.12	26.9	21.2	3.0
90	257	18.46	26.2	21.3	7.0
90	258	18.50	26.4	20.9	2.0
90	259	16.23	27.0	20.8	14.0
90	260	19.91	26.9	21.7	7.0
90	261	12.65	25.3	21.3	13.0
90	262	17.29	26.6	-99.0	0.0
90	263	14.17	27.1	22.6	0.0
90	264	23.80	28.0	19.6	0.0
90	265	14.67	25.8	20.8	2.0
90	266	23.02	26.4	20.4	4.0
90	267	21.88	26.8	21.1	1.0
90	268	24.25	26.6	20.5	0.0
90	269	23.23	26.2	20.5	1.0
90	270	23.49	26.4	21.2	0.0
90	271	18.68	25.6	20.7	0.0
90	272	7.60	24.3	21.0	6.0
90	273	20.78	26.8	20.6	7.0
90	274	16.99	25.7	19.9	8.0
90	275	23.10	26.9	20.6	0.0
90	276	15.80	27.0	20.9	1.0
90	277	22.78	26.9	20.8	1.0
90	278	22.18	26.4	20.9	1.0
90	279	22.73	26.3	21.5	0.0
90	280	22.86	26.6	21.6	0.0
90	281	22.88	27.0	20.9	0.0
90	282	21.79	26.8	20.7	0.0
90	283	13.83	25.2	20.3	9.0
90	284	16.23	25.0	19.8	6.0
90	285	17.63	25.5	20.5	2.0
90	286	21.14	25.7	20.7	1.0
90	287	13.87	25.6	20.7	1.0
90	288	18.12	26.1	20.8	6.0
90	289	11.08	25.4	20.3	20.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	290	14.86	24.5	19.9	25.0
90	291	14.38	24.3	20.2	0.0
90	292	19.48	27.0	20.7	0.0
90	293	16.16	27.5	20.9	0.0
90	294	19.59	27.4	21.1	0.0
90	295	19.54	26.1	21.2	0.0
90	296	17.47	25.6	19.6	0.0
90	297	20.26	25.8	20.4	1.0
90	298	20.12	25.4	20.1	0.0
90	299	13.10	24.6	19.2	1.0
90	300	20.88	25.6	20.4	0.0
90	301	20.51	25.4	19.2	0.0
90	302	13.14	24.5	19.9	0.0
90	303	14.64	25.3	19.1	0.0
90	304	20.61	26.0	20.9	0.0
90	305	15.10	27.9	19.7	0.0
90	306	17.43	26.6	21.7	0.0
90	307	19.08	25.6	20.1	0.0
90	308	19.05	25.6	19.4	0.0
90	309	14.06	25.2	20.3	0.0
90	310	18.45	26.2	20.8	0.0
90	311	16.06	27.6	21.3	0.0
90	312	18.74	25.8	21.0	0.0
90	313	18.99	26.3	19.5	0.0
90	314	15.44	28.1	17.1	0.0
90	315	16.21	27.0	17.9	0.0
90	316	2.92	25.2	19.5	0.0
90	317	12.24	26.2	19.2	1.0
90	318	9.78	21.6	17.9	9.0
90	319	16.28	24.2	19.1	1.0
90	320	12.55	24.8	18.1	15.0
90	321	5.52	23.5	18.5	13.0
90	322	3.12	20.4	17.8	43.0
90	323	12.04	24.7	16.7	83.0
90	324	1.60	24.0	18.9	9.0
90	325	9.75	25.8	20.0	0.0
90	326	16.35	30.3	18.5	0.0
90	327	4.73	23.7	16.7	9.0
90	328	15.05	24.4	15.6	10.0
90	329	7.47	22.5	17.6	0.0
90	330	11.40	25.5	16.9	0.0
90	331	8.66	27.7	19.2	0.0
90	332	13.24	27.0	18.3	0.0
90	333	17.46	25.9	19.7	0.0
90	334	17.80	25.0	20.5	0.0
90	335	17.21	25.5	19.9	0.0
90	336	14.77	25.0	19.9	0.0
90	337	13.91	24.2	19.5	0.0
90	338	11.47	23.3	18.9	0.0
90	339	14.50	23.6	19.3	0.0
90	340	13.97	24.4	19.2	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
90	341	15.43	25.4	17.5	0.0
90	342	8.15	23.5	16.5	13.0
90	343	7.35	20.4	15.9	60.0
90	344	13.47	23.3	18.0	1.0
90	345	17.34	23.5	17.8	1.0
90	346	7.63	22.4	15.9	12.0
90	347	7.09	21.4	15.9	31.0
90	348	8.17	21.1	16.6	10.0
90	349	17.19	24.0	18.4	0.0
90	350	13.82	27.1	18.0	0.0
90	351	11.80	27.1	16.4	0.0
90	352	6.60	22.0	18.8	0.0
90	353	2.35	20.3	16.5	1.0
90	354	6.91	20.9	16.7	0.0
90	355	3.92	22.2	17.9	11.0
90	356	5.22	24.2	17.5	0.0
90	357	5.02	27.7	16.1	1.0
90	358	6.89	24.3	16.6	8.0
90	359	18.16	26.4	16.3	0.0
90	360	3.73	22.3	17.2	0.0
90	361	16.88	25.9	17.2	0.0
90	362	16.12	24.8	16.7	0.0
90	363	14.30	24.1	14.4	0.0
90	364	14.75	24.9	15.8	1.0
90	365	15.31	22.9	13.5	3.0
91	1	18.44	22.2	16.0	0.0
91	2	18.08	22.6	15.0	0.0
91	3	9.33	23.7	16.0	0.0
91	4	9.84	21.0	15.4	0.0
91	5	-99.00	-99.0	-99.0	-99.0
91	6	4.54	21.4	16.9	0.0
91	7	16.14	23.0	16.6	0.0
91	8	18.51	24.7	17.1	0.0
91	9	17.39	24.7	15.2	0.0
91	10	7.18	21.1	16.6	0.0
91	11	19.30	24.4	18.1	0.0
91	12	18.18	24.8	15.8	0.0
91	13	13.86	25.1	17.2	0.0
91	14	12.38	27.3	17.9	0.0
91	15	18.50	24.7	18.4	0.0
91	16	19.53	24.1	17.3	0.0
91	17	15.39	25.5	18.0	0.0
91	18	16.13	26.2	17.6	0.0
91	19	8.24	23.4	16.2	0.0
91	20	12.50	21.4	17.4	0.0
91	21	13.19	21.8	17.0	0.0
91	22	12.95	20.8	14.7	2.0
91	23	11.26	21.1	15.2	0.0
91	24	14.16	23.0	15.2	0.0
91	25	16.15	24.7	13.1	0.0
91	26	18.10	26.2	14.3	0.0

Table J.2 (continued)

Year	Day	Solar Radiation (MJ m^{-2})	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)
91	27	8.23	25.6	16.2	0.0
91	28	20.52	26.8	15.4	0.0
91	29	21.37	26.3	13.6	0.0
91	30	21.28	25.2	13.9	0.0
91	31	20.44	25.5	18.7	0.0
91	32	17.42	25.8	14.9	0.0
91	33	21.28	26.3	15.9	0.0
91	34	9.43	26.3	15.6	0.0
91	35	19.72	27.3	15.5	0.0
91	36	21.00	28.6	18.9	0.0
91	37	21.90	28.4	15.7	0.0
91	38	21.59	27.5	15.2	0.0
91	39	21.62	28.2	16.0	0.0
91	40	17.15	28.6	15.9	0.0
91	41	17.29	25.9	15.2	0.0
91	42	14.38	26.9	15.4	0.0
91	43	16.11	28.0	17.3	0.0
91	44	7.37	18.0	12.7	0.0
91	45	20.46	23.5	16.2	0.0
91	46	22.57	23.2	17.2	0.0
91	47	16.76	26.5	16.2	0.0
91	48	17.93	24.7	15.9	0.0
91	49	15.65	24.3	14.6	0.0
91	50	17.44	23.7	10.5	2.0
91	51	12.43	22.5	8.3	2.0
91	52	20.01	23.7	12.1	0.0
91	53	20.40	28.3	14.9	0.0
91	54	22.63	28.0	13.3	0.0
91	55	16.03	25.7	13.6	0.0
91	56	23.29	23.1	13.4	0.0
91	57	24.10	24.3	12.5	0.0
91	58	24.13	26.0	12.6	1.0
91	59	18.30	26.1	15.1	0.0

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