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# Chemical composition and physical damage of soybeans [Glycine max (L.) Merill] as affected by cultivar, harvest date, and field weathering

Harjeet Singh. Sidhu

To the Graduate Council:

I am submitting herewith a thesis written by Harjeet Singh. Sidhu entitled "Chemical composition and physical damage of soybeans [Glycine max (L.) Merill] as affected by cultivar, harvest date, and field weathering." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Biosystems Engineering Technology.

Zachary A. Henry, Major Professor

We have read this thesis and recommend its acceptance:

J.L. Collins, Sharon L Melton, Rabindra N. Biswal, Joanne Logan

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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I am submitting herewith a thesis written by Harjeet Singh Sidhu entitled "Chemical Composition and Physical Damage of Soybeans (*Glycine max* (L.) Merill) as Affected by Cultivar, Harvest Date, and Field Weathering". I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science with a major in Agricultural Engineering Technology.

Zachary A. Henry

Dr. Zachary A. Henry, Major Professor

We have read this thesis
and recommend its acceptance:

Sharon L. Melton

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# CHEMICAL COMPOSITION AND PHYSICAL DAMAGE OF SOYBEANS [*Glycine max* (L.) Merill] AS AFFECTED BY CULTIVAR, HARVEST DATE, AND FIELD WEATHERING

A THESIS

PRESENTED FOR THE

MASTER OF SCIENCE

THE UNIVERSITY OF TENNESSEE, KNOXVILLE

HARJEET SINGH SIDHU

DECEMBER 1992

# DEDICATION

This thesis is dedicated to my parents

Mr. Nihal Singh Sidhu

and

Mrs. Bhagwan Kaur Sidhu

who have given me invaluable life experiences

and educational opportunities.

# ACKNOWLEDGMENT

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# ABSTRACT

Changes in the composition of soybeans left in the field after maturity were made to provide information that would permit management decisions by the growers with respect to timely harvesting for optimum price and end-use value. Specifically, the investigation was conducted to identify the effects of field exposure of soybeans after maturity on the chemical composition and physical damage, especially as related to atmospheric changes.

The soybean cultivars 'TN4-86' (maturity group IV), 'Essex' (maturity group V) and 'Leflore' (maturity group VI) were investigated across sixteen weeks of harvest following physiological maturity. When the beans were left unharvested in the field after harvest maturity, the effects of field weathering resulted in increased bean moisture. Repeated exposure of the mature beans to alternate wetting and drying after full natural desiccation caused the seed coat to develop cracks, wrinkles and splits. The damaged seed coat enhanced moisture entry into the beans as a result of elevated and uniform relative humidity, rainfall and above-freezing temperatures. The most striking effect of field weathering was evidenced by the apparent increase in percentage values of protein and oil due to reduction in soluble carbohydrates accompanied by a reduction in dry matter. However, the

protein, oil and ash did not change. The percentage increased because, as dry matter reduced with field exposure, more beans were required to provide the same sample weight as compared to the undamaged sample before weathering. Another significant effect was the increase of the free fatty acid component of the total oil which lowered the end-use value.

The comparison of cultivars showed that TN4-86 and Essex possessed higher percentage of protein, oil, free fatty acids and total damaged beans than Leflore. Free fatty acid content of TN4-86 and Essex increased substantially more than that of Leflore due to extended field exposure under high bean moisture conditions.

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# CHAPTER I

# INTRODUCTION

## 1.1. BACKGROUND:

Soybean [*Glycine max* (L.) Merill], a leguminous crop of Eastern Asian origin, is grown in the United States primarily for its edible oil and high protein content. The importance of soybeans in the United States has increased greatly in the last four decades because of its boosted production capacity and profitability to both farmers and processors. Also, soybean oil and protein offer maximum benefits to the consumer at cost lower than that obtained from other oilseeds. For this reason soybeans continue to dominate the United States and world vegetable oil and protein markets in spite of competition from other oilseeds. The soybean is an unusual source of high quality protein because it contains lysine, an amino acid, that is deficient in cereal grains.

Increased soybean production has paralleled the increased research on soybean oil and protein utilization in the non-food industries. Expansion of value-added industrial uses of soybeans such as the use of hydrogenated oleic acid from soybean oil to produce stearic acid (Villet, 1989), application of soy protein in paper coating applications (Garey, 1989), preparation of soybean based wood adhesives

(Conner, 1989), addition of soybean oil to diesel fuel as an extender (Bagby, 1989), formulation of soybean oil in news ink (Cunningham, 1989), and use of soybean oil in agrochemical crop protectants (Kapusta, 1989) have stimulated additional research on the composition of beans, particularly with respect to oil and protein. Use of soybeans is increasing also for much needed oil- and protein-based food products for human consumption and for high protein feed supplements for livestock.

Oil and protein composition of oilseed crops determines the oil and meal yields (Al-Katani, 1989). Therefore, the oil and protein contents are useful as marketing factors. The soybean seed contains 12 to 25% oil and 30 to 49% protein (Piper and Morse, 1943; Rackis, 1978).

The variable chemical composition of soybeans is affected by factors that include cultivar, soil fertility and climatic conditions (Weiss et al., 1952; Collins and Cartter, 1956; Howell and Cartter, 1958). Many researchers have reported that weather is known to play a very important role in shaping the quality and quantity of soybean oil and protein. Garner et al. (1914) reported that climate is a more potent factor than soil condition in controlling the bean size and oil content of soybeans. Temperature, rainfall, and relative humidity are the most important weather components (Weiss et al., 1952; Howell and Cartter, 1953; Agrawal and Vyas, 1971; Mourid et al. 1986).

Variable composition of soybeans, particularly that of oil and protein, has assumed a more important role recently due to changes in marketing. As of September 1989, the United States Department of Agriculture, Federal Grain Inspection Service added oil and protein content to the United States Soybean Standards for the purpose of pricing (Hurburgh and Lamb, 1989). The estimation of variation in oil and protein content is useful because it represents the differences in the processing value to the soybean crusher and also provides information needed by farmers to select cultivars and production practices to enhance quality and the potential increase in market value.

## 1.2. PURPOSE AND OBJECTIVES:

Voluminous research has been conducted on variations in composition of soybeans from flowering to maturity, but very little effort has been made to identify changes in composition of soybeans from physiological maturity (maximum dry matter stage) to harvest. The understanding of these changes will permit development and practice of farm management schemes to preserve optimum end-use quality. The purpose of this study was to identify more closely those changes following maturity that relate to extended field exposure.

The specific objectives were:

1. To investigate the changes in levels of total oil, protein, carbohydrates and free fatty acid (as percent oleic acid)

contents of soybeans which result from extended field exposure after physiological maturity,

2. To identify the specific effects of environment with special attention given to relative humidity, rainfall and temperature on chemical composition and physical damage of soybeans during this exposure, and

3. To determine the relationships among the chemical components and cultivars, especially as related to date of maturity.

# CHAPTER II

# REVIEW OF LITERATURE

Previous research on quality of soybeans, especially with respect to weather (environment), can be divided into three production time periods: (1) flowering to physiological maturity (pre-maturation); (2) physiological maturity to harvest (post-maturation); (3) storage following harvest (post-harvest) (Cartter, 1940; Robertson et al., 1973; Mondragon and Potts, 1974; Whighim and Minor, 1978; Rose, 1988).

The weather conditions at any given geographical location are so dynamic that no two years are alike. The environmental fluctuations from planting to harvest cannot be expected to be consistent over years or follow any pattern. Trends may be unclear as well. Literature has related the atmospheric and weather conditions to the changes in the physical and chemical properties of soybeans. Information on delayed harvesting with respect to variation in the chemical composition and end use value of beans is scanty. Most previous research has been confined to a few weeks after harvest maturity. Also, most of the literature on soybean seed quality as affected by field exposure and aging has been related to germination, viability and vigor. Only a few researchers have related field weather conditions and aging to chemical composition and end-use value (O'Kelly and Gieger, 1972; Ramstad and Geddes, 1942; Wilcox et al., 1974). Although some studies have been conducted to identify the influence of weather components on bean composition, those studies were done to show only an association of factors and did not explain fully the physiological or biochemical reasons. Some investigations have identified changes in the chemical composition during storage, as related to aging and environmental conditions (Howell and Cartter, 1953; Howell, 1963).

## 2.1. ENVIRONMENTAL EFFECTS PRIOR TO MATURITY:

It is well-known that quality of soybeans is strongly related to the weather conditions preceding maturity. Also, the response of beans to field exposure after maturity and before harvest has been related to the environmental effects before maturity. Morse et al. (1950) reported that unfavorable weather during the ripening period caused soybeans to deteriorate when subjected to damp periods following maturity while in the field. They also found that hot weather caused wrinkling of the soybean seed coat (testa). Green et al. (1965) concluded that early planted soybeans which mature during hot and dry weather produced lower quality seed than beans which matured after the hot and dry weather conditions.

Garner et al. (1914) found that carbohydrates which accumulated during vegetative growth were converted into oil during the reproductive stage. Smith and Circle (1980) stated that a change in the ratio of protein-to-oil as the bean matures should be reflected in the changes of other components of the bean. They further stated that the change in protein usually has an inverse relationship with the change in both oil and carbohydrates. Cartter and Hopper (1942) reported a positive correlation between sugars and total oil. They also reported a negative correlation of total sugar and oil with protein.

Availability of soil moisture prior to maturity has been found to effect quality profoundly. Seasons with lower rainfall produced higher protein, lower oil and smaller seed size (Rose, 1988). Controlled soil moisture with well-watered irrigation produced maximum oil and minimum protein (Dornbos, 1989). However, drought-stress conditions increased protein more than oil. In contrast, Whighim and Minor (1978) found that prolonged flooding of the soybean crop generally resulted in higher oil and lower protein. Also, Sionit and Kramer (1977) found no significant differences in oil and protein due to water stress.

Several researchers found that maximum, minimum and average temperatures during the growing season (before physiological maturity) were correlated positively with oil content (Weiss et al., 1952; Benati et al., 1988). A similar relationship between oil and temperature was found by Wolf et al. (1982) who reported that the largest increase in oil content occurred when the maximum temperature was in the range of 24°C to 27°C (75.2°F to 80.6°F) and minimum temperature from 19°C to 22°C (66.2°F to 71.6°F). They also found that protein content was stable in a temperature range of 18°C to 30°C (64.4°F to 86.0°F), but it increased slightly at 33°C (91.4°F). Lower levels of oleic acids were associated with cooler temperatures. Chang et al. (1988), in studies with groundnut (peanuts), used the differences between the maximum and minimum temperatures during the seed developing stage and found that the smaller differences resulted in higher oil content and larger differences resulted in higher protein content.

Howell and Cartter (1953) reported that maximum temperature at pod filling stage was more closely related to the oil content in the northern cultivars than minimum temperatures and the opposite was true for southern cultivars. Osler and Cartter (1954) showed that soybeans developed a higher oil content when planted early and matured under a warmer temperature, as compared to late plantings that matured during cooler weather. The same effect was observed by Agrawal and Vyas (1971) with planting on five subsequent dates. They found that mean temperature was correlated positively with protein and negatively with oil. Whighim and Minor (1978) obtained similar results when they compared early and late maturing cultivars. The reason given for higher oil content in early cultivars was that they escape cooler temperatures during maturation. In contrast to the findings of Agrawal and Vyas (1971), Whighim and Minor (1978) found no strong correlation between protein and temperature development.

Howell and Cartter (1958) showed that under controlled conditions the oil content increased markedly during the seed development period with an increase in temperature up to 29.4°C (85°F), but found no increase in oil content beyond 29.4°F (85°F). However, protein content was stable with respect to temperature but non-protein nitrogen increased with increase in temperature. They stated that temperature may affect the oil content by two means. First, the temperature may affect the oil forming mechanism, and secondly, the temperature may affect the equilibrium point of the oil forming reactions.

**2.2. FIELD WEATHERING AFTER MATURITY:**

The importance of weather damage after physiological maturity was illustrated by Cartter (1947) who showed that changes occurred in soybeans after reaching harvestable maturity. In many instances, the beans developed brown/dark-brown color and mealy or chalky texture and even tended to sprout or decay.

**2.2.1. PHYSICAL EFFECTS AND SEED QUALITY:**

Moore (1971) reported that hydration of beans caused wrinkling but the original shape was regained if dried slowly.

Alternate wetting and drying caused the seed coat to become loosened, develop cracks and lose ability to resist water uptake. Walker and Barre (1972) reported that cracks caused by drying were developed at the location of wrinkles. Brumm et al. (1990) reported that size of shrivelled and wrinkled seed resulting from dry, hot weather did not correlate with oil and protein contents. However, recovery of oil and protein from such seeds was less than normal.

Harrington (1972) stated that translocation of nutrients from the mother plant to the seed ceased at physiological maturity. This was confirmed also for soybean seed by greenhouse studies using $^{14}CO_2$ (Tekrony et al., 1979). Thus, at physiological maturity the soybean seed becomes an independent biological unit with highest potential seed quality because they have not been exposed to field deterioration. Mondragon and Potts (1974) concluded that the rate and fluctuation of temperature, relative humidity and rain determined the degree of field deterioration and not the actual temperature or relative humidity. They found a significant effect of rain water combined with a temperature rise. Leaf cover reduced solar radiation by 50% and improved the microclimate which resulted in a slower rate of seed deterioration. Mondragon and Potts (1974) further suggested that soybean plants be modified to minimize the effects of fluctuations in seed moisture. Morse (1965) observed that the physical disruption of seed tissues resulted from alternate wetting and drying and may be responsible for field weathering of seed. Whighim and Minor (1978) reported that the soybean seed quality deteriorated from warm temperature and high humidity if the seeds were not harvested immediately after full maturity. Alternate wetting and drying of seeds in their experiment caused serious deterioration when temperatures were high, even though seeds were protected in the pods.

Potts et al. (1978) concluded that hard-seeded cultivars, as compared with normal seeded ones, did not reabsorb moisture while still on the plant and remained within harvestable moisture even though left in the field for an extended time. These field-exposed beans also stored better after harvest without deterioration for longer periods than normal seeded beans with permeable seed coat. Longer and Degago (1990) and Dassou and Kueneman (1984) found that hard-seeded genotypes resisted field weathering even under delayed harvest conditions and produced seeds with higher seed germination compared to normal seeded genotypes with lower seed germination due to impermeability of hard seed to water. In addition, genotypes which were resistant to post-maturation also were resistant to deterioration in the storage environment.

Tekrony et al. (1980), in a study of seed viability and vigor as affected by field weathering, found that late maturing cultivars produced seeds with higher germination due to more favorable environmental conditions before harvest.

### 2.2.2. EFFECTS ON CHEMICAL COMPOSITION:

#### 2.2.2.1. GENERAL EFFECTS:

Cartter (1940) found that regional location and field conditions (environment) resulted in high protein and low oil content. Krober and Collins (1948) reported that weather-damaged beans in a sample were as much as 4.5% higher in crude protein and 0.6% higher in oil than sound beans.

Sanders (1944) investigated the flavor quality of oil from weather-damaged soybeans and found them more costly to refine and less edible. The oil from freeze damaged beans, however, was rich in chlorophyll and could be easily refined.

Wilcox et al. (1974) found that delay of harvest due to adverse weather in Indiana (USA) caused no change in protein content, but higher percentage oil (0.5%) compared with normal harvest. Early maturing cultivars deteriorated more than late maturing cultivars. It was concluded that deterioration was due to adverse environmental conditions after maturity rather than to inherent differences among cultivars. Singh and Gupta (1982), however, observed no significant differences in oil and protein percentages at physiological (maximum dry matter stage) and final (harvestable stage) maturities.

#### 2.2.2.2. MOISTURE/RELATIVE HUMIDITY/RAINFALL EFFECTS:

Barton (1961) found that variations in the chemical composition of oilseeds may be due to the amount of moisture absorbed, even under identical storage conditions. Neergaard

(1977) reported that seeds with high oil content have lower moisture than those high in protein and starch. Sopade and Obekpa (1990) found that the amount of water absorbed in soybeans, cowpeas and peanuts was reduced with higher total oil content. Hsu et al. (1983) found no correlation between water absorption and protein content and seed size. They also reported that the rate of water absorption varied for cultivars and increased with rise in temperature. Priestley (1986) stated that the moisture content in dry seed generally fluctuates in storage due to changes in the relative humidity of the storage environment and that the seed with higher oil tended to equilibrate at lower moisture levels. Higher moisture levels caused free fatty acids to be liberated as a result of hydrolysis of the triglycerides catalyzed by lipase enzyme, a finding similar to that of Patterson (1989).

When temperature was increased with constant relative humidity, seed moisture content decreased (Bass, 1979). Temperature had little effect when moisture content was increased as a result of increased relative humidity.

Moore (1971) found that alternate wetting and drying reduced the quality of mature seeds in storage. He also concluded that deterioration started with the effect of rain and dew on the dried bean in the field. Although the seed coat initially resisted rapid uptake of moisture, it gradually lost the resistance to water entry. This loss of resistance may be due to loosened seed coat surrounding cotyledons which facilitates formation of air spaces. These air spaces facilitate not only rapid water uptake but also water movement and accumulation in the seed. Smith and Nash (1961) reported that the principal controlling factor in absorption of water was the seed coat. They also observed that the rate of water absorption of sound whole beans was influenced by initial moisture content of the beans. Burdett (1977) observed that the seed moisture fluctuated with the actual and simulated rainfall when the mature seeds remained in the field unharvested.

Thomas (1972) stated that loss of water by seeds upon maturation was accompanied by profound changes in cell ultrastructure, condensation of reserve chemical components and a significant decrease in metabolic activity. This low activity of mature seeds was reactivated as soon as the seeds came in contact with moisture and initial imbibition. The increase of moisture content permits higher enzymatic activity that is reflected in more rapid production of free fatty acids. This effect has been reported by several scientists and is discussed in a section below.

Yaklich and Cregan (1981) measured permeability of 46 soybean cultivars from different maturity groups by immersing the pods in water and found significant differences in the seed moistening rates among the cultivars. They also observed that differences in the seed deterioration of soybeans depended upon the degree of resistance of water entry into the pods. The reason some cultivars resist weather deterioration in the field for a longer time than others may be due to the impermeability of the pod to water entry.

Asano et al. (1990) immersed whole soybeans into water at varying temperatures and studied the swelling behavior and leaching of components from soybeans into water. They concluded that the swelling time was reduced with the rise in temperature. They further reported that the solid material that leached out of whole soybeans was 2 to 8% dry matter which contained 60 to 77% carbohydrates and 8 to 14% protein.

## 2.3. STORAGE ENVIRONMENT (POST-HARVEST):

### 2.3.1. SEED DETERIORATION:

Moore (1963) reported that much of the deterioration in storage was initiated during seed maturation in the field. He suggested that steps taken to reduce field deterioration from physiological maturity until harvest and proper storage should be helpful in preventing storage losses.

Gavrechenkov and Sinha (1980) found that freshly harvested dry and damp beans did not loose quality when stored at 10°C (50°F) under either anaerobic or aerobic environments.

Ndimande et al. (1981) found that delayed harvest under wet conditions affected the germination of seeds more than under dry conditions. This was attributed to fungal growth under wet conditions with the observation that fungi played a more important role before harvest than during storage. They also concluded that the physiological factors favored by high temperature and moisture content were, most probably, the principal agents of seed deterioration in storage.

**2.3.2. CHEMICAL COMPOSITION:**

Milner and Geddes (1946) found that soybeans in storage lost $CO_2$ slowly due to respiration and constantly under conditions of low humidity and low moisture content. However, if the critical moisture of the seed of about 14% was exceeded, the loss of $CO_2$ was greatly accelerated due to increased respiration and sugar content decreased while acid value of oil rose rapidly. The partial loss of one substance will, therefore, alter the apparent percentages of the other substances present in the seed. They stated that this caused an apparent increase in protein and sometimes the oil although both the latter substances may have been reduced by a much lesser extent than the carbohydrates.

Priestley (1986) found that soybean cultivars responded differently, even under similar storage conditions. Tanteeratarm et al. (1989) harvested two cultivars at four stages of maturity and found that the oil and protein contents were unaffected by maturity during storage.

## 2.4. PHYSIOLOGICAL/BIOCHEMICAL FACTORS.

### 2.4.1. CHEMICAL COMPOSITIONAL COMPENSATION/BALANCE:

Chemical compositional balance refers to the change in one component compensated by the changes in the other components of the beans. It may be due to loss of one substance or change in the ratio of two substances which may be compensated by the other substances in the beans. These changes may occur due to weather, physiological or biochemical effects.

O'Kelly and Gieger (1937) working with storage-damaged soybeans, and Ramstad and Geddes (1942), working with field-damaged soybeans, found that the percentages of total oil, protein and ash increased due to oxidation of carbohydrates which resulted from increased bean moisture. Carbohydrates reduction resulted in proportional increase in the percentages of oil, protein and ash. Although the absolute values of oil, protein and ash did not change in undamaged original beans due to moisture levels below 14%, their percentages relative to original beans (which did not reduce due to oxidation) increased markedly.

Krober and Collins (1948) observed that lower seed weights seemed more common in seasons when harvesting of experimental plots was delayed or interrupted by wet weather. Also, weather damaged seeds had lower levels of sugars than sound seeds from the same lot. Krober and Cartter (1962) found that changes in sugars, oils, holocellulose and pentosans corresponded to changes in protein content. With the apparent increase in the percentage protein, there was a decrease in nonprotein substances which was compensated by one-third decrease in sugars, one-third decrease in oil with the remaining compensation in the decrease in holocellulose and pentosans. However, such changes were not consistent. They also reported that carbohydrates in mature soybeans consisted of 5 to 9% sugars, about 5% pentosans, about 5% crude fibre and 15 to 18% holocellulose. Generally, starch was absent at maturity.

Hymowitz et al. (1972) studied the relationship of oil and protein content with total sugars in soybean seed of 60 lines and found that oil content was correlated positively with total sugars, sucrose and raffinose, whereas, protein was correlated negatively with sucrose and raffinose but positively with stachyose. Total sugar content, however, was correlated positively with sucrose and raffinose. Also, sucrose was correlated positively with raffinose and negatively with stachyose.

Lam-Sanchez et al. (1989) observed that both oil and protein percentages were affected by two weeks of delay in harvest beyond harvest maturity under Brazilian conditions. The protein content was affected less by the temperature than oil. Both genotype and environment were observed to be responsible for increase in percentage oil, whereas, the protein was affected less. They stated that it was the compositional balance which caused one substance to increase as the other decreased.

Slack and Browse (1984) found that following physiological maturity there was little change in the dry matter and weight per seed during field drying. A net loss of phospholipid and glycolipid materials occurred during this period due to the breakdown of chloroplast and other organelles that were no longer required following the completion of oil synthesis.

**2.4.2. RESPIRATION:**

Howell (1958) reported that soybean seeds had a active respiration during development which continued at a high rate until the beans almost reached maturity.

Wet and humid weather increased respiration and consumed storage material in the hydrated seed and caused loss of sugars of saturated pods and seeds (Howell et al., 1959). Under actual and simulated rainfall, water entered the pods readily and absorbed quickly, but loss of sugars due to leaching was not observed. High temperature (80°F and above), high relative humidity (90% and above) and frequent wetting of dry beans by rain were found to be important pre-harvest stresses to soybean seed, especially in southern United States and tropical regions. Such stresses generally increased the loss of sugar and dry weight due to increased respiration in the moist state.

Mohd-Lassim (1977) reported that rate of respiration of soybean seed was affected by moisture, temperature, seed quality and mechanical damage. The respiration rate of soybean seed increased linearly with increase in seed moisture from 20 to 60% at 15°C (59°F). A temperature of 15°C (59°F) limited the rate of respiration possibly due to storage molds. Whigham and Minor (1978) observed that rate of respiration was increased by higher temperatures which results in greater loss of seed weight. They also reported that the respiration was affected more by moisture than by temperature.

Abdul-Baki and Anderson (1972) observed a higher respiratory quotient (RQ) in deteriorating seeds in storage which were attributed to an increase in the evolution of $CO_2$. Harrington (1973) observed that the rate of respiration in dry seeds was so slow it was near the limit of detection. Priestley (1986) stated that the sugar content of the beans was reduced with aging due to respiration.

**2.5. CULTIVARS AND THEIR DIFFERENCES:**

Tekrony et al. (1981) identified the physiological maturity stage when soybean seed attained maximum dry matter which occurred when one mature pod could be seen on the main stem.

Several researchers studied the influence of cultivars and environment on the chemical composition of soybean seed and found that variation of oil and protein, although influenced by environmental conditions, was largely genetic (Cartter and Hopper, 1942; Feaster, 1942; Piper and Morse, 1943; Wolf et al., 1982; Copeland and McDonald, 1985; Salunkhe et al., 1985). Many investigators reported that the oil and protein contents differed among cultivars from region to region and from year to year. Hot and dry (drought) conditions prior to maturity increased oil content (Hurburgh et al., 1987; Breene et al., 1988; Hurburgh, et al., 1988; Clark and Snyder, 1989; Hurburgh et al., 1990).

A wide range of oil, protein and carbohydrates among the many cultivars tested have been reported by several investigators as 12-24%, 30-51%, and 22-29%, respectively (Piper and Morse, 1943; Krivoruchco et al., 1979; Osmon and Ahmad, 1982;). Hymowitz and Collins (1974) reported that the soybean cultivars differed greatly with respect to total sugars, sucrose and stachyose content.

In a cultivar trial conducted in Tennessee across four locations in two years, Graves et al. (1989) reported an average oil and protein content of 22.4% and 37.4%, respectively, for the cultivar Essex. Average protein content for the cultivar Leflore was 37.5% for four locations for 1988. In a similar trial, Graves et al. (1972) concluded that neither dates of planting nor location affected oil and protein contents of soybeans. Hurburgh et al. (1990) reported that the average oil and protein content in Tennessee soybean seeds were 18.7 and 36.7% respectively.

Salunkhe et al. (1985) found that the chemical composition of food legumes was governed by the cultivar, geographical location and growth conditions. They further reported that the protein content in legume seeds was mainly affected by the genotype and environmental conditions under which they were grown.

Wilcox et al. (1974) found that when harvesting was delayed 8 to 10 weeks, early cultivars deteriorated more in seed quality than late maturing cultivars. Protein content was not significantly different, whereas, oil content showed 0.5 percentage points higher than normal harvesting. Beatty et al. (1982) reported that delayed planting of soybean cultivars caused decrease in both oil and protein content. Seed weight also decreased consistently with delayed harvesting. They proposed that certain cultivars might have to be avoided for late plantings if seed protein content was important for the market.

## 2.6. FREE FATTY ACIDS AS PERCENT OLEIC ACID (POST-MATURATION AND POST-HARVEST):

Abdul-Baki and Anderson (1972) stated that increased levels of free fatty acids of oily seeds were associated with seed deterioration. Harrington (1973) reported that an increase in the free fatty acids content was a major symptom of deterioration but only above a seed moisture content of 12%.

Robertson et al. (1973) found that the increase in the visual damage of soybean seeds was associated with increased free fatty acids. Yao et al. (1983) found increased levels of free fatty acids in the crude oil extracted from soybean seed after prolonged storage periods. Saio et al. (1980) observed an increase in free fatty acids in the crude oil extracted from soybean seed exposed to higher relative humidity during storage. Copeland and McDonald (1985) stated that seed metabolism was influenced by the higher seed moisture and temperature which resulted in the biochemical events such as increased hydrolytic enzyme activity, enhanced respiration and increased levels of free fatty acids. Seed moisture is more critical than temperature because temperature accelerate many enzymatic and metabolic reactions only at higher seed moisture content. Frankel et al. (1987) found that free fatty acids increased with increased storage moisture content. Russell (1989) reported that the free fatty acids were liberated by hydrolysis of the parent glyceride molecules. The free fatty acids in crude oil also determine the amount of oil that will be lost during refining. Patterson (1989) stated that the presence of moisture in the seed promoted the progressive splitting of triglycerides (lipids) into glycerol and free fatty acids.

Bewley and Black (1978) stated that initial degradation of triglycerides was catalyzed by lipase, an enzyme which aids in a step-wise breakdown of triglycerides to liberate free fatty acids and glycerol. Priestley (1986) stated that under higher moisture conditions, free fatty acids were liberated as result of hydrolysis of the triglycerides catalyzed by lipase enzyme.

# CHAPTER III

## METHODS AND MATERIALS.

Three soybean cultivars (TN4-86, maturity group IV; Essex, maturity group V and Leflore, maturity group VI) were grown in a field plot at the Plant Science Farm, University of Tennessee, Knoxville in 1989 and 1990. These cultivars were planted in a split-plot arrangement to test the effects of field exposure on the three cultivars over a 16-week harvesting period after physiological maturity (maximum dry matter). The three cultivars, 16 weekly harvests and three replications required 144 total plots as follows:

| | | |
|---|---|---|
| Weeks of harvest (main plots) | = | 16 |
| Cultivars (sub plots) | = | 3 |
| Replications (Blocks) | = | 3 |

The variable nature of the temperature, relative humidity and rainfall from one year to the next prevented the experiment from being considered as a replication across years. However, the effects caused by similar changes in weather may be compared even though they did not occur at the same time period after physiological maturity. Physiological maturity was determined when one mature pod was seen on the main stem (Tekrony et al., 1981). The beans were hand-harvested, dried at 85°F to 95°F (29°C to 35°C) to a moisture content below 14% (wet basis). The pods were shelled by hand and stored at 38°F (3.3°C), awaiting further tests. Weeks and dates of harvest for each cultivar are shown in Tables 1 and 2 for 1989 and 1990 seasons, respectively.

The information obtained from the beans produced in 1989 provided new directions for testing the beans produced in 1990. All tests performed in the former year were performed also in the later year. All tests, including the additional tests for beans in 1990, are described below.

Parameters tested and procedures used for the beans of both years were:

**1.** Initial moisture content was determined at the time of harvest for each plot (wet/fresh weight basis) by ASAE Standard Method: ASAE S352.1 (ASAE, 1984).

**2.** Total oil (%, db), protein (%, db) and moisture content (%, wb) at the time of testing. Measurements were made as follows.

Beans of the 1989 season were tested initially for total oil content by the AOCS Official Method Ba 3-38 (AOCS, 1978) and protein content by the Kjeltec 1015 Digester and Kjeltec 1026 Distilling Unit (Tecator, 1990). They were tested subsequently by the Infratech Grain Analyzer 1225, a near-infrared transmittance instrument (Hurburgh and Hartwig, 1989). The oil and protein contents (%, db) obtained from the two methods were statistically analyzed and differences

TABLE 1. Schedule of harvest dates along with their respective weeks of harvest for soybean cultivars TN4-86, Essex and Leflore for the 1989 season.

| Week of Harvest | Dates of Harvest | | |
|---|---|---|---|
| | TN4-86 | Essex | Leflore |
| 1 | 09-26-89 | 10-03-89 | 10-24-89 |
| 2 | 10-03-89 | 10-10-89 | 10-31-89 |
| 3 | 10-10-89 | 10-17-89 | 11-07-89 |
| 4 | 10-17-89 | 10-24-89 | 11-14-89 |
| 5 | 10-24-89 | 10-31-89 | 11-21-89 |
| 6 | 10-31-89 | 11-07-89 | 11-28-89 |
| 7 | 11-07-89 | 11-14-89 | 12-05-89 |
| 8 | 11-14-89 | 11-21-89 | 12-12-89 |
| 9 | 11-21-89 | 11-28-89 | 12-19-89 |
| 10 | 11-28-89 | 12-05-89 | 12-26-89 |
| 11 | 12-05-89 | 12-12-89 | 01-02-90 |
| 12 | 12-12-89 | 12-19-89 | 01-09-90 |
| 13 | 12-19-89 | 12-26-89 | 01-16-90 |
| 14 | 12-26-89 | 01-02-90 | 01-23-90 |
| 15 | 01-02-90 | 01-09-90 | 01-30-90 |
| 16 | 01-09-90 | 01-16-90 | 02-06-90 |

TABLE 2. Schedule of harvest dates along with their respective weeks of harvest for soybean cultivars TN4-86, Essex and Leflore for the 1990 season.

| Week of Harvest | Date of Harvest | | |
| --- | --- | --- | --- |
| | TN4-86 | Essex | Leflore |
| 1 | 09-19-90 | 09-26-90 | 10-17-90 |
| 2 | 09-26-90 | 10-03-90 | 10-24-90 |
| 3 | 10-03-90 | 10-10-90 | 10-31-90 |
| 4 | 10-10-90 | 10-17-90 | 11-07-90 |
| 5 | 10-17-90 | 10-24-90 | 11-14-90 |
| 6 | 10-24-90 | 10-31-90 | 11-21-90 |
| 7 | 10-31-90 | 11-07-90 | 11-28-90 |
| 8 | 11-07-90 | 11-14-90 | 12-05-90 |
| 9 | 11-14-90 | 11-21-90 | 12-12-90 |
| 10 | 11-21-90 | 11-28-90 | 12-19-90 |
| 11 | 11-28-90 | 12-05-90 | 12-26-90 |
| 12 | 12-05-90 | 12-12-90 | 01-02-91 |
| 13 | 12-12-90 | 12-19-90 | 01-09-91 |
| 14 | 12-19-90 | 12-26-90 | 01-16-91 |
| 15 | 12-26-90 | 01-02-91 | 01-23-91 |
| 16 | 01-02-91 | 01-09-91 | 01-30-91 |

between the two methods were non-significant. Therefore, only the instrumental values were used for the beans of 1990. All results were reported on a moisture-free basis. The Infratech Grain Analyzer 1225, however, has a bias with moisture. The values of oil and protein may read incorrectly by 0.5 to 1.0% (db). The moisture range for most accurate results usually is from 9 to 11.5% (db), moisture content in the beans for this investigation was between 5 and 8% (db) and

**3.** Test for free fatty acid content (as percent oleic acid) of crude soybean oil was determined according to AOAC Method 28.030, modified by Urbanski et al. (1980) and tested by Yao et al. (1983). The modification permitted the use of 2.0 g of crude oil instead of 7.05 g and titration with 0.01N NaOH rather than 0.25N NaOH. Approximately 25 g clean soybeans were ground in a micro-mill (Scienceware, Bel-Art) mixed well and packed in an air-tight bag. The full fat flour was used to extract at least 3.0 g of crude oil. The crude soybean oil used for the free fatty acids determination was extracted by Goldfish Apparatus using petroleum ether.

The nature of the results of the 1989 tests, as discussed in the next chapter, demanded additional information. Thus, the following additional tests were made on the 1990 beans:

**1.** Ash and dry matter percentages were determined from a two-stage test for ash determination (AOAC, 1975),

**2.** Carbohydrate percentage (nitrogen-free extract) was determined by the difference method. The total of oil, protein, and ash (on a moisture free basis) was subtracted from 100 and

3. Physical damage of seed coat was determined by examining the beans under magnification. Physical damage parameters included were cracked, wrinkled, cracked-wrinkled (beans with both cracks and wrinkles), and split beans.

### 3.1. WEATHER DATA:

Weather data at the field plots included temperature, relative humidity and rainfall. These data were obtained from Dr. Joanne Logan, Department of Plant and Soil Science, University of Tennessee, Knoxville (1990). Daily averages were used to calculate weekly averages. Averages over specifically identified time periods were used in the final analysis. The weather data were collected from a weather station located about 100 yards from the experimental field plot.

### 3.2. STATISTICAL ANALYSIS:

Statistical analysis was performed by the Statistical Analysis Software (SAS, 1987; SAS, 1988; Freund et al., 1986). The analysis of variance for the split-plot design is shown in Table 3. This design permitted comparison across all cultivars and weeks of harvest for all dependent variables. Additional comparisons and evaluations were made to identify specific exposure time and weather effects, sometimes these tests involving comparisons over the entire 16 weeks and only for specific blocks of time within the total period. Significant differences between means for the cultivars were identified by the Duncan's Multiple Range Test (Freund et al., 1986; SAS, 1988).

The extent to which the dependent variables were related to each other and to the weather components (temperature, relative humidity and rainfall) were estimated by simple correlation analyses. Two criteria were used to identify meaningful and true relationships in a similar way to that used by Hurburgh et al. (1987) for these types of biological relationships. First, a significant ($p < 0.01$) the correlation coefficient was required and second, the correlation coefficient was required to be greater than 0.30. Regression equations and curves were established for each significant dependent variable and weather component over the 16 weeks of harvest period.

TABLE 3. Analysis of variance[1] for effects of weeks of harvest and cultivars on soybean chemical composition (%, db) and physical properties (%) as a split-plot arrangement of factorial design.

| Source | Degrees of freedom | Notations |
|---|---|---|
| Replication (Rep) | 2 | $R_i$ |
| Week | 15 | $W_j$ |
| Rep*Week | 30 | $RW_{ij}$ |
| Cultivar | 2 | $V_k$ |
| Week*Cultivar | 30 | $(WV)_{jk}$ |
| Error | 64 | $\varepsilon_{(ijk)}$ |
| Total | 143 | $Y_{ijk}$ |

[1]Model $Y_{ijk} = \mu + R_i + W_j + (RW)_{ij} + V_k + (WV)_{jk} + \varepsilon_{(ijk)}$

# CHAPTER IV

# RESULTS AND DISCUSSION

The results show the effects of weather and field exposure on chemical composition and physical properties of soybeans for sixteen weeks after physiological maturity. Patterns of the weather parameters will be described first, followed by their relationship to bean moisture and the consequent effect on chemical and physical parameters. Special attention will be given to the effect of two separate periods after physiological maturity; first, the time from physiological maturity to full, natural desiccation, which is defined as harvest maturity and second, the time period after full, natural desiccation.

## 4.1. WEATHER PATTERNS AND THEIR EFFECTS:

Temperature, relative humidity and rainfall at the field plots for the harvesting periods of 1989 and 1990 are presented on Figs. B1 - B3, Appendix B. Changes in physical properties of soybeans and subsiquent alteration of chemical composition which might have taken place immediately after drastic changes in weather (as evidenced by such measurements as temperature, relative humidity and rainfall) were analyzed. Although these changes seemed to have an effect, no pattern could be identified. Longer term effects from weekly averages did give significant patterns and relationships. Consequently, weather data used in the analyses were weekly cumulative rainfall and the weekly averaged temperature and percentage relative humidity which included the minimum, maximum, average and difference between the maximum and minimum. Although the very different weather patterns for 1989 and 1990 showed their individual effects on the beans, some similar trends did appear over the two harvest periods. General patterns of weather and their effects during both the years have been summarized in the following paragraphs.

During the 1989 season, the onset of winter was early and harsher than 1990. Weekly minimum temperatures remained close to or below freezing and maximum temperatures were below 60°F (15°C) except for September and October. Weekly maximum relative humidity remained above 85% and minimum relative humidity remained above 40% most of the time. Weekly rainfall was low from the middle of November to the middle of December and moderate before and after this period. Overall, weather during the 1989 harvesting season was cold with some snow dusting, along with moderate to high moisture available in terms of rainfall and relative humidity. Harvested pods were wet most of the time during this period.

During the 1990 harvesting season, a very mild winter was observed with weekly minimum temperature dipping below freezing only between December 12 and 26 and weekly maximum temperature above 60°F (15°C) until November and above 50°F

(10°C) during the remainder of the harvesting period. The weekly minimum relative humidity remained between 40 and 55% during most of time before the middle of December 1990 and was higher through the middle of January, 1991. Weekly maximum relative humidity, however, remained above 80%. The weekly rainfall remained low until the middle of December and was moderate thereafter. Overall, the 1990-1991 winter season was a mild winter with moderate to high relative humidity and low to moderate rainfall. Mild winter temperatures enhanced the effect of moisture, especially since the occurrence of freezing temperatures was rare.

#### 4.1.1. BEAN MOISTURE:

The soybean at physiological maturity has high moisture content (approximately 55% moisture on wet weight basis) (Tekrony et al., 1979). However, the bean moisture at physiological maturity, in some cultivars, has been reported as low as 26% (Singh and Gupta, 1982). Due to the extended natural desiccation, this moisture content in the field normally is reduced to a minimum after physiological maturity, at about the fifth week or beyond, depending on rain and atmospheric moisture. The end of the desiccation period is the time when the beans have reached a point of change that gives them the optimum value in chemical composition, but before decomposition (damage) from field exposure begins. This has been defined as harvest maturity. Changes which occur in the bean during the desiccation period are different from those which occur later this period. When the bean becomes an independent biological unit at physiological maturity (week 1), field weather begins to show its effects (Harrington, 1972; Tekrony et al., 1979). During this initial period, bean desiccation progresses naturally unless a prolonged rainy condition exists at this time. The damage is either minimal or non-existent until the beans begin to reabsorb moisture and then, possibly, followed by drying. The weather conditions prevailing in Tennessee during maturation and up to harvest maturity are usually favorable for soybean production.

During the 1989 season, significant differences in the bean moisture percentage at harvest (Table C2, Appendix C, and Fig. 1-A) were observed among weeks of harvest. Bean moisture decreased from week 1 until week 9 or 10 but increased thereafter. This desiccation period was extended because of early onset of lower seasonal temperature and higher rainfall just after the physiological maturity. Although bean moisture was held high through the entire 16 week period, the harsh winter did not allow the moisture to fully activate enzymatic or oxidation processes.

Bean moisture percentage at harvest showed significant differences among the first five weeks of harvest because of accelerated natural desiccation during the 1990 season (Table C8, Appendix C, and Fig. 1-B). This natural desiccation period was reduced as compared to 1989 due to lower rainfall and mild

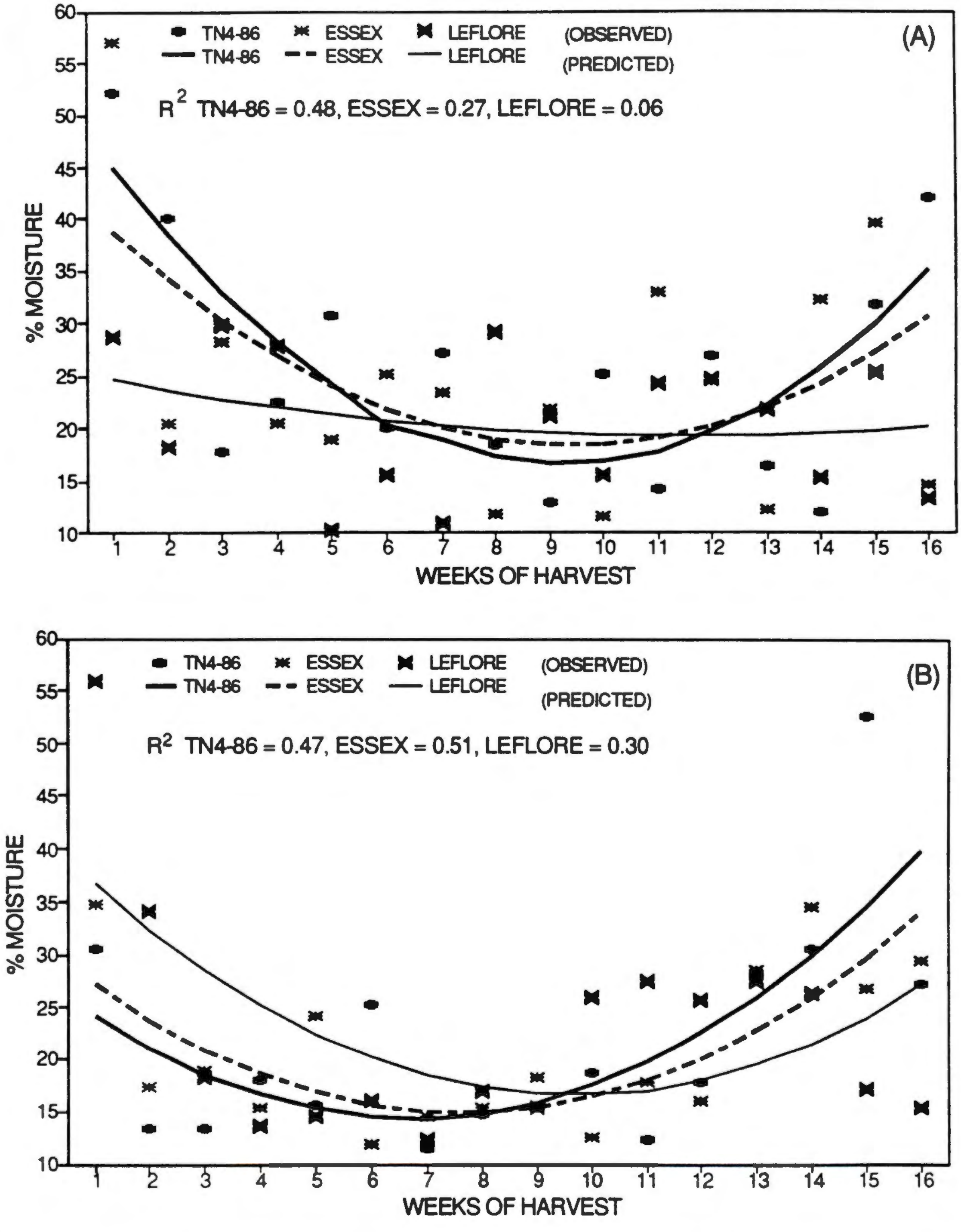



Figure 1. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) for soybeans TN4-86, Essex, and Leflore during the (A) 1989 and (B) 1990 season.

temperatures. The rainfall was very low except at week 3 for 'TN4-86' and week 2 for 'Essex' and 'Leflore.' Maximum temperature remained close to 80°F (27°C) and minimum temperature above 50°F (10°C). Although relative humidity was high, these temperatures were favorable for bean desiccation. Bean moisture increased significantly after week 6 and continued until week 16. The increase was slow from week 6 through 10 due to low rainfall (about 3 inches (75 mm) in 5 weeks) and minimum relative humidity, which dipped below 45% during this period. Bean moisture sharply increased after week 12 due to sudden increased rainfall and minimum relative humidity.

### 4.1.2. RELATIONSHIP BETWEEN BEAN MOISTURE AND WEATHER:

Bean moisture level at harvest was altered with percentage of total oil, protein, carbohydrates and free fatty acids. Since bean moisture level at harvest is dependent on the weather conditions to which the beans have been exposed, the correlation coefficients between moisture level and total oil, protein, carbohydrates and free fatty acids, also can be attributed to the field weathering. The time of harvest and cultivars as related to the effects of bean moisture on the percentages of total oil, protein, carbohydrates and free fatty acids were also identified for their relationships with weather components. Results of the simple correlations were summarized in the Tables C30 - C34, Appendix C.

These correlations were obtained from the full sixteen week harvesting period for both the 1989 and 1990 season. The 1989 season showed no significant correlations over the total 16 week harvesting period except between bean moisture and free fatty acids for Leflore cultivar.

In 1990, the trends of the data and the resultant significant differences demanded a separate analysis for the effects during the initial 5 to 6 week desiccation period and the later weeks. The nature of constituent changes indicated that when a strong correlation existed for the total period, a stronger correlation usually was found for the latter period only (Table C31, Appendix C), and usually was non-significant for the desiccation period. In 1990, bean moisture was profoundly affected by differences between the maximum and minimum of both temperature and relative humidity. However, temperature independent of the differences showed a very low effect. This difference was primarily a result of relatively stable maximum temperature and varying minimum temperature. In addition to this, minimum and average relative humidities and cumulative rainfall amounts contributed to the increase in bean moisture.

These results showed the expected strong weather effect on the bean moisture. In turn, bean moisture is the primary contributing factor that causes physical and chemical changes presented below. In addition to the correlations relating directly to bean moisture, the indirect effect of moisture values can be seen in Tables C30 through C34, Appendix C, which show the effects of weather parameters on levels of oil, protein, carbohydrates, free fatty acids and physical damage. Bean moisture showed a strong negative correlation with carbohydrates and positive correlation with free fatty acid and protein for TN4-86 and Essex. Positive correlations were shown with total oil for Leflore. Physical damage parameters such as cracks, wrinkles and splits also have shown positive correlations with bean moisture.

The physical seed coat damage became more visible after the desiccation period. Fluctuation of bean moisture (wetting and drying) occurred as the relative humidity and rainfall fluctuated with resultant increased physical changes (damage). This damage enhanced moisture absorption into the bean and resulted in accelerated chemical changes in a similar way to that noted by Moore (1971).

The bean moisture was held high enough to continue the reduction in carbohydrates due to increased respiration even at reduced temperatures. Temperatures in 1990 remained moderate even though they decreased as the season progressed. This effect was similar to that found by Milner and Geddes (1946), Howell et al. (1959), Mohd-Lassim (1977) and Bass (1979).

## 4.2. CHEMICAL COMPOSITIONAL COMPENSATION/BALANCE:

During the 1990 season, a percentage increase protein and decrease in carbohydrates were observed after full, natural desiccation (weeks 1 - 5) for TN4-86 and Essex. The observed increase in percentage protein from week 6 through 16 was not expected since no nitrogen source was available after physiological maturity. In addition, after the desiccation period, there was no reason to assume that there would be a change in the absolute value of the total oil, although there would be an expected increase of the free fatty acid component of the oil. In order to explain this increase in percentage protein, absolute values were calculated using week 6 as the base week, from which field weathering began to show its effects, as previously discussed. Table 4 presents the observed values of the percentage protein, oil, ash, carbohydrates and dry matter and the sum of protein, oil and ash as determined by the identified tests. The assumption was made that there was no actual absolute change in the protein, oil and ash and that the only decrease in the beans could be totally attributed to carbohydrates, which was the conclusion of O'Kelly and Gieger (1937) and Ramstad and Geddes (1942). However, they did not attempt to quantify the reduction in carbohydrates and dry matter. This experiment quantified these values which are shown as the adjusted values in Table 4. The adjusted values for these components were calculated as the g/100 g of sample that would have existed at week X which is

TABLE 4. Changes in the observed values as tested and adjusted to absolute values of proximate composition (dry basis) and dry matter after full, natural desiccation period from sixth through sixteenth week of harvest during the 1990. season.

| CULTIVAR | WEEK OF HAR- VEST | PROTEIN | | TOTAL OIL | | ASH | | SUM OF OPA[3] | | CARBOHYDRATES | | TOTAL SAMPLE TESTED[4] | | | DRY MATTER[5] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | OBS[1] % | ADJ[2] g/100g | OBS % | ADJ g/100g | OBS % | ADJ g/100g | OBS % | ADJ g/100g | OBS % | ADJ g/100g | OBS g/100g | ADJ DEC g/100g | ADJ INC g/100g | OBS g/100g | ADJ g/100g |
| TN4-86 | 6 | 43.4 | 43.4 | 21.3 | 21.3 | 5.4 | 5.4 | 70.1 | 70.1 | 29.9 | 29.9 | 100.0 | 100.0 | 100.0 | 94.5 | 94.5 |
| | 7 | 43.5 | 43.4 | 21.0 | 21.0 | 5.5 | 5.5 | 70.1 | 70.1 | 29.9 | 30.0 | 100.0 | 100.0 | 100.0 | 94.0 | 94.0 |
| | 8 | 43.5 | 42.6 | 22.0 | 21.5 | 5.6 | 5.5 | 71.1 | 70.1 | 28.9 | 28.5 | 100.0 | 98.6 | 101.4 | 94.4 | 93.0 |
| | 9 | 42.9 | 42.3 | 22.0 | 21.7 | 5.9 | 5.8 | 70.8 | 70.1 | 29.2 | 28.9 | 100.0 | 98.9 | 101.1 | 94.1 | 93.1 |
| | 10 | 44.8 | 43.7 | 21.0 | 20.6 | 5.5 | 5.3 | 71.3 | 70.1 | 28.8 | 28.3 | 100.0 | 98.3 | 101.7 | 93.9 | 92.4 |
| | 11 | 43.8 | 43.3 | 21.4 | 21.1 | 5.5 | 5.4 | 70.6 | 70.1 | 29.4 | 29.1 | 100.0 | 99.2 | 100.8 | 93.9 | 93.2 |
| | 12 | 43.5 | 42.9 | 21.8 | 21.5 | 5.5 | 5.4 | 70.7 | 70.1 | 29.3 | 29.0 | 100.0 | 99.1 | 100.9 | 94.2 | 93.3 |
| | 13 | 44.7 | 44.4 | 20.7 | 20.5 | 5.1 | 5.0 | 70.4 | 70.1 | 29.6 | 29.4 | 100.0 | 99.5 | 100.5 | 93.9 | 93.4 |
| | 14 | 46.1 | 43.5 | 21.6 | 20.4 | 5.5 | 5.2 | 73.1 | 70.1 | 26.9 | 25.7 | 100.0 | 95.8 | 104.2 | 94.3 | 90.3 |
| | 15 | 45.2 | 42.2 | 22.4 | 20.9 | 6.2 | 5.8 | 73.7 | 70.1 | 26.3 | 25.0 | 100.0 | 95.1 | 104.9 | 94.2 | 89.6 |
| | 16 | 46.2 | 43.6 | 21.5 | 20.3 | 5.4 | 5.1 | 73.1 | 70.1 | 26.9 | 25.8 | 100.0 | 95.8 | 104.2 | 94.7 | 90.7 |
| ESSEX | 6 | 44.6 | 44.6 | 19.5 | 19.5 | 5.6 | 5.6 | 69.7 | 69.7 | 30.3 | 30.3 | 100.0 | 100.0 | 100.0 | 94.0 | 94.0 |
| | 7 | 45.1 | 44.9 | 19.5 | 19.4 | 5.3 | 5.3 | 70.0 | 69.7 | 30.0 | 29.9 | 100.0 | 99.6 | 100.4 | 93.9 | 93.5 |
| | 8 | 44.8 | 44.7 | 19.6 | 19.5 | 5.4 | 5.4 | 69.8 | 69.7 | 30.2 | 30.1 | 100.0 | 99.8 | 100.2 | 93.5 | 93.3 |
| | 9 | 44.9 | 44.8 | 19.5 | 19.5 | 5.4 | 5.4 | 69.8 | 69.7 | 30.2 | 30.2 | 100.0 | 99.9 | 100.1 | 93.1 | 93.0 |
| | 10 | 45.4 | 45.2 | 18.9 | 18.8 | 5.7 | 5.6 | 70.0 | 69.7 | 30.0 | 29.9 | 100.0 | 99.6 | 100.4 | 93.8 | 93.4 |
| | 11 | 44.6 | 44.3 | 19.5 | 19.4 | 6.0 | 5.9 | 70.0 | 69.7 | 30.0 | 29.9 | 100.0 | 99.6 | 100.4 | 94.0 | 93.6 |
| | 12 | 44.4 | 43.7 | 19.0 | 18.7 | 5.5 | 5.4 | 68.9 | 69.7 | 31.1 | 31.4 | 100.0 | 101.2 | 101.1 | 94.2 | 95.3 |
| | 13 | 48.2 | 45.0 | 19.8 | 18.5 | 5.3 | 5.0 | 73.4 | 69.7 | 26.6 | 25.3 | 100.0 | 95.0 | 105.0 | 93.8 | 89.1 |
| | 14 | 47.4 | 44.6 | 19.9 | 18.7 | 5.6 | 5.3 | 73.0 | 69.7 | 27.0 | 25.8 | 100.0 | 95.5 | 104.5 | 94.5 | 90.3 |
| | 15 | 46.9 | 44.3 | 20.3 | 19.2 | 5.4 | 5.1 | 72.6 | 69.7 | 27.4 | 26.3 | 100.0 | 96.0 | 104.0 | 94.0 | 90.3 |
| | 16 | 47.0 | 44.1 | 20.5 | 19.2 | 5.6 | 5.2 | 73.0 | 69.7 | 27.0 | 25.8 | 100.0 | 95.5 | 104.5 | 93.8 | 89.6 |
| LEFLORE | 6 | 42.9 | 42.8 | 17.9 | 17.9 | 4.6 | 4.6 | 65.3 | 65.3 | 34.7 | 34.7 | 100.0 | 100.0 | 100.0 | 94.0 | 94.0 |
| | 7 | 42.3 | 42.1 | 18.3 | 18.2 | 4.9 | 4.9 | 65.5 | 65.3 | 34.5 | 34.4 | 100.0 | 99.7 | 100.3 | 94.3 | 94.0 |
| | 8 | 41.8 | 42.3 | 18.3 | 18.5 | 4.7 | 4.8 | 64.8 | 65.3 | 35.2 | 35.5 | 100.0 | 100.8 | 99.2 | 93.5 | 94.2 |
| | 9 | 41.9 | 42.5 | 17.7 | 18.0 | 5.1 | 5.2 | 64.7 | 65.3 | 35.3 | 35.7 | 100.0 | 101.1 | 99.0 | 94.6 | 95.6 |
| | 10 | 43.4 | 42.5 | 17.9 | 17.5 | 5.0 | 4.9 | 66.2 | 65.3 | 33.8 | 33.4 | 100.0 | 98.7 | 101.3 | 93.6 | 92.4 |
| | 11 | 43.5 | 42.1 | 18.0 | 17.4 | 5.3 | 5.1 | 66.8 | 65.3 | 33.2 | 32.5 | 100.0 | 97.8 | 102.2 | 94.0 | 92.0 |
| | 12 | 43.4 | 42.4 | 18.1 | 17.6 | 4.9 | 4.8 | 66.4 | 65.3 | 33.7 | 33.1 | 100.0 | 98.5 | 101.5 | 93.6 | 92.2 |
| | 13 | 43.0 | 42.0 | 18.6 | 18.1 | 4.8 | 4.7 | 66.4 | 65.3 | 33.7 | 33.1 | 100.0 | 98.5 | 101.5 | 94.2 | 92.0 |
| | 14 | 43.5 | 41.9 | 18.7 | 18.0 | 4.9 | 4.7 | 67.0 | 65.3 | 33.0 | 32.2 | 100.0 | 97.5 | 102.5 | 94.0 | 91.7 |
| | 15 | 43.3 | 42.2 | 18.3 | 17.9 | 4.8 | 4.7 | 66.4 | 65.3 | 33.6 | 33.0 | 100.0 | 98.4 | 101.6 | 92.8 | 91.3 |
| | 16 | 42.3 | 41.6 | 19.0 | 18.7 | 4.8 | 4.7 | 66.1 | 65.3 | 33.9 | 33.6 | 100.0 | 98.9 | 101.1 | 93.8 | 92.8 |

1. OBS = Observed value, 2. ADJ = Adjusted value. 3. OPA = Sum of oil, protein and ash.
4. ADJ DEC = Adjusted decrease. This column represents the reduction of the sample tested at week X, as compared to the equivalent sample that would have existed at week 6, before being reduced by field weathering. ADJ INC = Adjusted increase. This column represents the weight of the beans actually tested at week X, relative to 100g at week 6 if they had been weighed at week 6 before being reduced by field weathering.
5. The dry matter observed is the g/100g sample tested at week X. The dry matter adjusted represents the g/100g reduction of the sample at week X as compared to the equivalent sample that would have existed at week 6 before being reduced by field weathering.

the field weathered sample after week 6 (field weathered sample after week 6) if the sample had been composed of the equivalent number of beans tested at week 6 before being reduced by field weathering. The calculations for adjustments were made as shown below.

Week 6 beans, after the desiccation period, were taken as the initial week for primary chemical degradation. At this time the percentage values of all components were considered to be g/100 g of total sample. The beans under field exposure reduced in weight after week 6. Thus, the beans taken for a sample at week X would weigh less than the same beans weighed at week 6. Consequently, to obtain the same weight sample at week X, a larger number of beans was required. The reduction in weight of the sample of beans from the initial week 6 to the weight at the week of testing, X, would be:

$$\text{Weight of the sample} - \frac{(\text{Sum \% OPA at week 6 observed})}{(\text{Sum \% OPA at week X observed})},$$

where

OPA = oil, protein, ash,
Sum %OPA = %oil + %protein + %ash, and
Week X is the field weathered sample after week 6.

Since weight of the total sample is reduced only by the reduction in carbohydrates, this adjustment also represents reduction in carbohydrates. Also, the reduction in the values of the carbohydrates in Table 4 at week X is the same as the decrease in the dry weight of the sample in g/100 g if the sample could have been composed of the same number of beans as that at week 6. Also, if the weight of the sample tested at week X was 100 g, the weight which would have been at week 6 would have been greater than 100 g by the amount of reduction in carbohydrates. Thus, to correctly compare the dry matter values at week X, they must be normalized to the equivalent samples which would have all weighed 100 g at week 6. This is shown in the adjusted dry matter column in Table 4. To illustrate by example, the sample collected at week 6 had a total of percentage oil, protein, ash and carbohydrates as 100 percent (or 100 g/100 g of sample). If the same sample had been held in the field until week 16 for TN4-86, the sample would have reduced to 95.8 g/100 g (of original sample). As previously discussed, the reduction was totally a result of the amount of reduction in carbohydrates (4.2 g) which was also reflected in dry matter reduction of the same amount (4.2 g) (Table 4). Thus, if the sample taken at week 16 would have been taken at week 6, it would have required 4.2 g more beans to have the same number. Therefore, the sample tested at week 16 would have been 104.2 g at week 6 instead of 100 g. When the g/100 g of protein was adjusted to the 104.2 g of initial sample at week 16 the adjusted value was 43.6 as compared to the observed 46.2 (Table 4). The increased amount (number) of beans in the samples after week 6 was unavoidable because the nature of the experiment did not permit early harvest for later proximate composition tests.

## 4.3. WEATHERING EFFECT ON PROXIMATE COMPOSITION:

The adjustments of Table 4 relate to the condition of the weathered beans as compared to the condition of the beans before weathering began. However, when beans are harvested in a weathered condition these are the actual beans available for use. The previously discussed "observed" values represent this harvested condition and must be appropriately considered, even though it must be understood that the yield has been reduced. Thus, the significance of the changes in proximate composition of the actual harvested beans are presented. Note that the data are only from the harvestable beans; beans that shattered were neither collected nor included in this study.

### 4.3.1. PROTEIN AND CARBOHYDRATES:

During the 1989 season, the significant variation in the percentage protein (Figure 2A) for TN4-86 across sixteen weeks of harvest was small and limited to about one percentage point or less (Tables A3 and C3, Appendices A and C respectively). This small variation in percentage protein could have been due to cold weather which did not allow the reduction of carbohydrates due to respiration and resulted in comparatively stable percentage carbohydrates and protein. Essex and Leflore, however, did not develop significant changes.

During the 1990 season, TN4-86 and Essex showed significant differences at the 99% level in the percentage protein (Figure 2B) and carbohydrates (Figure 3) among the

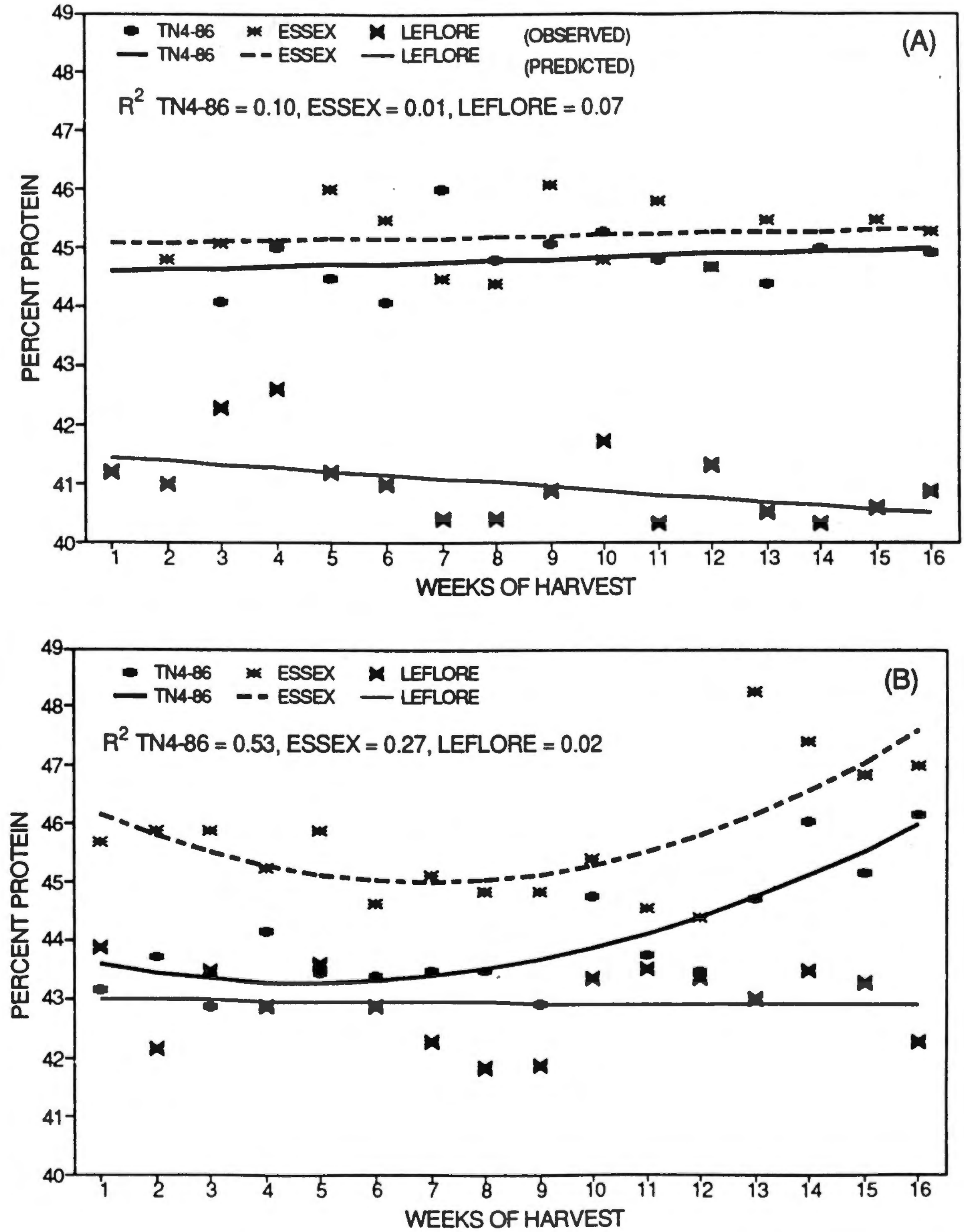



Figure 2. Predicted curves generated from the observed data showing the trends of changes in the protein (%, db) for soybeans TN4-86, Essex, and Leflore during the (A) 1989 and (B) 1990 season.

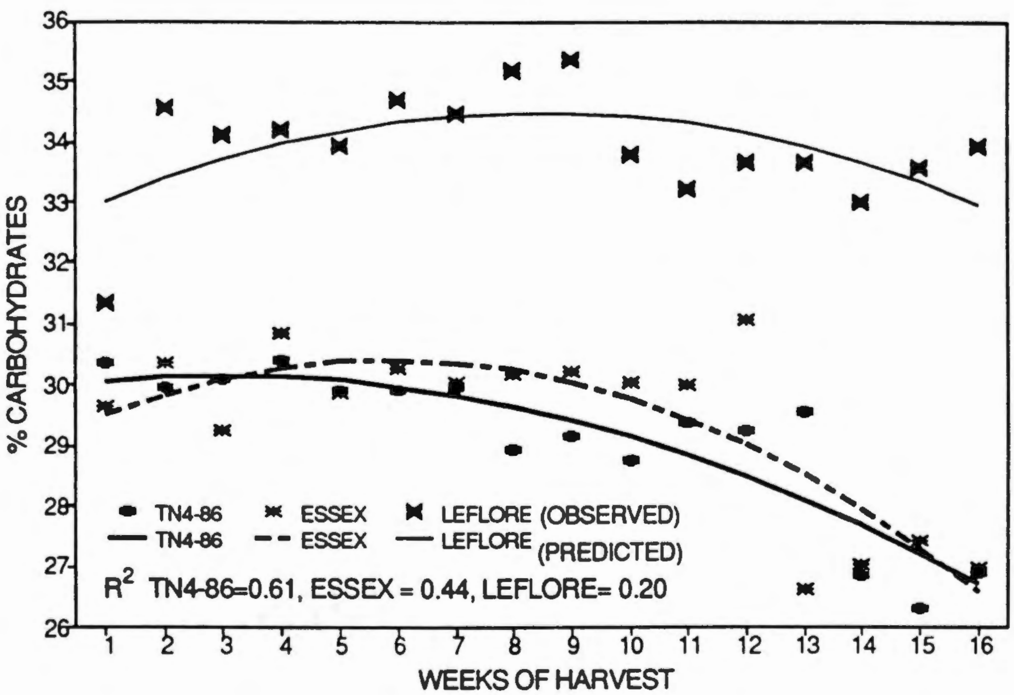



Figure 3. Predicted curves generated from the observed data showing the trends of changes in the carbohydrates (%, db) for soybeans TN4-86, Essex, and Leflore during the 1990 season.

last eleven weeks (6 to 16 weeks) and non-significant differences among the first five weeks of harvests (Tables C9 to C12, Appendix C). This lack of change in percentage protein from physiological maturity to harvest maturity also was observed by Singh and Gupta (1982). Even though there was not a significant change in protein during the first five weeks, a declining trend was evident with an increasing trend in carbohydrates, O'Kelly and Gieger (1937) reported similar findings. However, Leflore did not show significant differences among weeks of harvests.

The previously identified significant proportionate increase in percentage of protein due to a decrease in percentage of carbohydrates after week 5 of harvest was small until about week 8 to 11, with marked increased thereafter (Figure 4). The more rapid proportional increase in percentage protein due to decrease in carbohydrates occurred after week 13 in TN4-86 and week 12 in Essex which corresponded with the sudden increase in weekly rainfall and increase in minimum relative humidity. The percentage protein showed a strong negative correlation with carbohydrates for TN4-86 (r= -0.78, Figure 4-A and Table C32, Appendix C) and for Essex (r= -0.84, Figure 4-B and Table C32, Appendix C). The increased percentage protein also showed a strong positive correlation with bean moisture for TN4-86 (r=0.48, Figure B10-A and Table C31, Appendix C) and for Essex (r=0.53, Figure B10-B and Table C31, Appendix C). Carbohydrates, on the other hand,

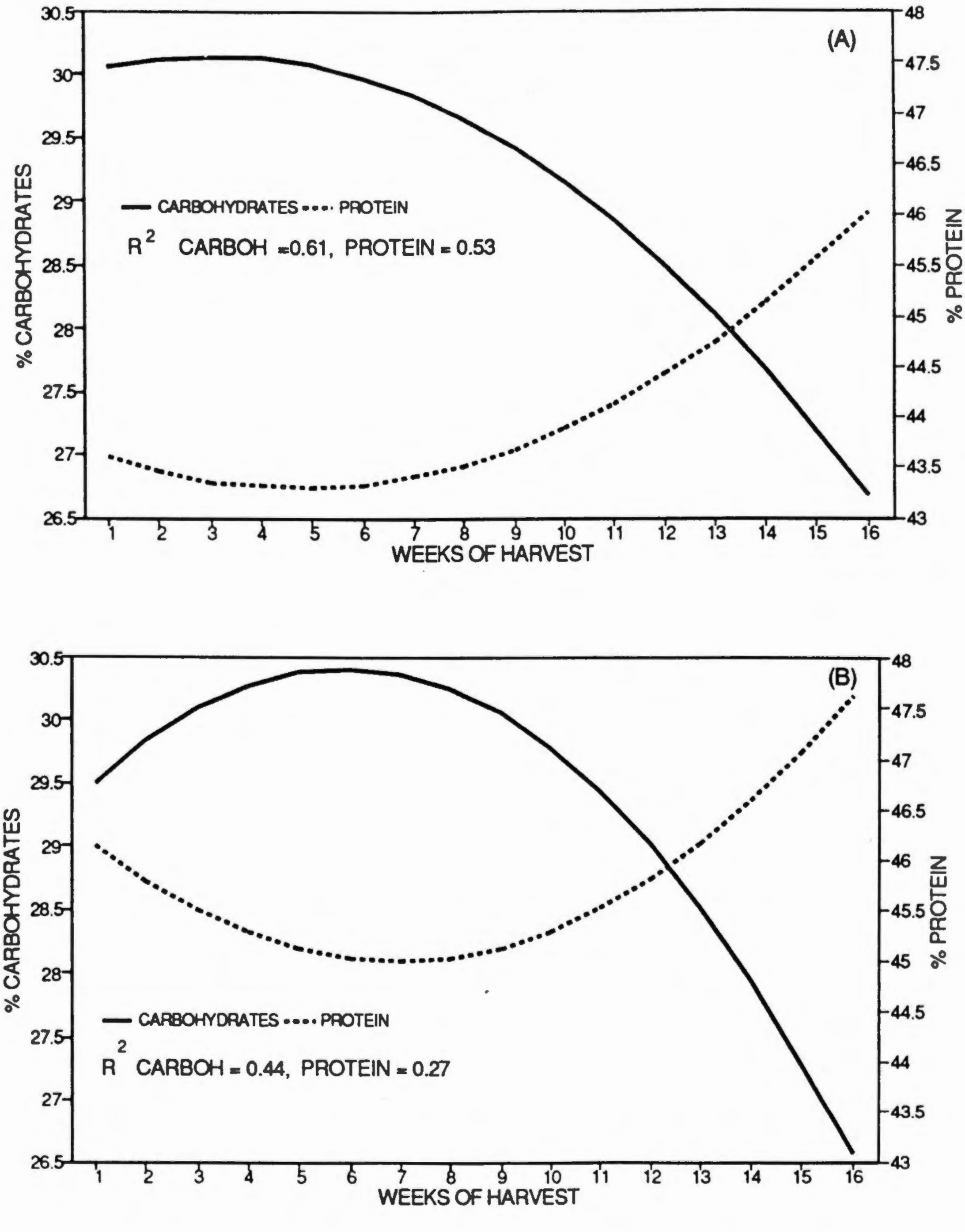



Figure 4. Predicted curves generated from the observed data showing the trends of changes in the protein (%, db), and carbohydrates (%, db) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

showed a negative correlation with bean moisture for TN4-86 (r= -0.59, Figure B11-A and Table C31, Appendix C) and Essex (r= -0.57, Figure B11-B and Table C31, Appendix C).

The positive correlation of bean moisture with percent protein and negative correlation of bean moisture with carbohydrates was a result of increased rate of respiration, due to increased bean moisture content which led to the loss of soluble carbohydrates/sugars. The partial loss of carbohydrates increased the percentage of protein in the bean by compositional compensation. These changes due to field exposure are consistent with the similar effects found by O'Kelly and Gieger (1937), Ramstad and Geddes (1942), Krider et al. (1944) and Krober and Collins (1948).

### 4.3.2. TOTAL OIL:

Significant differences were observed for percentage oil for Leflore across sixteen weeks of harvest during the 1989 season (Tables A3 and C5, Appendices A and C, respectively). In 1990, significant differences were observed for percentage oil among the first five weeks and non-significant differences thereafter (Tables A4 and C13, Appendices A and C, respectively). Even though there was no significant difference after week 5 in 1990, there were similar decreasing trends in both years for Leflore for the first eight weeks with a proportionate increase thereafter (Fig. 5). The decrease in oil content corresponded to the similar decrease in the bean

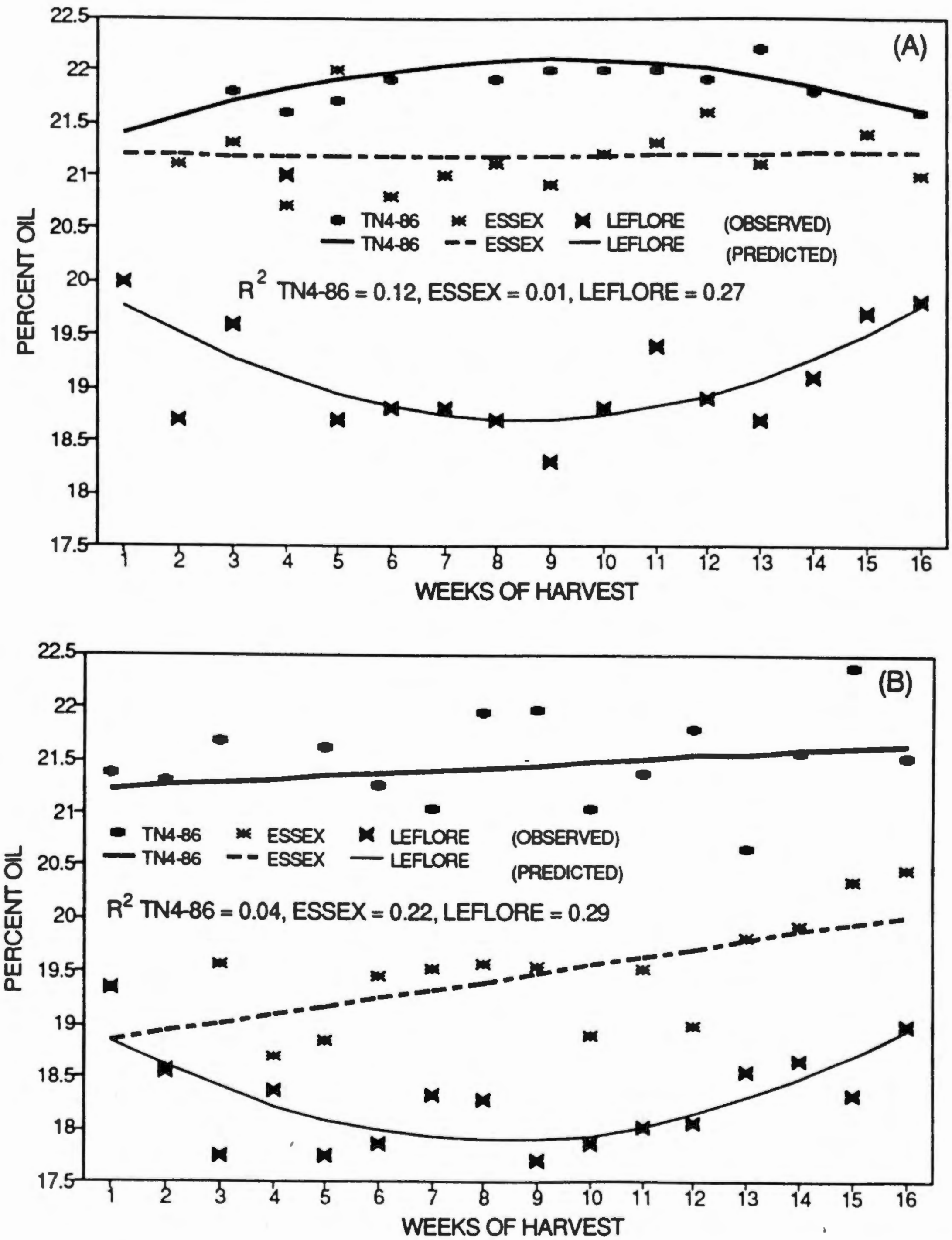


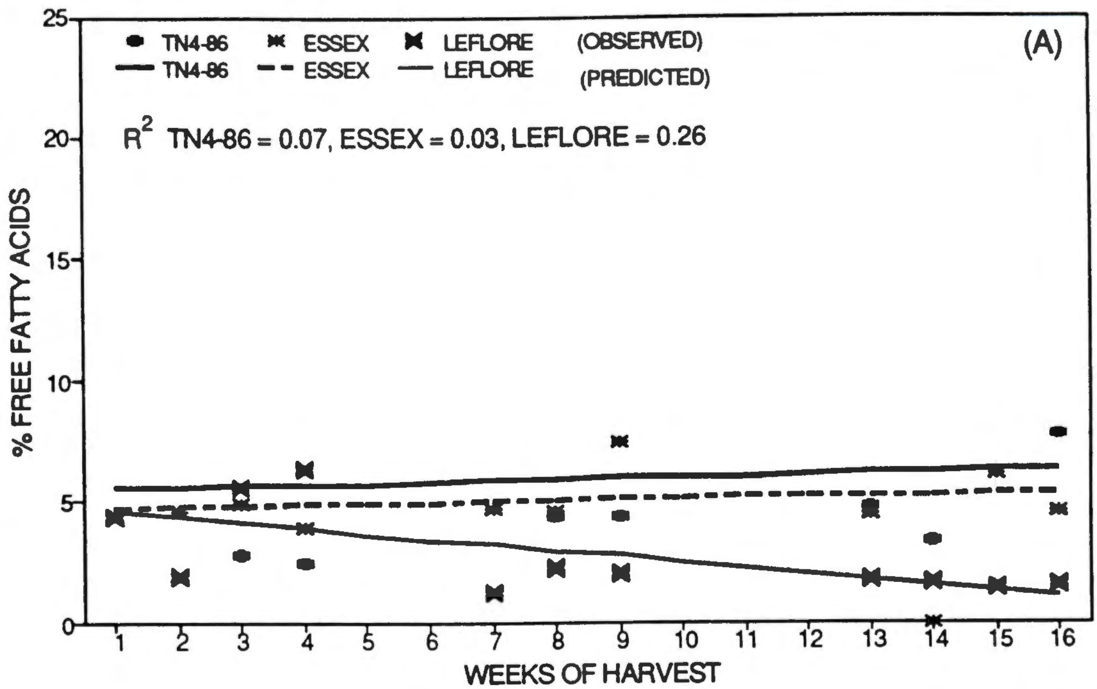

Figure 5. Predicted curves generated from the observed data showing the trends of changes in the total oil (%, db) for soybeans TN4-86, Essex, and Leflore, during the (A) 1989 and (B) 1990 season.

moisture. Decrease in oil content may be associated with loss of phospholipid and glycolipid which decrease during the desiccation period (Slack and Browse, 1984). Soybean lipids include approximately 10% phospholipid and 2% glycolipid (Salunkhe et al., 1985). The apparent increase in percentage oil after week 8 could have been offset with reduced percent carbohydrates through compositional compensation so that the absolute oil remained the same. The explanation of this is similar to that given in Section 4.2. Percentage oil was not significantly different for Essex and TN4-86 over sixteen weeks of harvest during both years.

### 4.3.3. FREE FATTY ACIDS (AS PERCENTAGE OLEIC ACID):

Free fatty acid (FFA) is determined as a percentage of the total oil only and is not affected by the bean yield (dry matter) or compositional compensation which only affects primary chemical components. Similar effects of weather on free fatty acids were observed during both the years.

During the 1989 season, FFA for TN4-86 and Leflore showed significant differences over harvest, whereas, Essex did not differ significantly (Tables A3, C3 & C5, Appendix A and C, respectively). The higher FFA content for TN4-86, compared to Leflore, increased with delayed harvesting and corresponded with higher bean moisture. The FFA for Leflore decreased with decreasing bean moisture (r=0.56, Table C30 and Appendix C). Lower bean moisture for Leflore (Figure 6A) may be the result



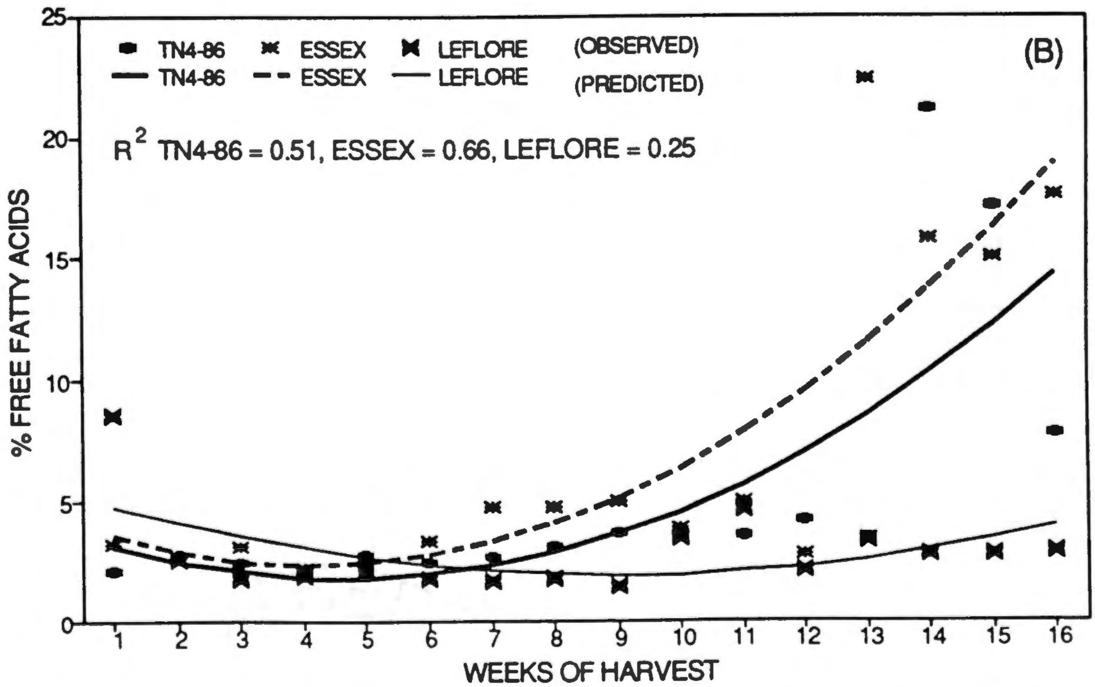




Figure 6. Predicted curves generated from the observed data showing the trends of changes in the free fatty acids (as percent oleic acid) for soybeans TN4-86, Essex, and Leflore during the (A) 1989 and (B) 1990 season.

of minimum temperature being below freezing most of the harvesting period which did not allow the beans to absorb adequate moisture to activate lipase (enzyme) and resulted in actually reducing FFA.

During the 1990 season, significant differences were observed in FFA content among weeks of harvest for all the cultivars from weeks 6 through 16 and with no significance for the first five weeks (Tables A4 and C15 to C20, Appendices A and C, respectively). Although the trends of changes in FFA for
Leflore was, to some extent, similar to both Essex and TN4-86, the values were substantially lower (Figure 6B). Although FFA for Leflore at week 16 was higher than at the end of desiccation period, it was lower than at week 1. The higher values at week 1 for Leflore in both years was a result of higher moisture. Positive correlations between weeks of harvest and percentage FFA for Essex (r=0.73) and TN4-86 (r=0.63) showed increased FFA with delayed harvesting. FFA had a strong positive correlation with bean moisture for TN4-86 (r=0.66, Fig. B13-A and Table C31, Appendices B and C, respectively) and Essex (r=0.86, Fig. B13-B and Table C31, Appendices B and C, respectively). This increase in FFA with increased bean moisture was due most likely to the lipase (enzyme) which catalyzed the step-wise degradation of triglycerides to diglycerides, monoglycerides and ultimately produced glycerol and FFA. Similar effects of moisture have

been found by Abdul-Baki and Anderson (1972), Bewley and Black (1978), Copeland and McDonald (1985) and Hamilton and Russell (1986).

### 4.3.4. ASH AND DRY MATTER:

Percentage ash and dry matter did not show significant changes (Figure 7A) over sixteen weeks of harvest for all the cultivars (Tables A4 and C9 to C20, Appendix A and C, respectively). Since ash is the non-decomposable part of the bean, no change was expected. However, the dry matter was expected to decrease because of the oxidation of carbohydrates as explained in Section 4.2. The non-significant change for the observed dry matter value (Figure 7B), compared to the significant change in the adjusted dry matter value (Table 4, page 43), was due to increase in number of beans tested. The dry matter in the original beans did reduce, due to field weathering, as illustrated by 94.5 g for TN4-86 at week 6 and 90.7 g at week 16 (Table 4, page 44).

### 4.4. CULTIVAR DIFFERENCES:

The differences in the chemical components and physical parameters among cultivars are presented below for the sixteen weeks of harvest. All results are presented on the moisture-free basis.

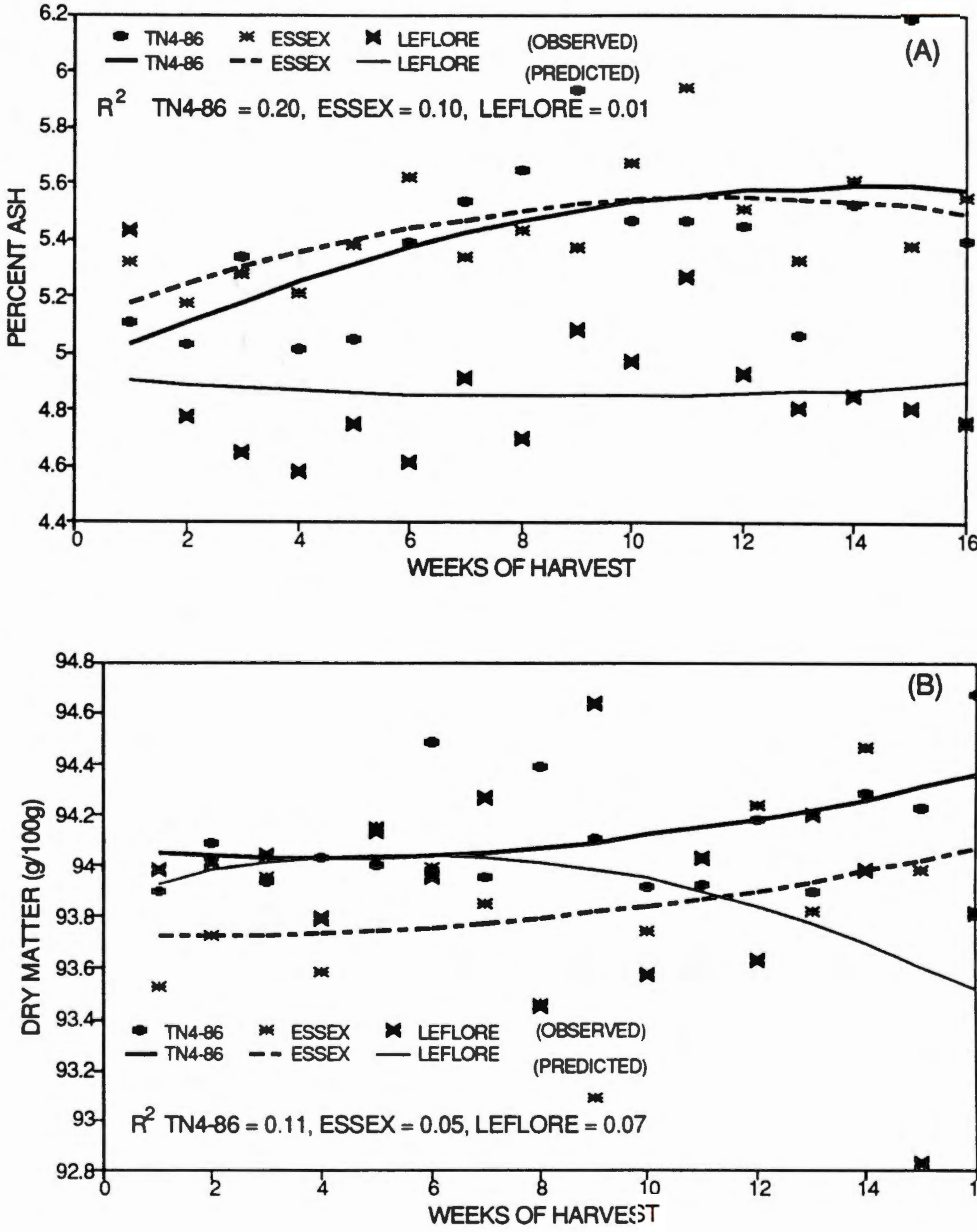



Figure 7. Predicted curves generated from the observed data showing the trends of changes in the (A) ash (%, db) and (B) dry matter (g/100g db) for soybeans TN4-86, Essex, and Leflore during the 1990 season.

### 4.4.1. PHYSICAL DAMAGE OF SEED COAT:

Examination of the 1990 beans for cracks, wrinkles, splits, cracked-wrinkled and total damaged beans, and the subsequent analyses showed significant differences at the 99% level among cultivars. Interaction was shown between weeks of harvest and cultivars (Tables A5 and C21 to C29, Appendices A and C, respectively). The interaction indicated that cultivars were affected differently for specific periods of field exposure. Wrinkled beans percentage was significantly higher for TN4-86 than for Essex or Leflore (Table 5). The cracked beans of all cultivars were significantly different among themselves. The split beans were found only for TN4-86, whereas, Essex and Leflore beans did not split. TN4-86 had the highest percentage of cracked and wrinkled beans followed by Essex and then Leflore. When all damaged beans were combined, TN4-86 and Essex showed the greatest damage with 31% and 30%, respectively, and Leflore, the lowest with 17%. All relative damage values are shown in Table 5.

The increased damage with field exposure enhanced moisture absorption which, in turn, enhanced the chemical activity as previously discussed. It may be seen that the increasing degree of physical damage follows closely the patterns of change in the chemical values.

TABLE 5. Cultivar means[1] (%) for the physical damage parameters over sixteen weeks of harvest for the soybeans TN4-86, Essex, and Leflore during the 1990 season.

| Cultivar | Undamaged Beans (%) | Cracked Beans (%) | Wrinkled Beans (%) | Split Beans (%) | Cracked-Wrinkled (%) | Damaged[2] Beans (%) |
|---|---|---|---|---|---|---|
| Essex | 69 b | 20 a | 5 b | 0 b | 6 b | 31 a |
| Leflore | 83 a | 9 b | 4 b | 0 b | 4 c | 17 a |
| TN4-86 | 70 b | 7 c | 8 a | 2 a | 13 a | 30 b |

[1]Means in a column with different letters are significantly different at 5% level of significance (Duncan's Multiple Range Test).

[2]Sum of cracked, wrinkled, cracked-wrinkled and split beans.

### 4.4.2. TOTAL OIL AND PROTEIN:

Total oil and protein were significantly different among the cultivars across the sixteen weeks of harvest at 99% level with interaction between weeks of harvest and cultivars (Table A4 and C6 to C7, Appendices A and C, respectively) in the 1989 and 1990 seasons. The interaction showed that cultivars did not react similarly from the beginning to the end of harvest during both years. The comparison test (Table 6 and 7) showed that all the cultivars were different for levels of oil and protein across both years. The oil content ranging from high to low percentage in the cultivars was TN4-86, Essex and Leflore. Although there was variation between years, the order remained the same. All mean oil and protein values are shown in Tables 6 and 7.

These variations across years are consistent with the research of Garner et al. (1914), Piper and Morse (1943), Breene et al. (1988), Clark and Snyder (1989) and Hurburgh et al. (1990). This variation presents another justification for examining the weather effects within a specific year rather than considering years as replications. This variation also allows the effects of field weathering (delayed harvesting) to be considered separately for the specific weather conditions in a given year.

The higher contents of oil and protein for the cultivars TN4-86 and Essex (early maturing) compared to Leflore (late maturing) are consistent with results from a previous

Table 6. Cultivar means[1] for the total oil (%, db), protein (%, db) and free fatty acid (as percent oleic acid) over sixteen weeks of harvest for soybeans TN4-86, Essex and Leflore for the 1989 season.

| Cultivar | Total oil (%) | Protein (%) | FFA[2] (%) |
|---|---|---|---|
| TN4-86 | 21.94 A | 44.82 B | 5.95 A |
| Essex | 21.19 B | 45.22 A | 5.03 A |
| Leflore | 19.11 C | 40.96 C | 2.78 B |

[1]Means in a column with different letters are significantly different at 5% level of significance (Duncan's Multiple Range Test).

[2]Free fatty acids.

TABLE 7. Cultivar means[1] for the total oil (%, db) protein (%, db), carbohydrates (%, db), ash (%, db), dry matter (g/100 g) and free fatty acids (as percent oleic acid) over sixteen weeks of harvest for the soybeans TN4-86, Essex, and Leflore.

| Cultivar | Oil (%) | Protein (%) | FFA[2] (%) | Ash (%) | DM[3] (%) | Carbo[4] (%) |
|---|---|---|---|---|---|---|
| TN4-86 | 21.44 a | 44.05 b | 5.30 b | 5.41 a | 94.13 a | 29.12 b |
| Essex | 19.44 b | 45.75 a | 6.89 a | 4.89 a | 93.84 b | 29.35 b |
| Leflore | 18.27 c | 42.95 c | 2.84 c | 5.45 b | 93.30 b | 33.95 a |

[1]Means in a column with different letters are significantly different at 5% level of significance (Duncan's Multiple Range Test).

[2]Free fatty acids.
[3]Dry matter.
[4]Carbohydrates.

investigation which showed that the early maturing cultivars contain greater amounts of oil (Krivoruchco et al., 1979) and protein (Graves et al., 1989) than late maturing cultivars (Osler and Cartter, 1954; Whighim and Minor, 1978; Beatty et al., 1982; Benati et al., 1988).

A negative correlation between percentage of oil and protein was obtained in the present study over sixteen weeks of harvest. In 1989, the cultivars TN4-86, Essex and Leflore showed correlation coefficients of -0.11, -0.15, -0.35 (Table C30, Appendix C) and in 1990, -0.09, -0.15, -0.39, respectively (Table C31, Appendix C). Negative correlations have been reported previously from -0.07 to -0.83 (Weiss et al., 1952; Lal et al., 1973; Krivoruchco et al., 1979). TN4-86 and Essex are characterized as early and semi-early cultivars for Tennessee and have a low negative correlation of -0.09 and -0.15, respectively. Leflore has been characterized as medium late to late and yielded a higher correlation of -0.39. These results are consistent with that of Krivoruchco et al. (1979). They reported that the negative correlation was higher for the late and semi-late cultivars (r = -0.65) than for the early and semi-early cultivars (r = -0.10).

### 4.4.3. CARBOHYDRATES:

A difference in carbohydrate percentages was shown at the 99% level of significance among the cultivars across sixteen weeks of harvest and for week and cultivar interaction (Table

C6, Appendix C). Thus, cultivars did not respond equally over field exposure time. Significant differences also were observed between Leflore and the two other cultivars, between which no differences were found. Because of the difference method of determining carbohydrates, the range of values among cultivars was opposite that of protein (Table 7, page 61). The cultivar means were 29.12% (TN4-86), 29.35% (Essex) and 33.95% (Leflore). These observed values of protein, oil and carbohydrates were similar to those reported by MacMasters et al. (1941), Pryde (1980) and Snyder and Kwon (1987).

**4.4.4. FREE FATTY ACIDS (AS PERCENT OLEIC ACID):**

Significant differences for FFA among cultivars across sixteen weeks of harvest with significant interaction between weeks of harvest and cultivars for the 1990 season were observed at the 99% level of significance. Thus, cultivars differed with respect to FFA as time progressed after physiological maturity (Appendix C, Table C8). The variation among cultivar means showed significant differences among all cultivars (Table 7). The values were 5.30% (TN4-86), 6.89% (Essex) and 2.84% (Leflore).

Similar cultivar mean values were observed during the 1989 season for FFA except that Essex and TN4-86 were not statistically different. Leflore was found to be lower than the other cultivars in FFA content both the years. TN4-86 (5.95%) and Essex (5.03%) were significantly higher in FFA than Leflore (2.78%).

The FFA of soybean oil provides an indication of the amount of oil lost in refining which reduces the final amount of refined oil, thus, increasing the cost of refining (Hamilton and Rossell, 1986). Even though Leflore has a lower oil content than Essex and TN4-86, the lower FFA may compensate partially due to decreased loss in refining. At least one cause of this difference can be attributed to the warmer early season weather to which Essex and TN4-86, but not Leflore, were exposed during seed development. These findings agreed with the observation made by Whighim and Minor (1978) who showed that cooler temperatures were associated with lower levels of oleic acid.

### 4.4.5. ASH CONTENT AND DRY MATTER PERCENTAGE:

Cultivar comparison of percent ash and dry matter across sixteen weeks of harvest showed significant differences at the 99% level along with interaction between weeks of harvest and cultivar. This interaction showed that cultivars reacted differently from physiological maturity to the sixteenth week of harvest (Appendix C, Tables C7 and C8). Leflore had a significantly lower ash content compared to Essex and TN4-86, between which no difference was found (Table 7, page 61). Leflore was shown to be lower in ash (4.89%), whereas, Essex (5.45%) and TN4-86 (5.41%) ash levels were higher. These results compare to Cartter and Hopper (1942) who found a range of ash content among cultivars of 3.67 to 5.37%. The dry matter percentage of TN4-86 (94.13%) was significantly different from Essex (93.84%) and Leflore (93.90%) with no difference between Essex and Leflore.

# CHAPTER V

# SUMMARY AND CONCLUSIONS

## 5.1. SUMMARY

Effects of field weathering (delayed harvesting) on chemical composition and physical damage of TN4-86, Essex and Leflore soybeans were investigated across sixteen weeks of harvest following physiological maturity. The effect of field environment was shown by the increase of bean moisture content which enhanced physical damage of the seed coat. Cracks, wrinkles and splits of the seed coat accelerated the moisture entry into the beans and resulted in increased chemical changes. Chemical changes in the beans increased when beans began to reabsorb moisture after full, natural desiccation.

Moisture was the primary contributing factor that brought about the physical and chemical changes. Moisture effect on the chemical composition of soybeans grown in 1989 was low due to harsh winter temperatures compared to enhanced moisture effects in 1990 under mild winter temperatures. Temperatures below the freezing point prevented the bean moisture from activating the enzymatic or oxidation processes. Moisture increased in the beans after desiccation as a result of elevated and uniform relative humidity, rainfall and above freezing temperatures. Increased bean moisture caused the reduction of dry matter due to oxidation of soluble carbohydrates. The reduction in soluble carbohydrates caused a relative (apparent) increase in percentage protein (dry matter basis) in TN4-86 and Essex and oil (dry matter basis) in Leflore. The proportional (relative) percentage protein and oil increased only due to compositional compensation. Their absolute amounts remained unchanged. Ash content was unaffected by bean moisture. Elevated bean moisture also increased free fatty acids (FFA) (as percent oleic acid) in the crude soybean oil due to extended field exposure. The FFA content of TN4-86 and Essex increased substantially more than that of Leflore as the field exposure time increased. It was notable that TN4-86 and Essex, the early and semi early cultivars respectively, were very different from Leflore, the late cultivar. Field weathering was a destructive process of significant economic importance because of losses in dry matter. However, such losses may possibly be compensated at the market through relative increased percentage of protein and oil on a dry weight basis.

**5.2. CONCLUSIONS**

Specific conclusions drawn from this investigation of the effects of field weathering on chemical composition are as follows:

1. Field weathering affected chemical changes and physical damage in soybeans as moisture increased,

2. Bean moisture caused oxidation of carbohydrates to reduce dry matter,

3. Absolute values of protein, oil and ash did not change with delayed harvesting but the proportional percentage values changed due to compositional alteration,

4. TN4-86 and Essex cultivars had higher mean percentages of protein, oil, free fatty acids and total damaged beans than Leflore cultivar,

5. TN4-86 and Essex had increased relative percentage protein after the desiccation period, whereas, Leflore had decreased relative percentage total oil during the desiccation period,

6. Free fatty acids in crude oil of TN4-86 and Essex soybeans increased substantially more than Leflore due to extended field exposure and

7. Guidelines can be established from these results for soybean growers which will permit them to estimate the time of harvest for optimum value, both in terms of chemical composition and market price.

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# APPENDICES

# APPENDIX 'A'

Tables of experimental data
for field weathering experiment

TABLE A1. Average weekly weather data for temperature, relative humidity, and rainfall from field plots area during the 1989 season.

| Date of Harvest | Temperature °F | | | Relative Humidity (%) | | | Rainfall (Inches) | |
|---|---|---|---|---|---|---|---|---|
| | Avg[1] | Max[2] | Min[3] | Avg[1] | Max[2] | Min[3] | Weekly | Cumul[4] |
| 26-Sep-89 | 62.56 | 68.14 | 56.97 | 87.64 | 92.91 | 79.05 | 4.08 | 4.08 |
| 03-Oct-89 | 61.41 | 74.07 | 48.76 | 78.64 | 94.41 | 49.00 | 0.04 | 4.12 |
| 10-Oct-89 | 61.23 | 76.12 | 46.35 | 79.96 | 94.56 | 44.00 | 0.01 | 4.13 |
| 17-Oct-89 | 54.73 | 63.63 | 45.82 | 80.87 | 94.46 | 65.98 | 1.52 | 5.65 |
| 24-Oct-89 | 57.83 | 73.87 | 41.79 | 74.50 | 94.16 | 30.26 | 0.00 | 5.65 |
| 31-Oct-89 | 50.30 | 63.41 | 37.18 | 79.87 | 94.46 | 49.69 | 0.22 | 5.87 |
| 07-Nov-89 | 55.68 | 66.94 | 44.42 | 74.65 | 92.67 | 56.76 | 1.80 | 7.67 |
| 14-Nov-89 | 47.53 | 58.89 | 36.18 | 74.25 | 89.40 | 55.47 | 1.99 | 9.66 |
| 21-Nov-89 | 41.58 | 51.46 | 31.69 | 73.88 | 91.50 | 52.53 | 1.09 | 10.75 |
| 28-Nov-89 | 42.38 | 54.09 | 30.67 | 69.45 | 90.91 | 43.99 | 0.46 | 11.21 |
| 05-Dec-89 | 41.07 | 49.51 | 32.63 | 70.15 | 85.63 | 54.81 | 0.59 | 11.80 |
| 12-Dec-89 | 28.30 | 35.19 | 21.42 | 77.17 | 87.26 | 64.41 | 0.47 | 12.27 |
| 19-Dec-89 | 19.51 | 27.23 | 11.79 | 67.51 | 79.80 | 50.52 | 0.24 | 12.51 |
| 26-Dec-89 | 34.81 | 44.22 | 25.39 | 83.02 | 94.47 | 64.24 | 1.38 | 13.89 |
| 02-Jan-90 | 40.86 | 49.15 | 32.56 | 83.06 | 93.20 | 63.40 | 1.15 | 15.04 |
| 09-Jan-90 | 38.51 | 50.52 | 26.49 | 64.78 | 85.94 | 40.62 | 0.61 | 15.65 |
| 16-Jan-90 | 50.77 | 60.19 | 41.36 | 78.01 | 92.10 | 60.97 | 2.22 | 17.87 |
| 23-Jan-90 | 44.47 | 55.69 | 33.26 | 69.25 | 89.50 | 40.73 | 1.06 | 18.93 |
| 30-Jan-90 | 46.63 | 58.73 | 34.52 | 83.24 | 93.43 | 63.07 | 3.12 | 22.05 |
| 06-Feb-90 | 46.33 | 60.01 | 32.65 | 77.36 | 91.51 | 49.56 | 0.53 | 22.58 |

[1]Average
[2]Maximum
[3]Minimum
[4]Cumulative

TABLE A2. Average weekly weather data for temperature, relative humidity, and rainfall obtained from field plots area during the 1990 season.

| DATE OF HARVEST | TEMPERATURE °F | | | | RELATIVE HUMIDITY (%) | | | | RAINFALL (INCHES) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | AVG | MAX | MIN | MAX-MIN[1] | AVG | MAX | MIN | MAX-MIN[2] | WEEKLY | CUMULATIVE |
| 19-Sep-90 | 68.5 | 78.8 | 59.9 | 18.9 | 74.4 | 86.7 | 55.1 | 31.6 | 0.0 | 0.0 |
| 26-Sep-90 | 63.0 | 75.9 | 51.5 | 24.5 | 71.3 | 86.0 | 44.8 | 41.2 | 0.3 | 0.4 |
| 03-Oct-90 | 66.0 | 80.9 | 54.0 | 26.9 | 72.9 | 86.2 | 42.9 | 43.3 | 0.3 | 0.6 |
| 10-Oct-90 | 66.2 | 79.5 | 56.3 | 23.2 | 76.5 | 86.2 | 51.2 | 35.0 | 2.2 | 2.8 |
| 17-Oct-90 | 62.2 | 74.7 | 52.5 | 22.2 | 74.8 | 84.2 | 53.0 | 31.1 | 0.2 | 3.0 |
| 24-Oct-90 | 55.3 | 66.4 | 43.5 | 22.9 | 73.4 | 84.3 | 51.5 | 32.9 | 1.9 | 4.9 |
| 31-Oct-90 | 46.6 | 62.9 | 34.1 | 28.8 | 68.8 | 84.8 | 34.5 | 50.3 | 0.0 | 4.9 |
| 07-Nov-90 | 52.1 | 71.0 | 39.0 | 31.9 | 69.7 | 84.5 | 36.6 | 47.9 | 0.4 | 5.3 |
| 14-Nov-90 | 45.7 | 58.4 | 35.0 | 23.4 | 69.3 | 83.2 | 41.6 | 41.6 | 1.0 | 6.3 |
| 21-Nov-90 | 47.9 | 63.7 | 34.7 | 29.0 | 70.1 | 84.7 | 39.6 | 45.1 | 0.1 | 6.4 |
| 28-Nov-90 | 57.0 | 70.3 | 42.9 | 27.4 | 66.0 | 82.8 | 40.5 | 42.3 | 0.7 | 7.1 |
| 05-Dec-90 | 40.9 | 53.7 | 30.4 | 23.4 | 66.8 | 82.1 | 39.2 | 42.9 | 1.0 | 8.1 |
| 12-Dec-90 | 39.3 | 56.6 | 26.5 | 30.1 | 66.9 | 84.1 | 30.0 | 54.0 | 0.0 | 8.1 |
| 19-Dec-90 | 50.5 | 58.8 | 43.3 | 15.6 | 75.6 | 82.8 | 61.9 | 20.9 | 2.1 | 10.1 |
| 26-Dec-90 | 41.7 | 50.3 | 32.1 | 18.3 | 74.6 | 83.2 | 61.7 | 21.5 | 4.1 | 14.2 |
| 02-Jan-91 | 41.1 | 49.0 | 32.7 | 16.3 | 78.1 | 83.0 | 67.1 | 16.0 | 2.6 | 16.7 |
| 09-Jan-91 | 45.4 | 49.8 | 41.4 | 8.5 | 76.5 | 80.0 | 71.9 | 8.1 | 0.9 | 17.6 |
| 16-Jan-91 | 41.0 | 49.5 | 34.1 | 15.4 | 74.8 | 81.6 | 59.9 | 21.7 | 1.2 | 18.8 |
| 23-Jan-91 | 35.1 | 44.3 | 26.9 | 17.4 | 68.4 | 80.1 | 53.1 | 27.0 | 0.3 | 19.1 |
| 30-Jan-91 | 39.5 | 52.1 | 28.5 | 23.7 | 63.7 | 77.5 | 42.8 | 34.7 | 0.5 | 19.7 |

1. Difference between maximum and minimum temperature.
2. Difference between maximum and minimum relative humidity.

TABLE A3. Observed and predicted experimental data for chemical composition (%, db) and bean moisture at harvest (%, wb) for soybeans TN4-86, Essex and Leflore during the 1989 season.

| | | Protein | | Total oil | | Free Fatty Acid | | Bean Moisture | |
|---|---|---|---|---|---|---|---|---|---|
| Cultivar | Week | Obs[1] | Pred[2] | Obs[1] | Pred[2] | Obs[1] | Pred[2] | Obs[1] | Pred[2] |
| TN4-86 | 1 | x | 44.61 | x | 21.40 | x | 5.483 | 51.96 | 44.88 |
| | 2 | x | 44.64 | x | 21.56 | x | 5.540 | 40.09 | 38.48 |
| | 3 | 44.1 | 44.67 | 21.8 | 21.70 | 2.8 | 5.596 | 17.83 | 32.9 |
| | 4 | 45.0 | 44.69 | 21.6 | 21.81 | 2.5 | 5.653 | 22.39 | 28.15 |
| | 5 | 44.5 | 44.72 | 21.7 | 21.91 | --- | 5.710 | 30.74 | 24.21 |
| | 6 | 44.1 | 44.74 | 21.9 | 21.99 | --- | 5.766 | 20.09 | 20.1 |
| | 7 | 46.0 | 44.77 | 22.7 | 22.04 | 18.0 | 5.823 | 27.18 | 18.8 |
| | 8 | 44.8 | 44.79 | 21.9 | 22.08 | 4.3 | 5.879 | 18.35 | 17.33 |
| | 9 | 45.1 | 44.82 | 22.0 | 22.10 | 4.3 | 5.936 | 12.87 | 16.67 |
| | 10 | 45.3 | 44.84 | 22.0 | 22.08 | --- | 5.992 | 25.10 | 16.84 |
| | 11 | 44.8 | 44.87 | 22.0 | 22.06 | --- | 6.049 | 14.21 | 17.82 |
| | 12 | 44.7 | 44.90 | 21.9 | 22.01 | --- | 6.106 | 26.99 | 19.63 |
| | 13 | 44.4 | 44.92 | 22.2 | 21.94 | 4.8 | 6.162 | 16.39 | 22.25 |
| | 14 | 45.0 | 44.95 | 21.8 | 21.85 | 3.3 | 6.219 | 11.83 | 25.7 |
| | 15 | x | 44.97 | x | 21.74 | x | 6.275 | 31.72 | 29.96 |
| | 16 | 44.9 | 45.00 | 21.6 | 21.62 | 7.8 | 6.332 | 42.02 | 35.05 |
| ESSEX | 1 | x | 45.09 | x | 21.19 | x | 4.670 | 57.00 | 38.77 |
| | 2 | 44.8 | 45.10 | 21.1 | 21.19 | 4.6 | 4.718 | 20.47 | 34.19 |
| | 3 | 45.2 | 45.12 | 21.5 | 21.18 | 4.9 | 4.765 | 28.10 | 30.19 |
| | 4 | 45.1 | 45.14 | 20.7 | 21.18 | 3.9 | 4.813 | 20.34 | 26.77 |
| | 5 | 46.0 | 45.15 | 22.0 | 21.18 | --- | 4.861 | 18.94 | 23.92 |
| | 6 | 45.5 | 45.17 | 20.8 | 21.18 | --- | 4.908 | 25.16 | 21.65 |
| | 7 | 44.5 | 45.19 | 21.0 | 21.18 | 4.7 | 4.956 | 23.34 | 19.96 |
| | 8 | 44.4 | 45.21 | 21.1 | 21.18 | 4.6 | 5.003 | 11.78 | 18.85 |
| | 9 | 46.1 | 45.22 | 20.9 | 21.18 | 7.5 | 5.051 | 21.75 | 18.31 |
| | 10 | 44.8 | 45.24 | 21.2 | 21.18 | --- | 5.098 | 11.56 | 18.35 |
| | 11 | 45.8 | 45.26 | 21.3 | 21.19 | --- | 5.146 | 32.83 | 18.97 |
| | 12 | 44.7 | 45.27 | 21.6 | 21.20 | --- | 5.193 | 24.45 | 20.17 |
| | 13 | 45.5 | 45.29 | 21.1 | 21.20 | 4.4 | 5.241 | 12.16 | 21.94 |
| | 14 | x | 45.31 | x | 21.21 | x | 5.288 | 32.15 | 24.29 |
| | 15 | 45.5 | 45.33 | 21.4 | 21.22 | 6.1 | 5.336 | 39.71 | 27.22 |
| | 16 | 45.3 | 45.34 | 21.0 | 21.23 | 4.5 | 5.384 | 14.53 | 30.73 |
| LEFLORE | 1 | 41.2 | 41.45 | 20.0 | 19.77 | 4.3 | 4.510 | 28.70 | 24.53 |
| | 2 | 41.0 | 41.38 | 18.7 | 19.51 | 1.9 | 4.280 | 18.09 | 23.59 |
| | 3 | 42.3 | 41.32 | 19.6 | 19.28 | 5.5 | 4.050 | 29.75 | 22.73 |
| | 4 | 42.9 | 41.26 | 20.9 | 19.09 | 6.3 | 3.820 | 27.73 | 21.98 |
| | 5 | 41.2 | 41.19 | 18.7 | 18.94 | --- | 3.590 | 10.13 | 21.31 |
| | 6 | 41.0 | 41.13 | 18.8 | 18.83 | --- | 3.360 | 15.59 | 20.74 |
| | 7 | 40.4 | 41.07 | 18.8 | 18.75 | 1.2 | 3.130 | 10.91 | 20.26 |
| | 8 | 40.4 | 41.03 | 18.7 | 18.71 | 2.2 | 2.900 | 29.06 | 19.87 |
| | 9 | 40.9 | 40.94 | 18.3 | 18.71 | 2.0 | 2.700 | 21.05 | 19.57 |
| | 10 | 41.7 | 40.88 | 18.8 | 18.75 | --- | 2.440 | 15.67 | 19.37 |
| | 11 | 40.3 | 40.81 | 19.4 | 18.82 | --- | 2.210 | 24.18 | 19.26 |
| | 12 | 41.2 | 40.75 | 18.6 | 18.93 | --- | 1.980 | 24.74 | 19.24 |
| | 13 | 40.5 | 40.69 | 18.7 | 19.08 | 1.7 | 1.750 | 21.74 | 19.32 |
| | 14 | 40.3 | 40.63 | 19.1 | 19.27 | 1.6 | 1.520 | 15.29 | 19.49 |
| | 15 | 40.6 | 40.56 | 19.7 | 19.50 | 1.4 | 1.290 | 25.26 | 19.75 |
| | 16 | 40.9 | 40.50 | 19.8 | 19.76 | 1.5 | 1.050 | 13.20 | 20.1 |

x = Samples damaged in storage. [1]Observed (experimental).
--- =Samples were not analyzed. [2]Predicted (regression).

TABLE A4. Observed (OBS) and predicted (PRED) Chemical composition (%, db), bean moisture at harvest (%, wb) and dry matter (g/100g db) for soybeans TN4-86, Essex and Leflore during the 1990 season.

| | | PROTEIN | | TOTAL OIL | | ASH | | CARBOHYDRATES | | FREE FATTY ACID | | BEAN MOISTURE | | DRY MATTER | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CULTIVAR | WEEK | OBS | PRED | OBS | PRED | OBS | PRED | OBS | PRED | OBS | PRED | OBS | PRED | OBS | PRED |
| TN4-86 | 1 | 43.14 | 43.59 | 21.38 | 21.23 | 5.11 | 5.03 | 30.36 | 30.06 | 2.13 | 3.11 | 30.70 | 24.15 | 93.90 | 94.05 |
| | 2 | 43.72 | 43.45 | 21.30 | 21.26 | 5.03 | 5.11 | 29.95 | 30.13 | 2.80 | 2.48 | 13.50 | 21.03 | 94.09 | 94.04 |
| | 3 | 42.87 | 43.35 | 21.69 | 21.29 | 5.34 | 5.18 | 30.10 | 30.15 | 2.47 | 2.05 | 13.33 | 18.51 | 93.94 | 94.03 |
| | 4 | 44.14 | 43.30 | 20.46 | 21.31 | 5.01 | 5.25 | 30.39 | 30.14 | 1.83 | 1.82 | 18.00 | 16.58 | 94.03 | 94.03 |
| | 5 | 43.45 | 43.29 | 21.61 | 21.34 | 5.05 | 5.31 | 29.89 | 30.08 | 2.80 | 1.78 | 15.63 | 15.24 | 94.00 | 94.03 |
| | 6 | 43.41 | 43.32 | 21.26 | 21.37 | 5.39 | 5.37 | 29.93 | 29.98 | 2.43 | 1.95 | 25.27 | 14.50 | 94.48 | 94.04 |
| | 7 | 43.49 | 43.40 | 21.03 | 21.40 | 5.53 | 5.42 | 29.95 | 29.84 | 2.67 | 2.30 | 11.30 | 14.36 | 93.96 | 94.05 |
| | 8 | 43.49 | 43.51 | 21.95 | 21.43 | 5.64 | 5.46 | 28.92 | 29.65 | 3.03 | 2.86 | 14.73 | 14.80 | 94.39 | 94.07 |
| | 9 | 42.91 | 43.68 | 21.99 | 21.45 | 5.93 | 5.50 | 29.16 | 29.43 | 3.70 | 3.61 | 15.47 | 15.85 | 94.11 | 94.09 |
| | 10 | 44.75 | 43.88 | 21.03 | 21.48 | 5.47 | 5.53 | 28.75 | 29.16 | 3.60 | 4.56 | 18.63 | 17.49 | 93.92 | 94.12 |
| | 11 | 43.79 | 44.13 | 21.38 | 21.51 | 5.47 | 5.55 | 29.36 | 28.85 | 3.57 | 5.71 | 12.30 | 19.72 | 93.93 | 94.15 |
| | 12 | 43.49 | 44.42 | 21.80 | 21.54 | 5.45 | 5.57 | 29.26 | 28.50 | 4.17 | 7.05 | 17.77 | 22.55 | 94.18 | 94.18 |
| | 13 | 44.71 | 44.75 | 20.66 | 21.56 | 5.07 | 5.58 | 29.57 | 28.11 | 3.43 | 8.59 | 28.10 | 25.97 | 93.90 | 94.22 |
| | 14 | 46.05 | 45.13 | 21.57 | 21.59 | 5.52 | 5.59 | 26.85 | 27.67 | 21.20 | 10.32 | 30.48 | 29.98 | 94.29 | 94.26 |
| | 15 | 45.17 | 45.55 | 22.38 | 21.62 | 6.18 | 5.59 | 26.27 | 27.19 | 17.20 | 12.26 | 52.67 | 34.60 | 94.23 | 94.31 |
| | 16 | 46.17 | 46.01 | 21.53 | 21.64 | 5.40 | 5.58 | 26.90 | 26.68 | 7.80 | 14.39 | 27.23 | 39.80 | 94.67 | 94.36 |
| ESSEX | 1 | 45.67 | 46.14 | 19.34 | 18.85 | 5.32 | 5.18 | 29.66 | 29.50 | 3.23 | 3.52 | 34.63 | 27.28 | 93.53 | 93.73 |
| | 2 | 45.90 | 45.79 | 18.59 | 18.94 | 5.17 | 5.24 | 30.34 | 29.84 | 2.63 | 2.89 | 17.33 | 23.85 | 93.73 | 93.73 |
| | 3 | 45.90 | 45.50 | 19.57 | 19.01 | 5.28 | 5.30 | 29.24 | 30.10 | 3.07 | 2.50 | 18.80 | 20.97 | 93.95 | 93.73 |
| | 4 | 45.25 | 45.28 | 18.70 | 19.09 | 5.21 | 5.35 | 30.84 | 30.28 | 2.20 | 2.34 | 15.23 | 18.66 | 93.59 | 93.74 |
| | 5 | 45.90 | 45.12 | 18.85 | 19.17 | 5.38 | 5.40 | 29.87 | 30.39 | 2.33 | 2.42 | 24.17 | 16.89 | 94.15 | 93.75 |
| | 6 | 44.64 | 45.02 | 19.46 | 19.25 | 5.62 | 5.44 | 30.28 | 30.42 | 3.30 | 2.74 | 11.73 | 15.68 | 93.99 | 93.76 |
| | 7 | 45.13 | 44.99 | 19.51 | 19.32 | 5.34 | 5.47 | 30.02 | 30.38 | 4.80 | 3.29 | 14.43 | 15.03 | 93.85 | 93.77 |
| | 8 | 44.83 | 45.03 | 19.57 | 19.4 | 5.43 | 5.50 | 30.16 | 30.26 | 4.80 | 4.08 | 15.43 | 14.93 | 93.46 | 93.79 |
| | 9 | 44.87 | 45.12 | 19.54 | 19.48 | 5.37 | 5.52 | 30.23 | 30.06 | 4.97 | 5.11 | 18.17 | 15.38 | 93.09 | 93.82 |
| | 10 | 45.40 | 45.28 | 18.89 | 19.56 | 5.67 | 5.54 | 30.03 | 29.79 | 3.87 | 6.37 | 12.50 | 16.39 | 93.75 | 93.84 |
| | 11 | 44.56 | 45.51 | 19.51 | 19.63 | 5.94 | 5.55 | 30.00 | 29.44 | 5.03 | 7.87 | 17.77 | 17.95 | 94.03 | 93.87 |
| | 12 | 44.41 | 45.80 | 19.00 | 19.71 | 5.51 | 5.55 | 31.08 | 29.02 | 2.83 | 9.61 | 16.10 | 20.07 | 94.24 | 93.90 |
| | 13 | 48.24 | 46.16 | 19.80 | 19.79 | 5.33 | 5.54 | 26.62 | 28.52 | 22.43 | 11.58 | 28.53 | 22.74 | 93.82 | 93.94 |
| | 14 | 47.43 | 46.58 | 19.92 | 19.87 | 5.61 | 5.53 | 27.03 | 27.94 | 15.83 | 13.79 | 34.53 | 25.97 | 94.46 | 93.98 |
| | 15 | 46.86 | 47.06 | 20.34 | 19.94 | 5.38 | 5.52 | 27.42 | 27.29 | 15.00 | 16.24 | 26.83 | 29.75 | 93.98 | 94.02 |
| | 16 | 47.01 | 47.61 | 20.46 | 20.02 | 5.55 | 5.49 | 26.98 | 26.56 | 17.57 | 18.93 | 29.43 | 34.05 | 93.81 | 94.07 |
| LEFLORE | 1 | 43.87 | 43.24 | 19.34 | 18.86 | 5.43 | 4.90 | 31.35 | 33.00 | 8.53 | 4.80 | 55.97 | 36.80 | 93.98 | 93.93 |
| | 2 | 42.15 | 43.13 | 18.54 | 18.61 | 4.78 | 4.89 | 34.53 | 33.37 | 2.53 | 4.12 | 33.97 | 32.43 | 94.01 | 93.98 |
| | 3 | 43.49 | 43.04 | 17.74 | 18.40 | 4.65 | 4.88 | 34.12 | 33.69 | 1.8 | 3.53 | 18.30 | 28.58 | 94.04 | 94.01 |
| | 4 | 42.87 | 42.96 | 18.36 | 18.22 | 4.58 | 4.87 | 34.20 | 33.95 | 1.87 | 3.04 | 13.70 | 25.27 | 93.79 | 94.03 |
| | 5 | 43.60 | 42.90 | 17.74 | 18.08 | 4.75 | 4.86 | 33.91 | 34.16 | 2.1 | 2.63 | 14.47 | 22.49 | 94.14 | 94.04 |
| | 6 | 42.87 | 42.85 | 17.85 | 17.98 | 4.61 | 4.85 | 34.66 | 34.32 | 1.73 | 2.31 | 15.90 | 20.25 | 93.96 | 94.04 |
| | 7 | 42.30 | 42.81 | 18.31 | 17.91 | 4.91 | 4.85 | 34.48 | 34.42 | 1.63 | 2.08 | 12.37 | 18.54 | 94.27 | 94.03 |
| | 8 | 41.84 | 42.79 | 18.28 | 17.89 | 4.70 | 4.85 | 35.18 | 34.47 | 1.77 | 1.93 | 16.80 | 17.36 | 93.45 | 94.01 |
| | 9 | 41.88 | 42.79 | 17.70 | 17.89 | 5.08 | 4.85 | 35.34 | 34.47 | 1.4 | 1.88 | 15.27 | 16.71 | 94.63 | 93.98 |
| | 10 | 43.37 | 42.80 | 17.85 | 17.93 | 4.97 | 4.85 | 33.80 | 34.42 | 3.43 | 1.91 | 25.97 | 16.60 | 93.58 | 93.95 |
| | 11 | 43.52 | 42.83 | 18.01 | 18.01 | 5.27 | 4.85 | 33.20 | 34.31 | 4.63 | 2.04 | 27.40 | 17.02 | 94.03 | 93.90 |
| | 12 | 43.37 | 42.87 | 18.05 | 18.13 | 4.93 | 4.86 | 33.65 | 34.14 | 2.13 | 2.25 | 25.60 | 17.98 | 93.63 | 93.84 |
| | 13 | 42.99 | 42.92 | 18.54 | 18.29 | 4.81 | 4.87 | 33.66 | 33.93 | 3.3 | 2.55 | 27.43 | 19.47 | 94.20 | 93.77 |
| | 14 | 43.49 | 42.99 | 18.66 | 18.47 | 4.85 | 4.87 | 33.00 | 33.66 | 2.77 | 2.94 | 26.43 | 21.49 | 93.98 | 93.70 |
| | 15 | 43.30 | 43.08 | 18.31 | 18.70 | 4.81 | 4.89 | 33.58 | 33.34 | 2.83 | 3.42 | 17.13 | 24.04 | 92.83 | 93.61 |
| | 16 | 42.30 | 43.18 | 19.00 | 18.95 | 4.76 | 4.90 | 33.94 | 32.96 | 2.93 | 3.99 | 15.47 | 27.13 | 93.81 | 93.52 |

TABLE A5. Observed and predicted experimental data for physical damage parameters (%) for soybeans TN4-86, Essex and Leflore during the 1990 season.

| Cultivar | Week of Harvest | Cracked Beans | | Wrinkled Beans | | Split Beans | | Cracked+ Wrinkled[3] | | Total Damaged Beans[4] | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Obs[1] | Pred[2] | Obs[1] | Pred[2] | Obs[1] | Pred[2] | Obs[1] | Pred[2] | Obs[1] | Pred[2] |
| TN4-86 | 1 | 5 | 5 | 4 | 3 | 0 | 0 | 2 | 3 | 11 | 11 |
| | 4 | 2 | 2 | 4 | 5 | 0 | 0 | 0 | 0 | 6 | 7 |
| | 7 | 3 | 3 | 6 | 7 | 0 | 0 | 6 | 3 | 15 | 12 |
| | 10 | 4 | 5 | 9 | 9 | 0 | 0 | 6 | 10 | 19 | 25 |
| | 13 | 13 | 11 | 10 | 11 | 6 | 0 | 24 | 23 | 53 | 48 |
| | 16 | 17 | 18 | 13 | 12 | 8 | 0 | 40 | 40 | 78 | 80 |
| ESSEX | 1 | 15 | 16 | 2 | 2 | 0 | 0 | 0 | 0 | 17 | 14 |
| | 4 | 12 | 12 | 1 | 3 | 0 | 0 | 0 | 2 | 13 | 18 |
| | 7 | 17 | 13 | 6 | 4 | 0 | 0 | 2 | 5 | 25 | 25 |
| | 10 | 18 | 17 | 5 | 5 | 0 | 0 | 11 | 7 | 34 | 33 |
| | 13 | 17 | 25 | 12 | 6 | 0 | 0 | 17 | 10 | 46 | 43 |
| | 16 | 42 | 38 | 3 | 7 | 0 | 0 | 7 | 13 | 52 | 54 |
| LEFLORE | 1 | 10 | 8 | 2 | 0 | 0 | 0 | 5 | 5 | 17 | 12 |
| | 4 | 2 | 6 | 1 | 4 | 0 | 0 | 0 | 1 | 3 | 11 |
| | 7 | 5 | 5 | 5 | 7 | 0 | 0 | 0 | 0 | 10 | 12 |
| | 10 | 7 | 7 | 12 | 7 | 0 | 0 | 0 | 1 | 19 | 15 |
| | 13 | 11 | 11 | 4 | 6 | 0 | 0 | 7 | 5 | 26 | 22 |
| | 16 | 14 | 16 | 2 | 2 | 0 | 0 | 12 | 13 | 28 | 31 |

[1]Observed (experimental) value are expressed as percentage.
[2]Predicted (regression) value are expressed as percentage.
[3]Beans with both cracks and wrinkles.
[4]Sum of cracked, wrinkled, split and beans with both cracks and wrinkles.

# APPENDIX 'B'

Figures for field weathering experiment

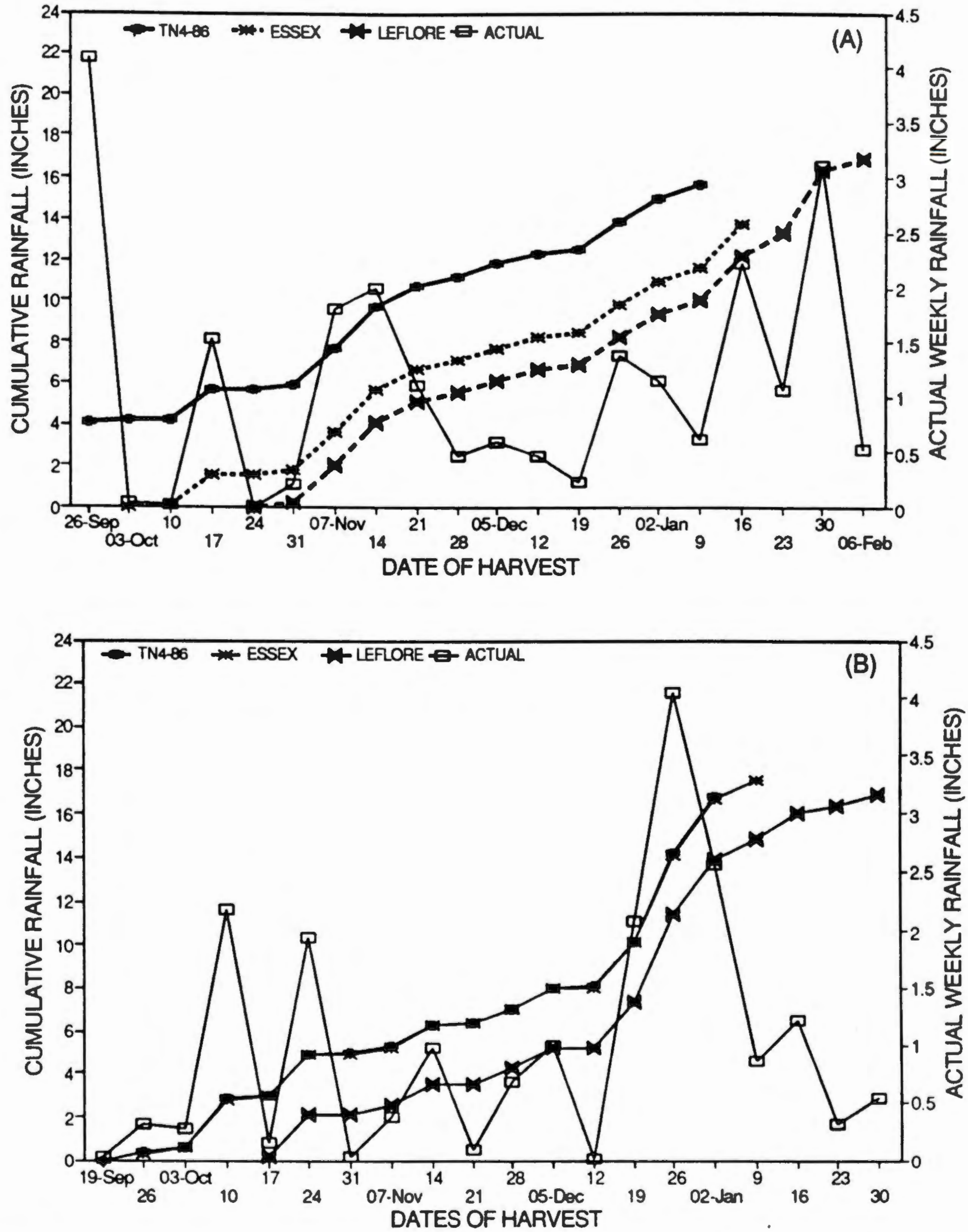
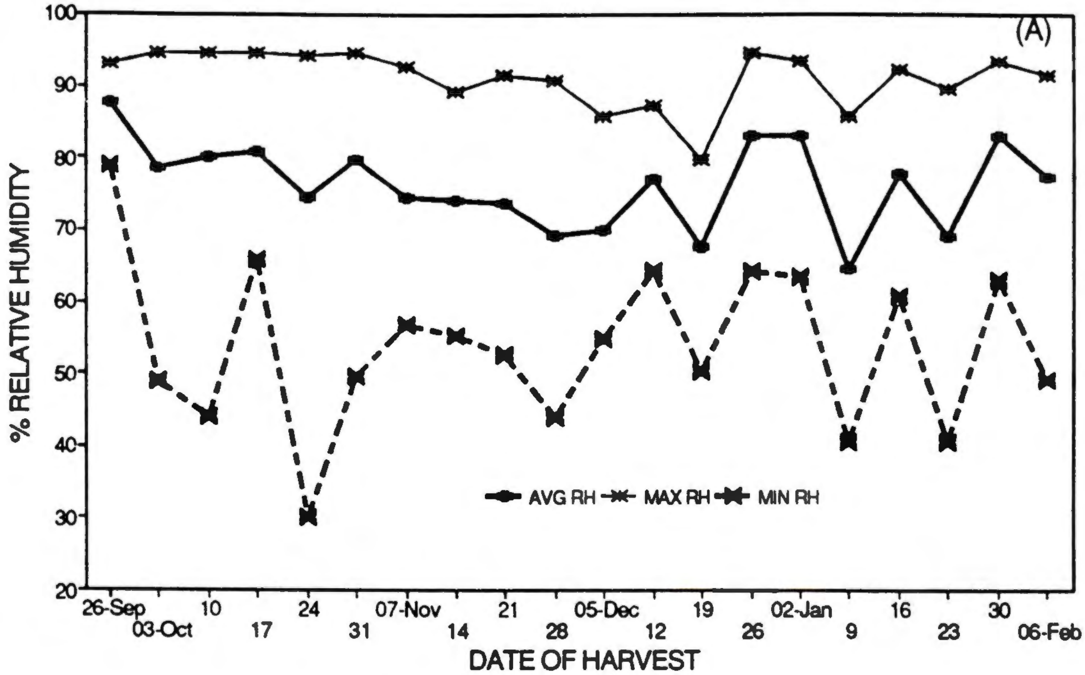



Figure B1. Weekly actual and cumulative rainfall at the field plot for the harvest weeks of soybeans TN4-86, Essex and Leflore which extended from (A) September 19, 1989 to February 6, 1990 and (B) September 13, 1990 to January 30, 1991.



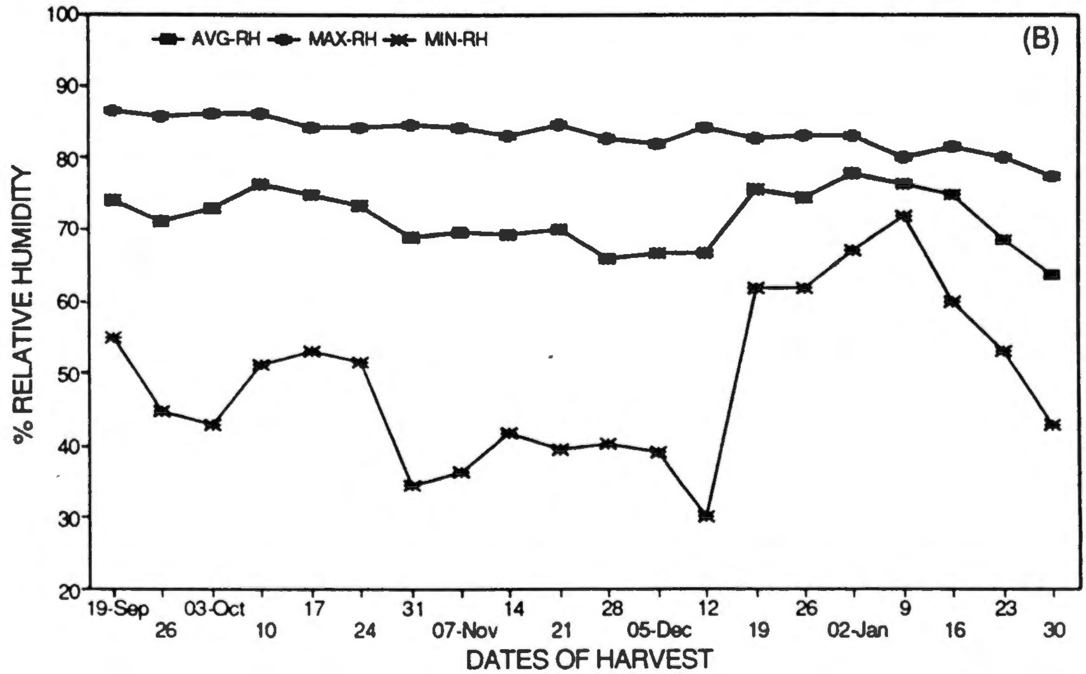




Figure B2. Weekly average, maximum and minimum relative humidity (%) at the field plot for the harvest weeks of soybeans TN4-86, Essex, and Leflore which extended from (A) September 19, 1989 to February 6, 1990 and (B) September 13, 1990 to January 30, 1991.

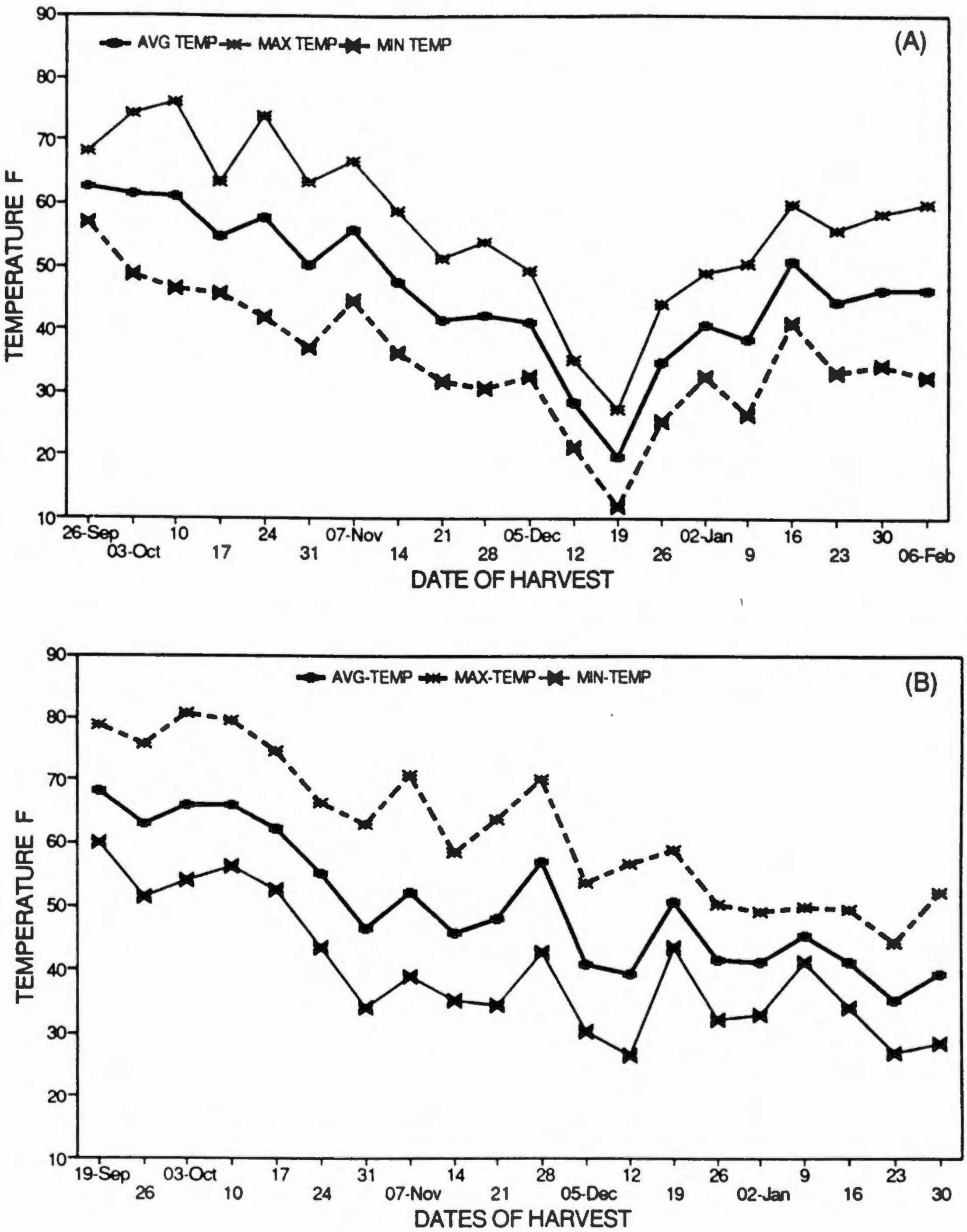



Figure B3. Weekly average, maximum and minimum temperature (°F) at the field plot for the harvest weeks of soybeans TN4-86, ESSEX, and Leflore which extended from (A) September 19, 1989 to February 6, 1990 (B) September 13, 1990 to January 30, 1991.

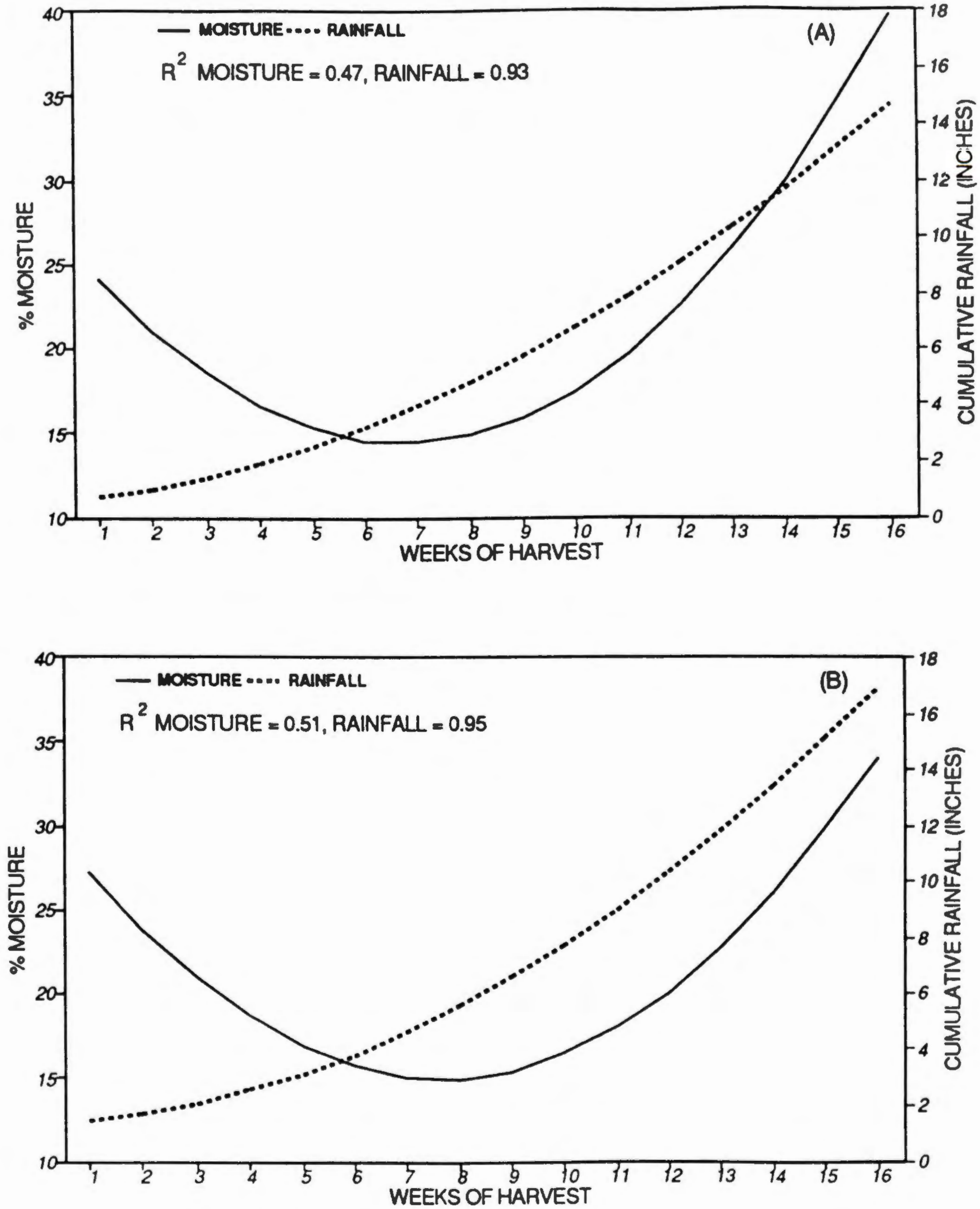



Figure B4. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and cumulative rainfall (inches) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

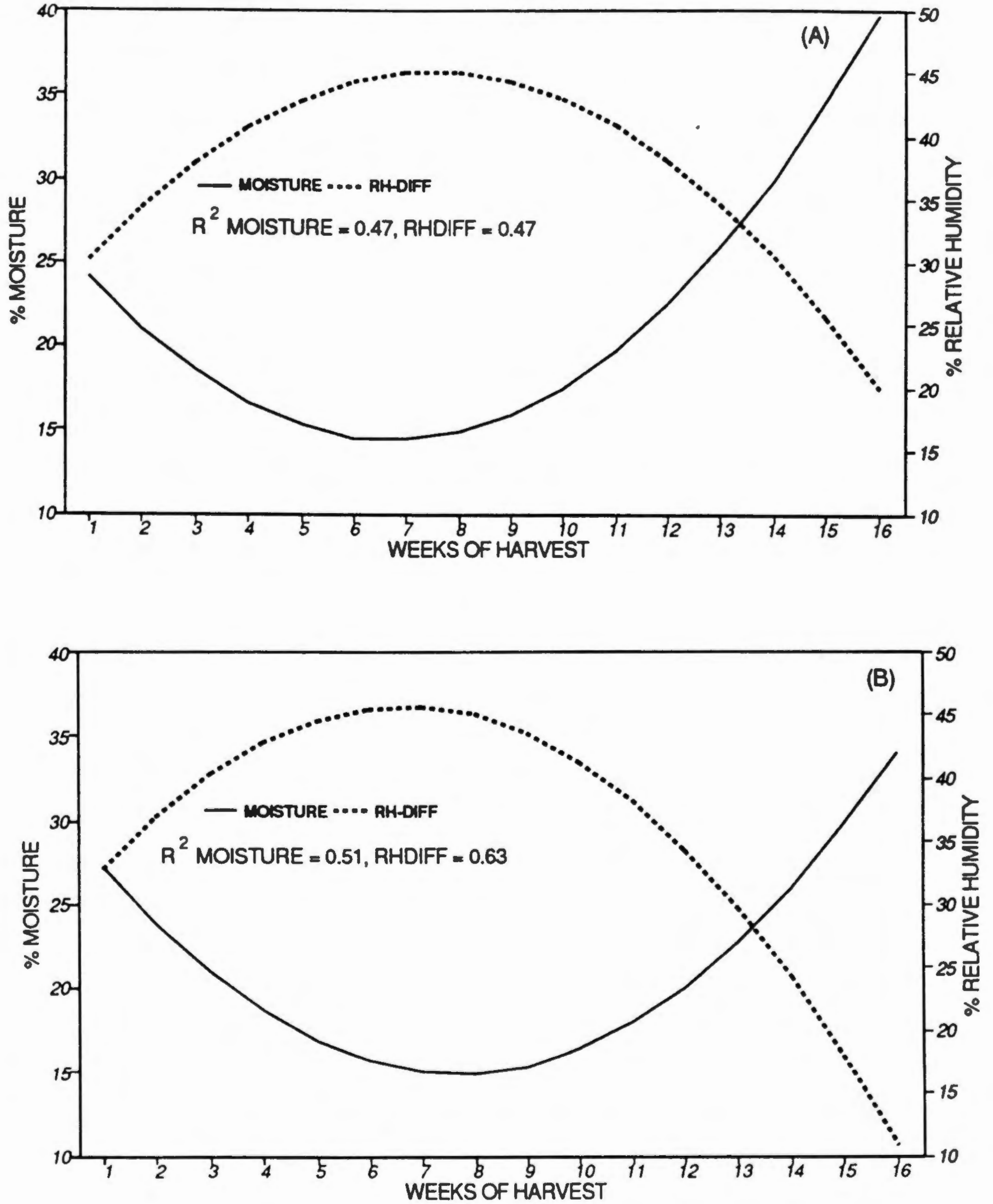
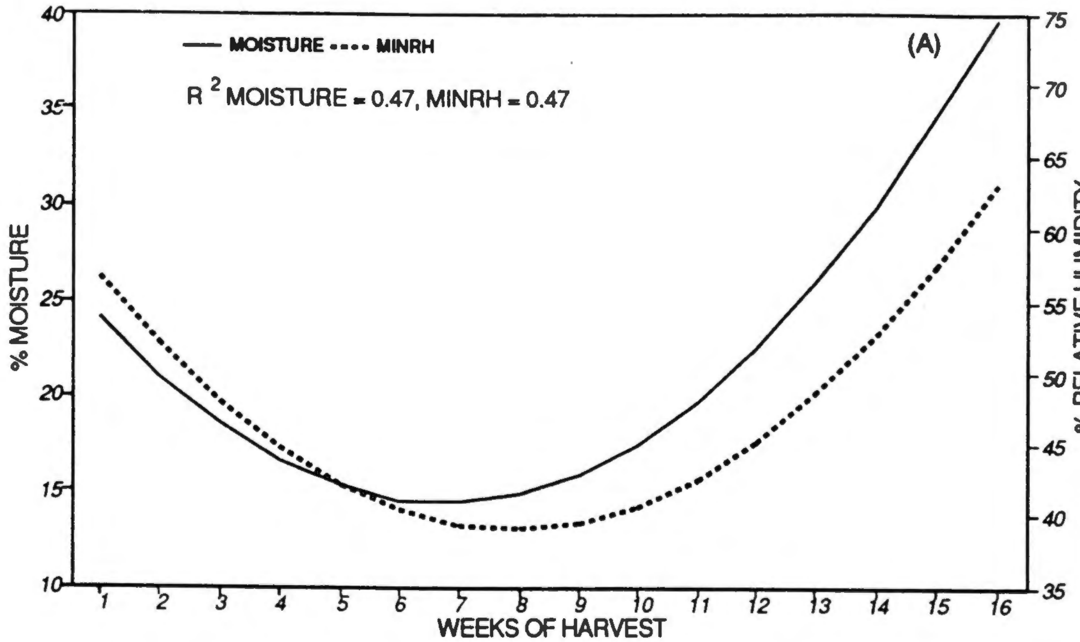



Figure B5. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and difference in maximum and minimum relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



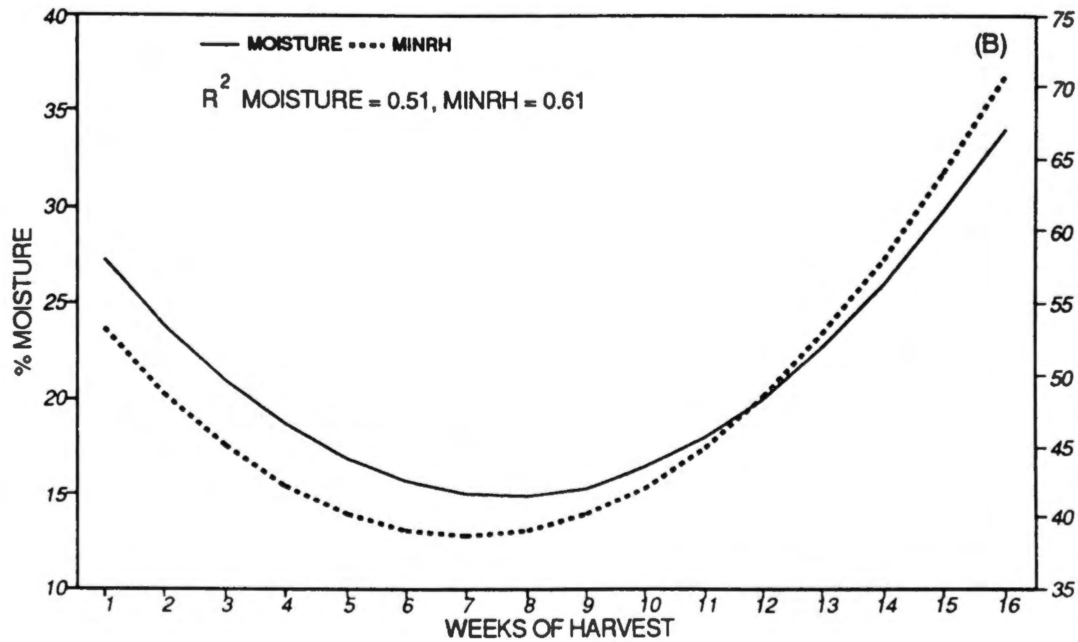




Figure B6. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and minimum relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

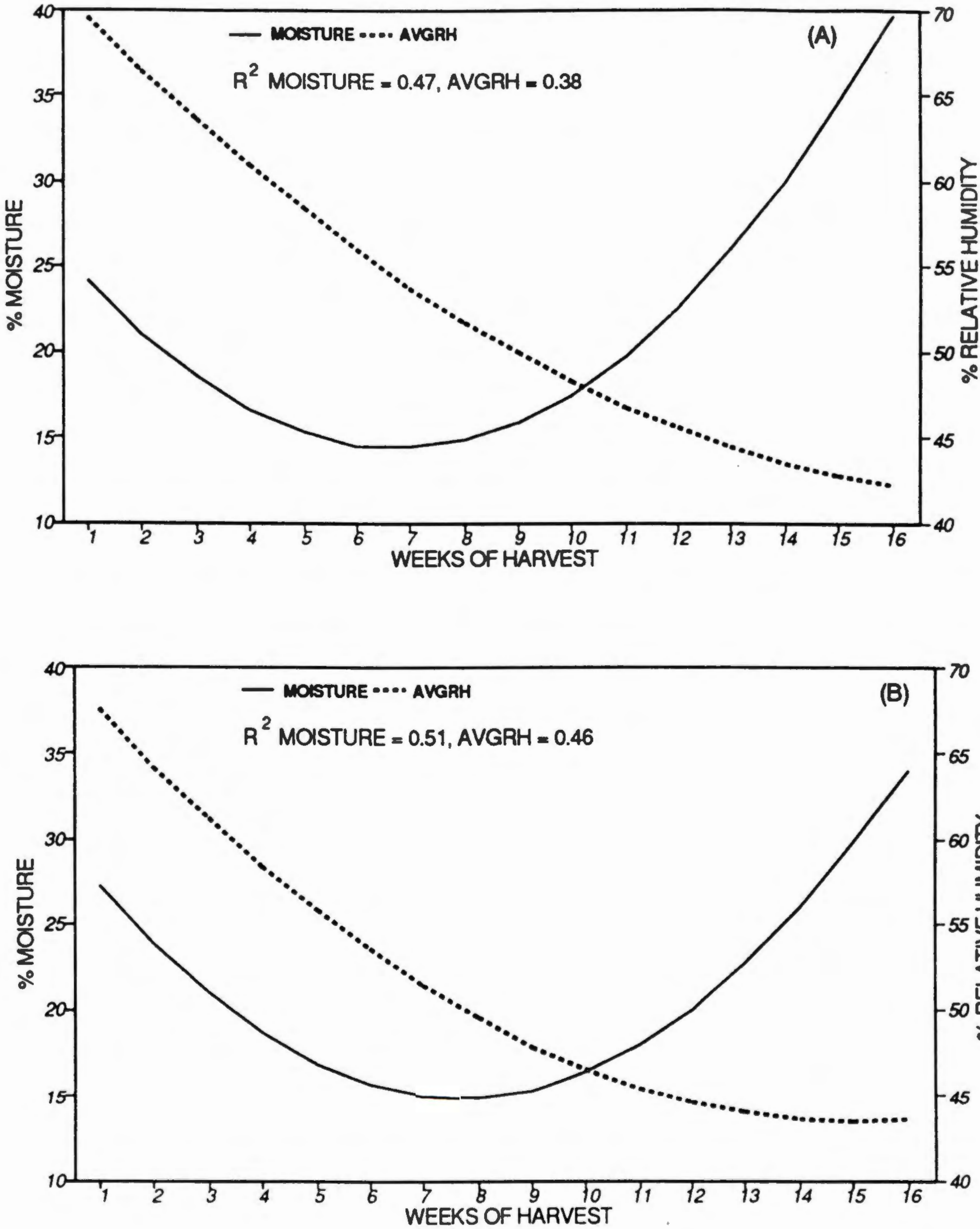



Figure B7. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and the average relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

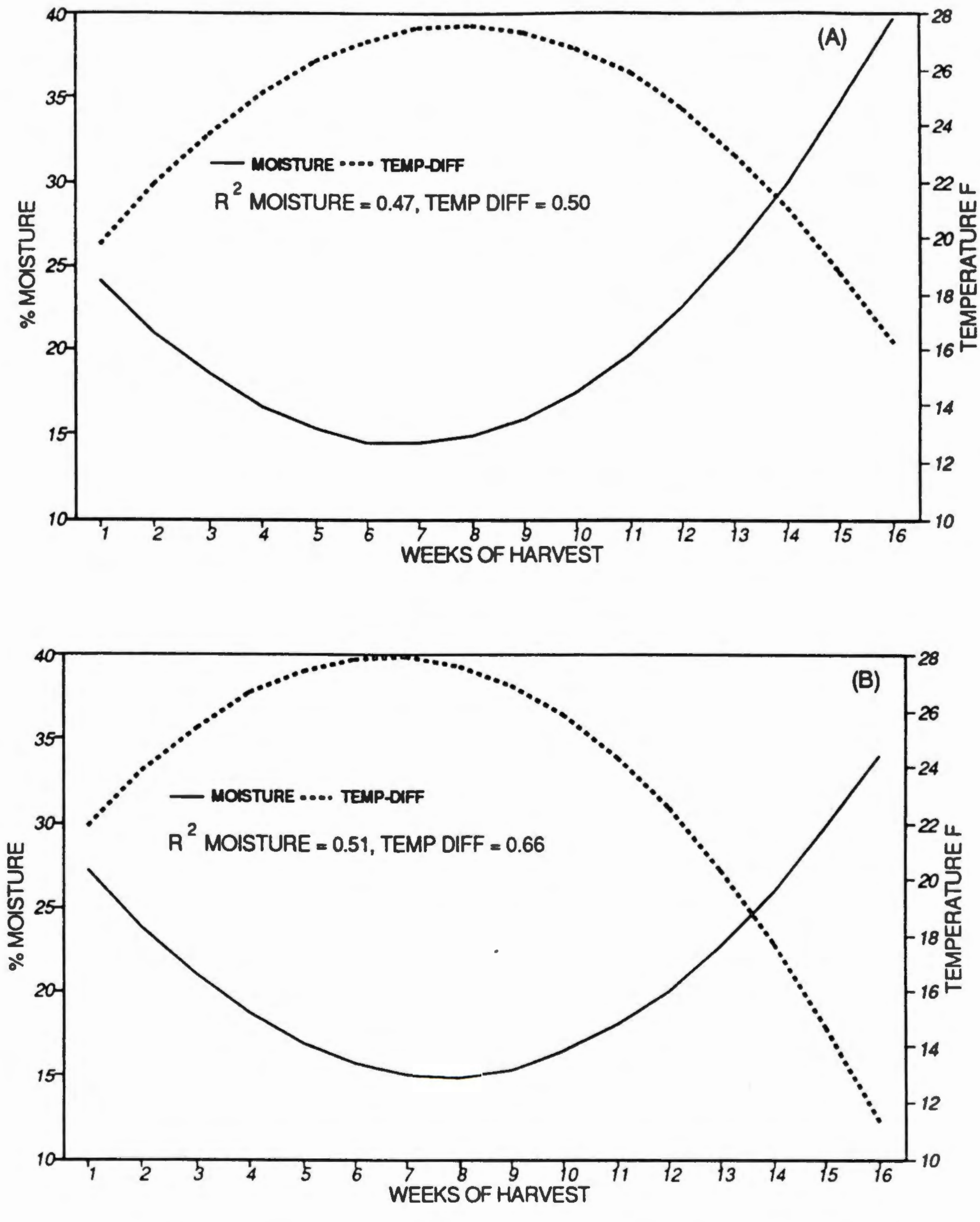
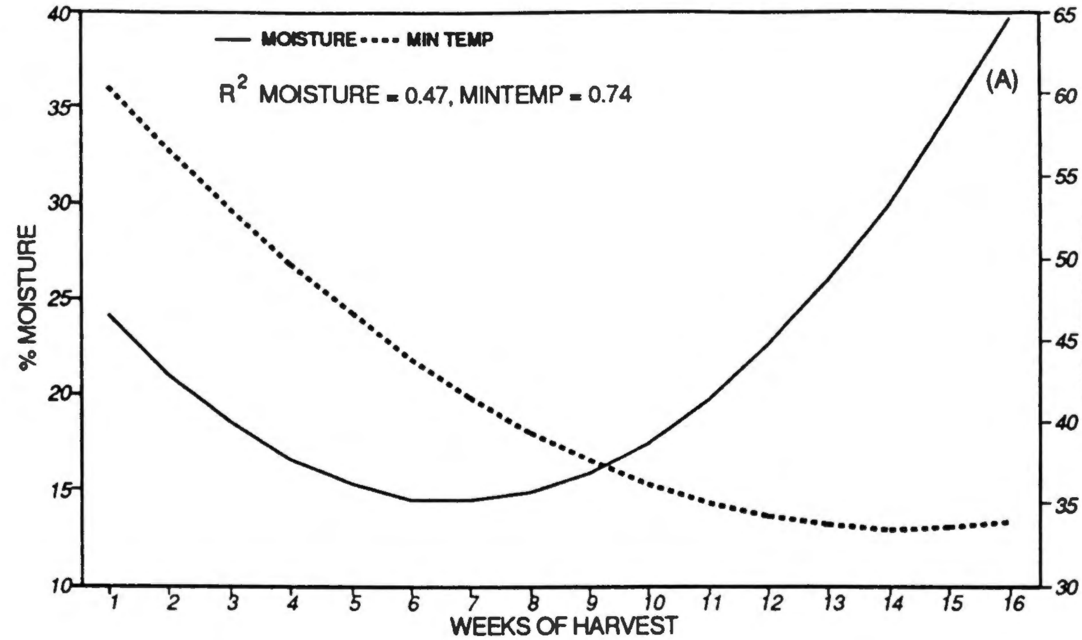



Figure B8. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and the difference in maximum and minimum temperature (°F) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



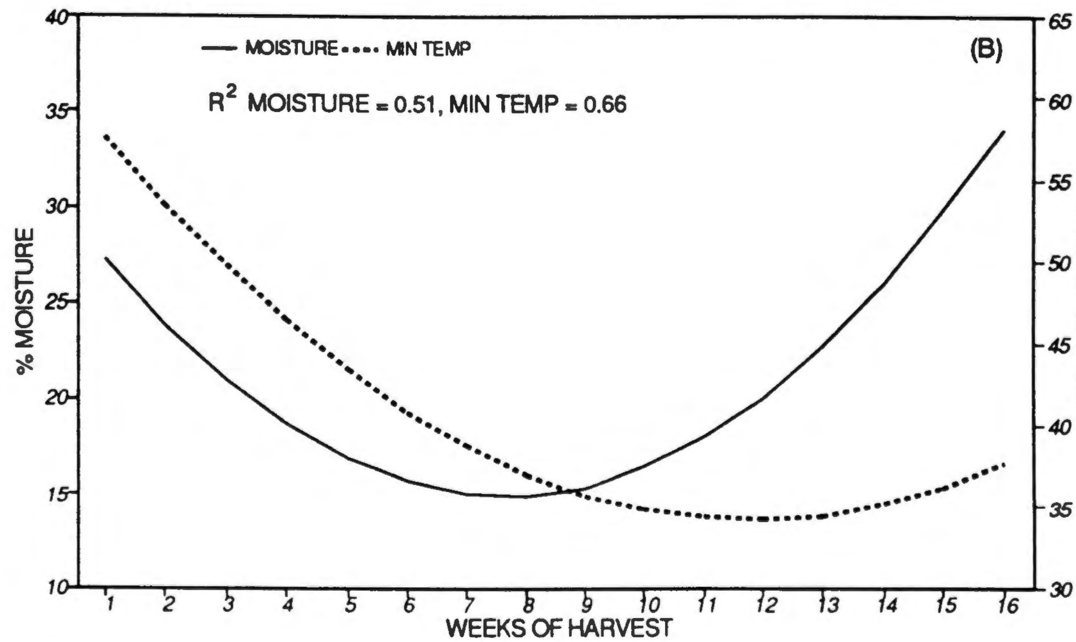




Figure B9. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and the minimum temperature (°F) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

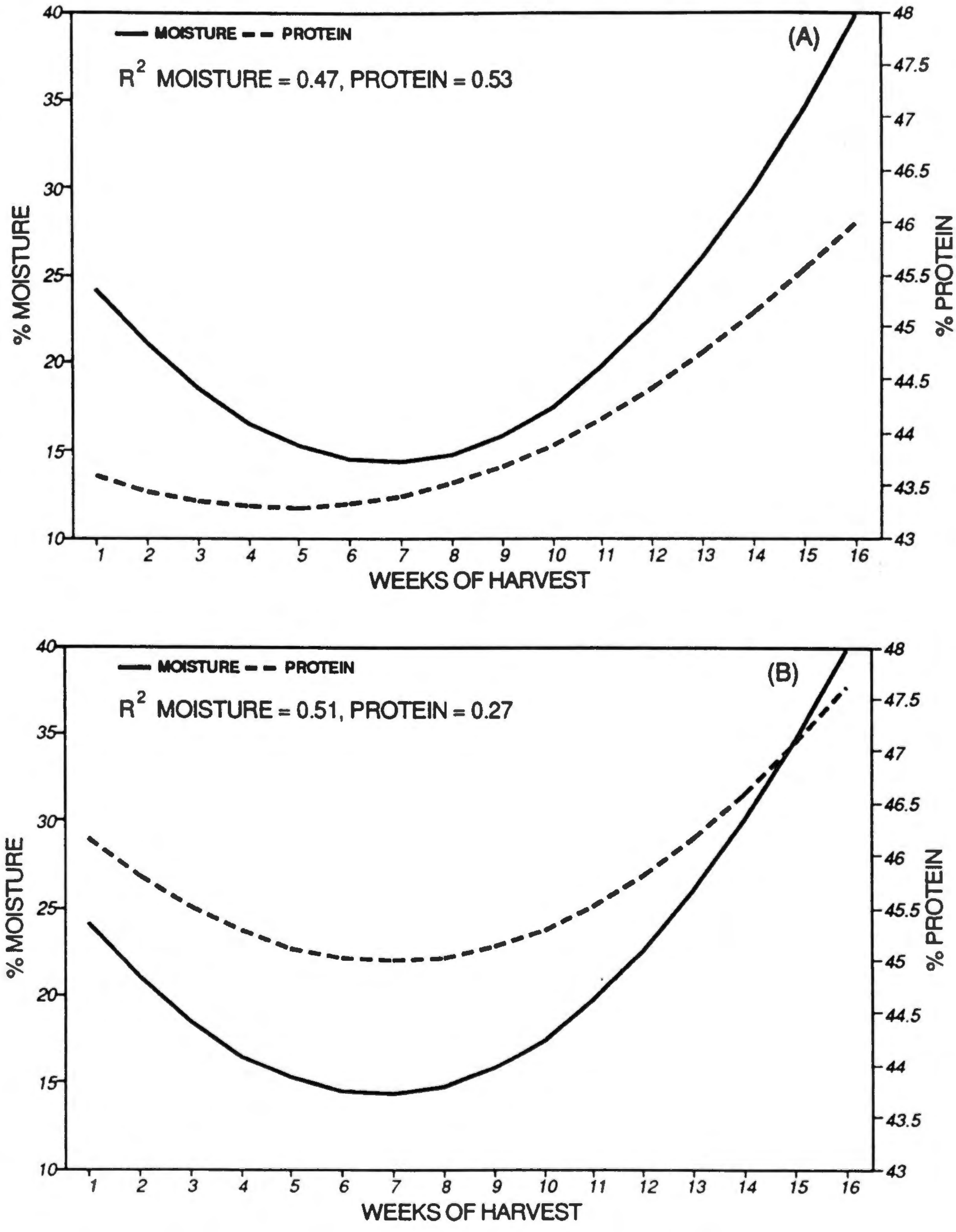
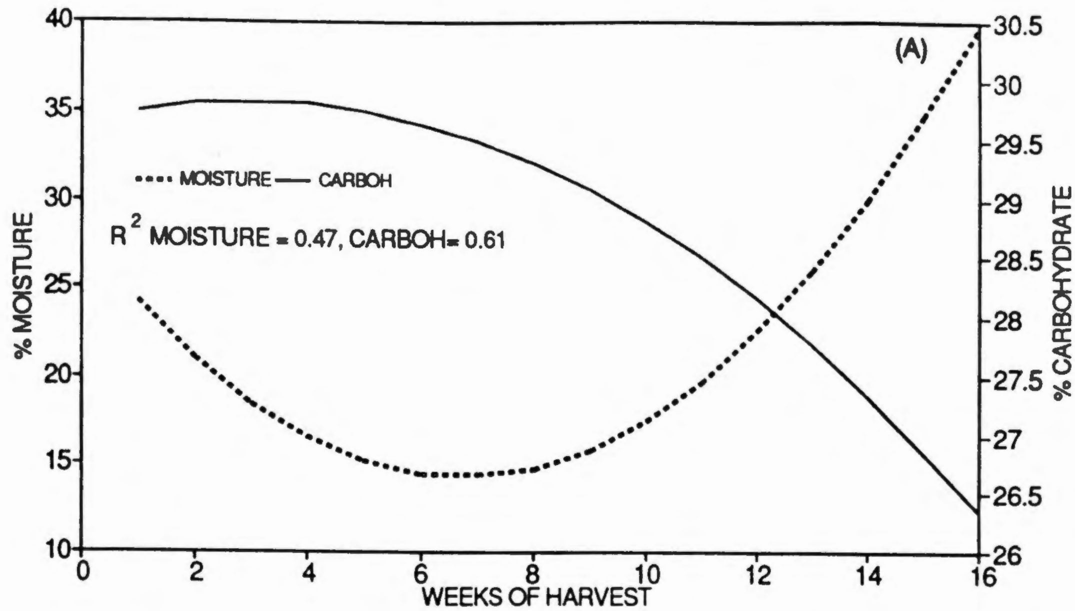



Figure B10. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and protein (%, db) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



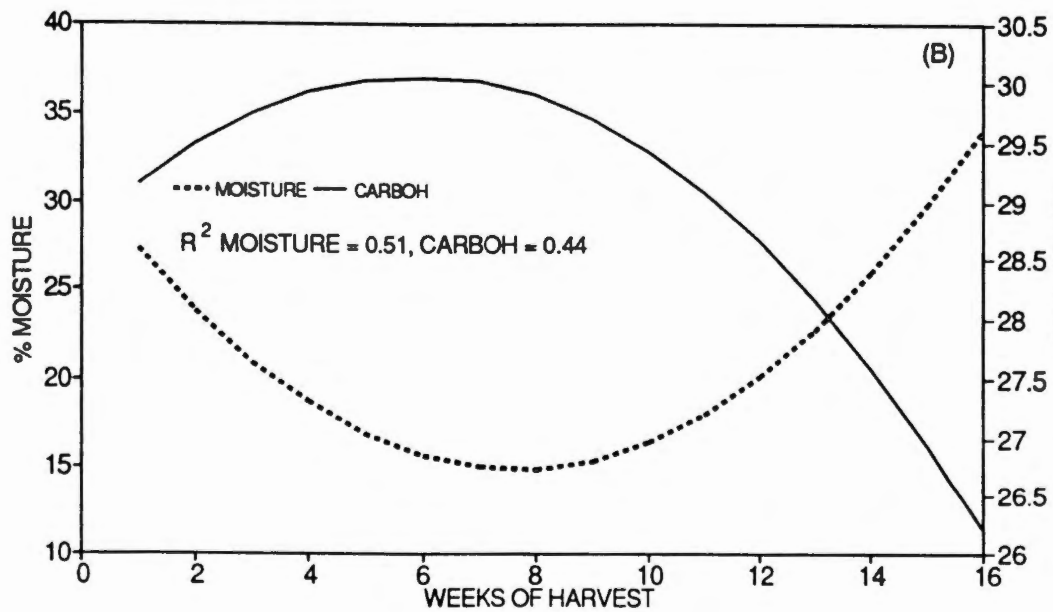




Figure B11. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and carbohydrates (%, db) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

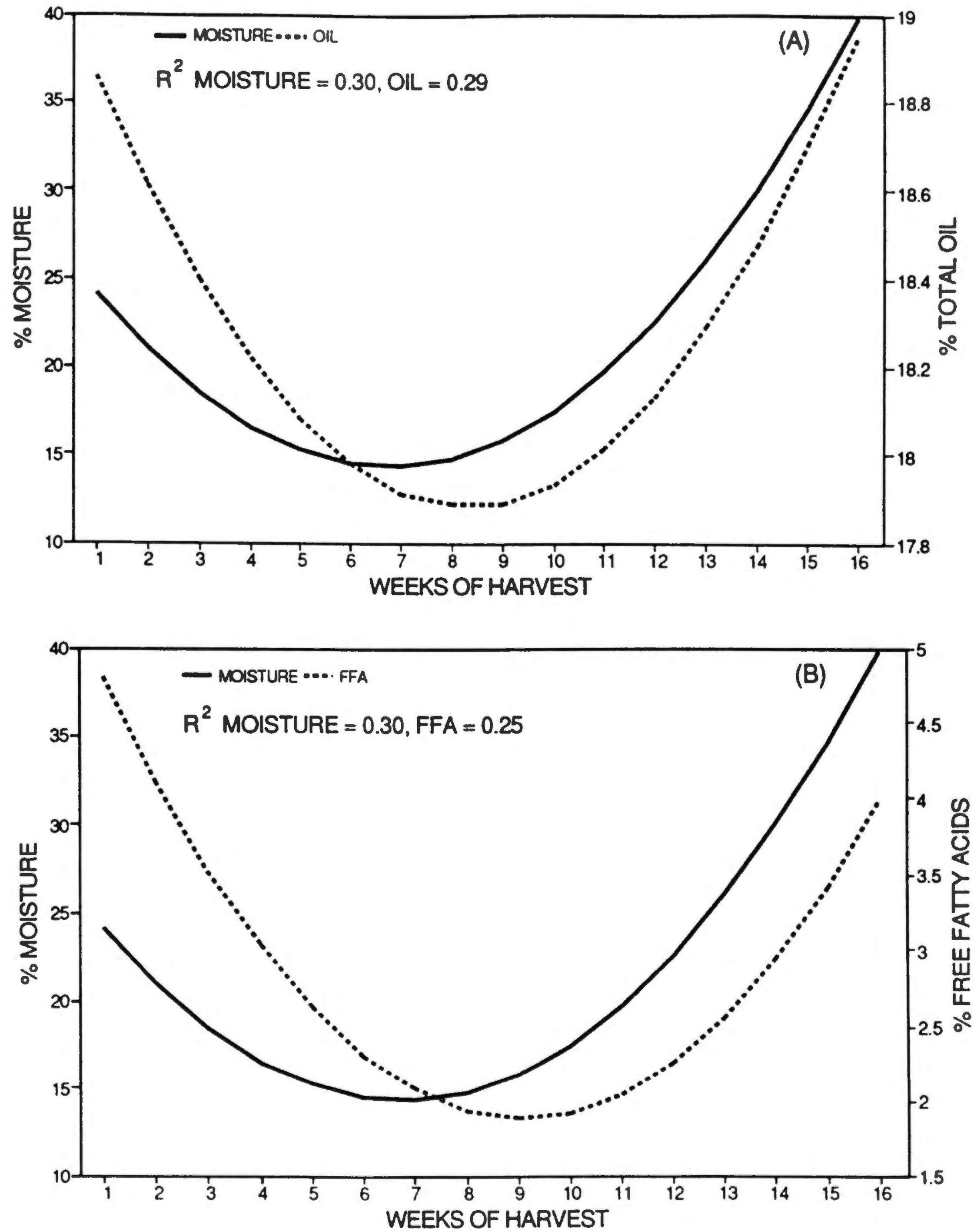



Figure B12. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and (A) total oil (%, db), (B) free fatty acids (as percent oleic acid) for soybean Leflore during the 1990 season.

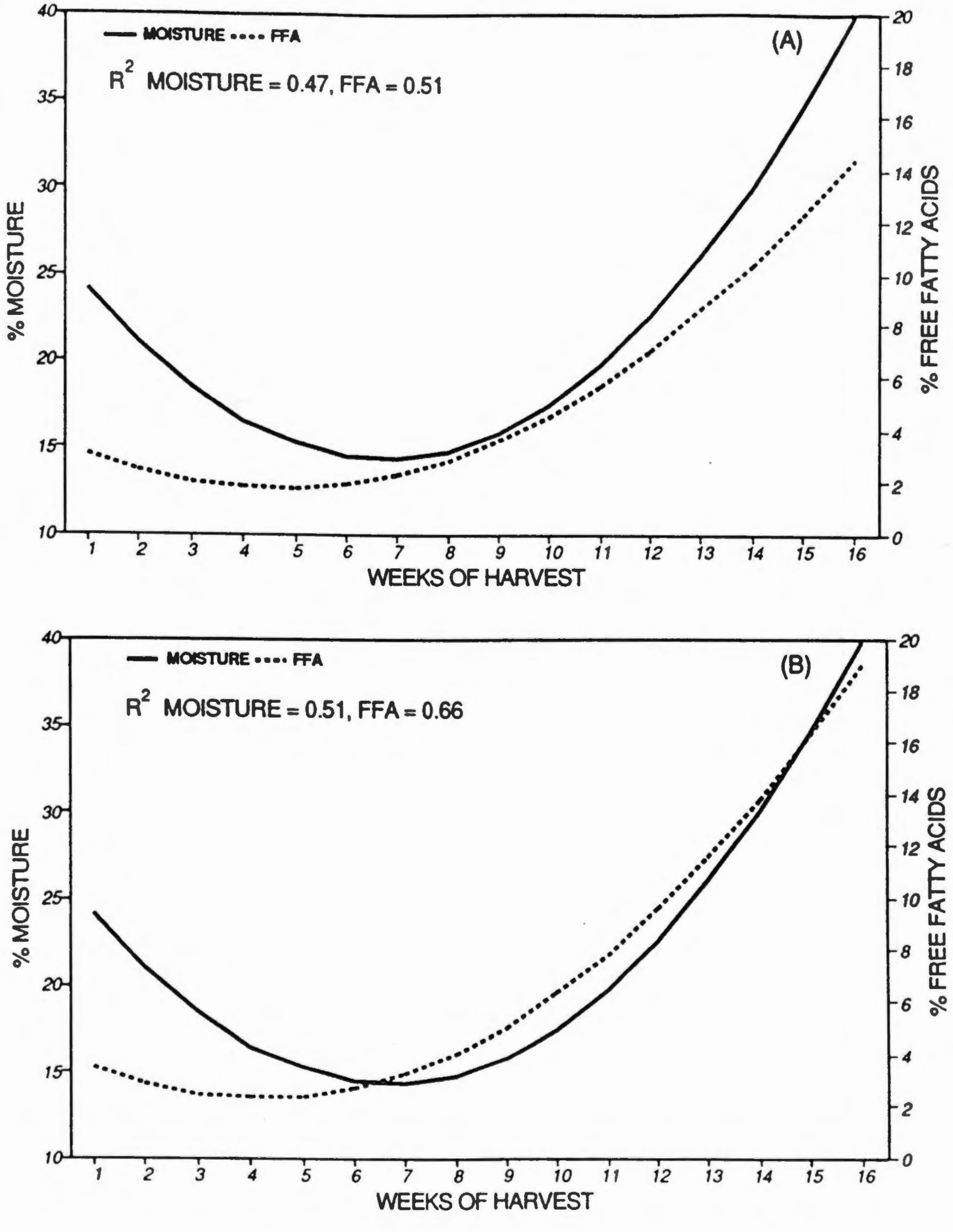



Figure B13. Predicted curves generated from the observed data showing the trends of changes in the bean moisture at harvest (%, wb) and free fatty acids (as percent oleic acid) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

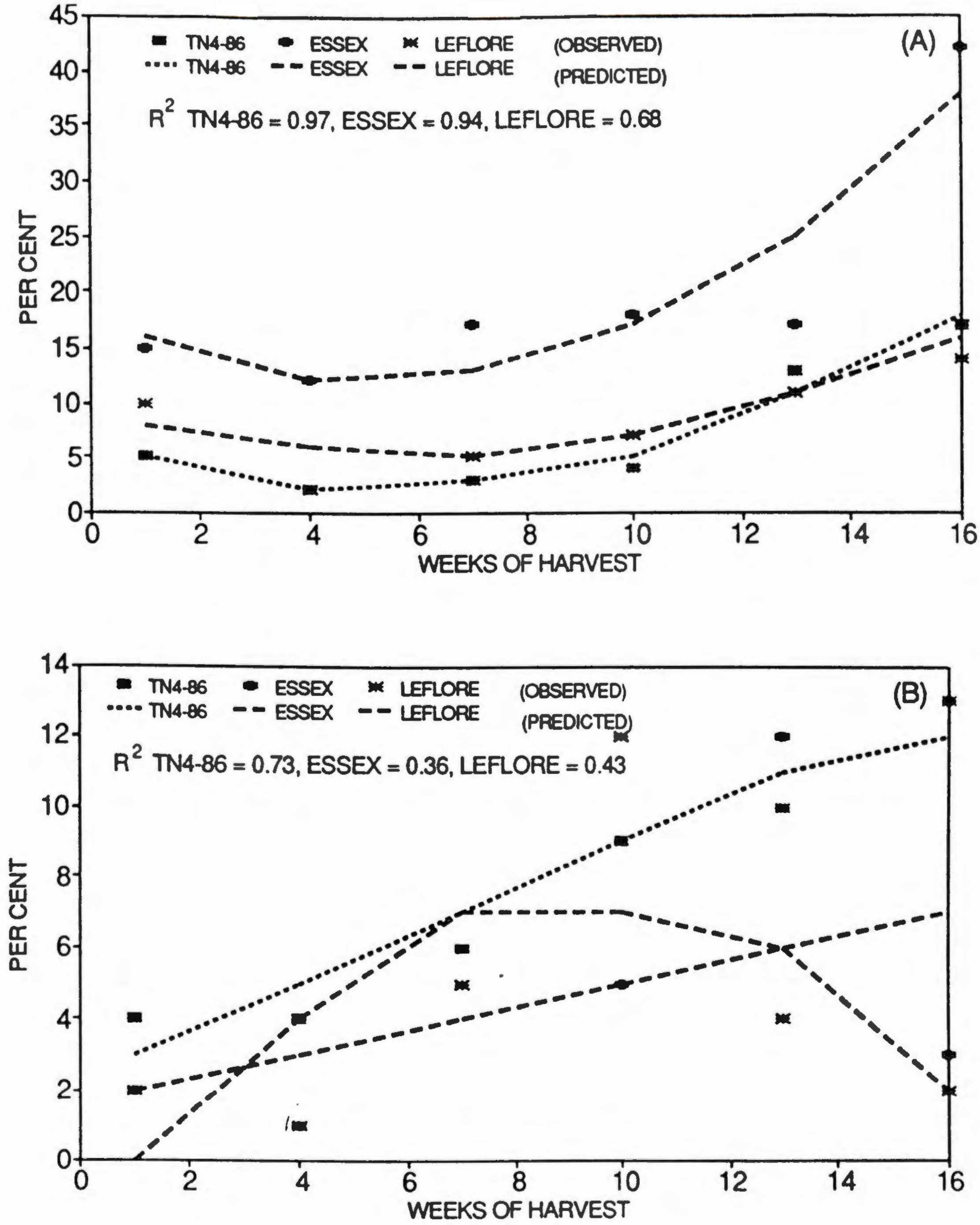



Figure B14. Predicted curves generated from the observed data showing the trends of changes in the (A) cracked beans (%) and (B) wrinkled beans (%) for TN4-86, Essex, and Leflore during the 1990 season.

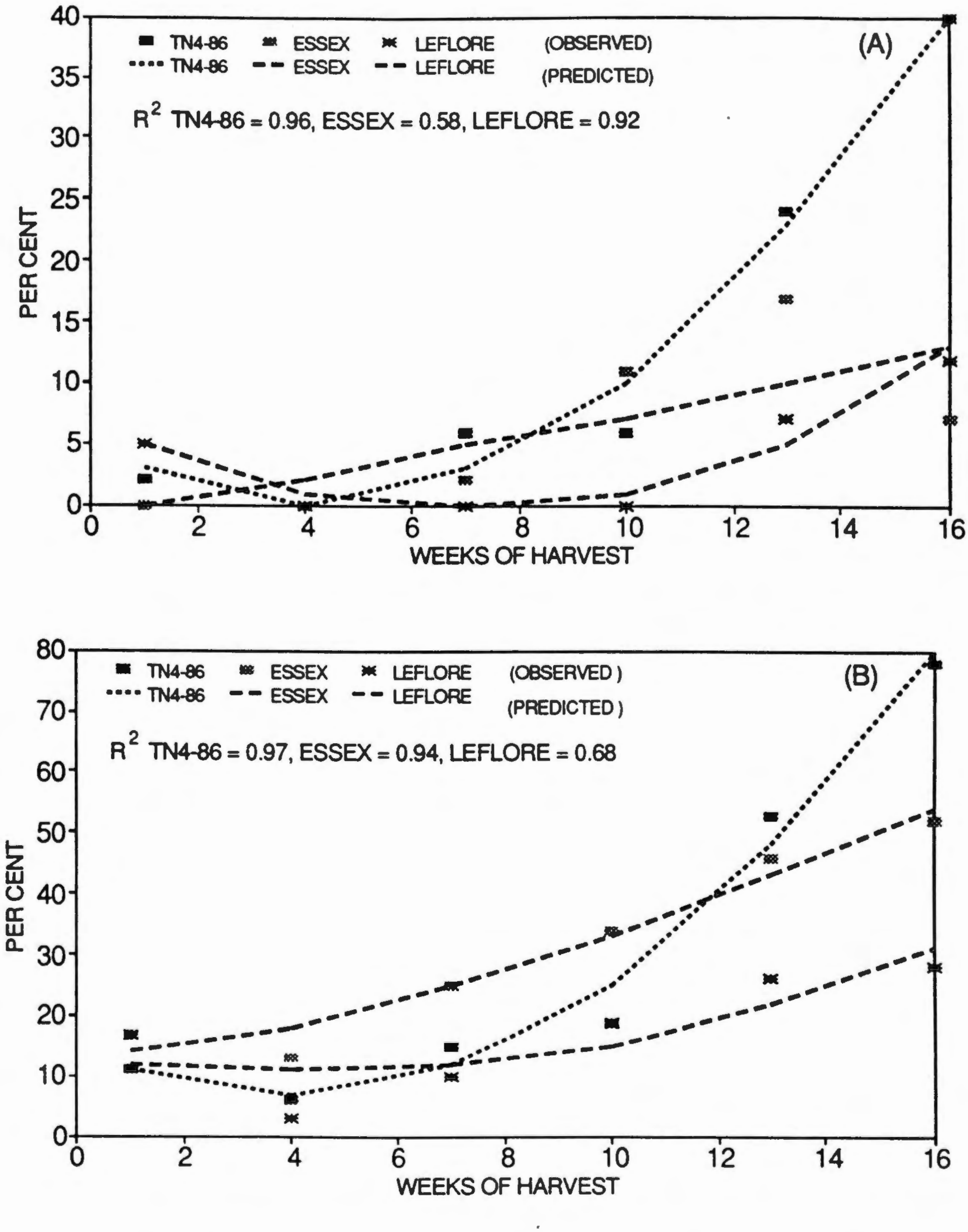
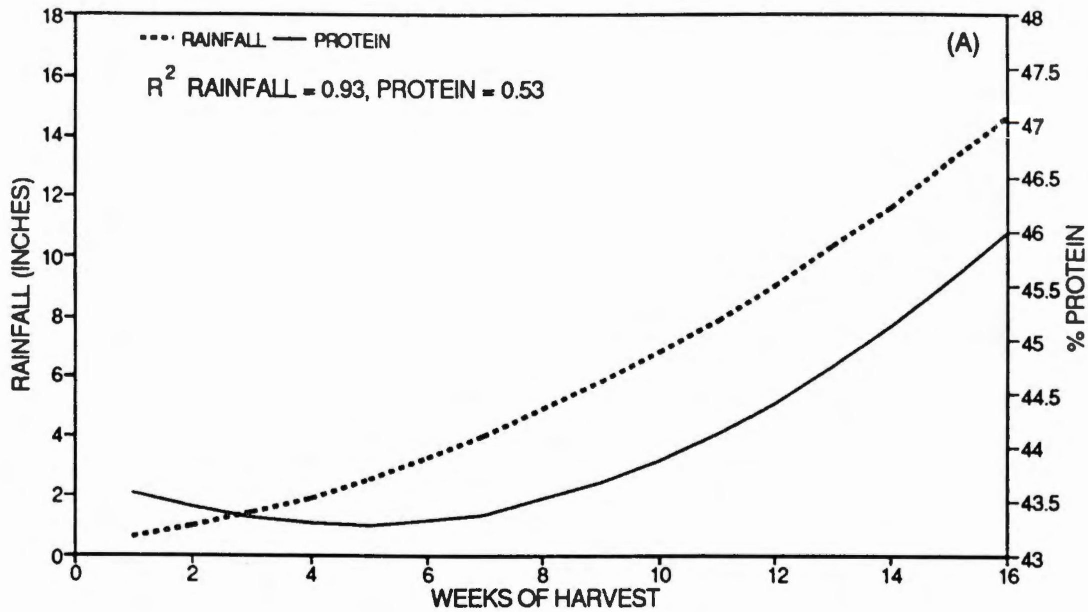



Figure B15. Predicted curves generated from the observed data showing the trends of changes in the (A) cracked-wrinkled beans (%) and (B) total damaged beans for soybeans TN4-86, Essex, and Leflore during the 1990 season.



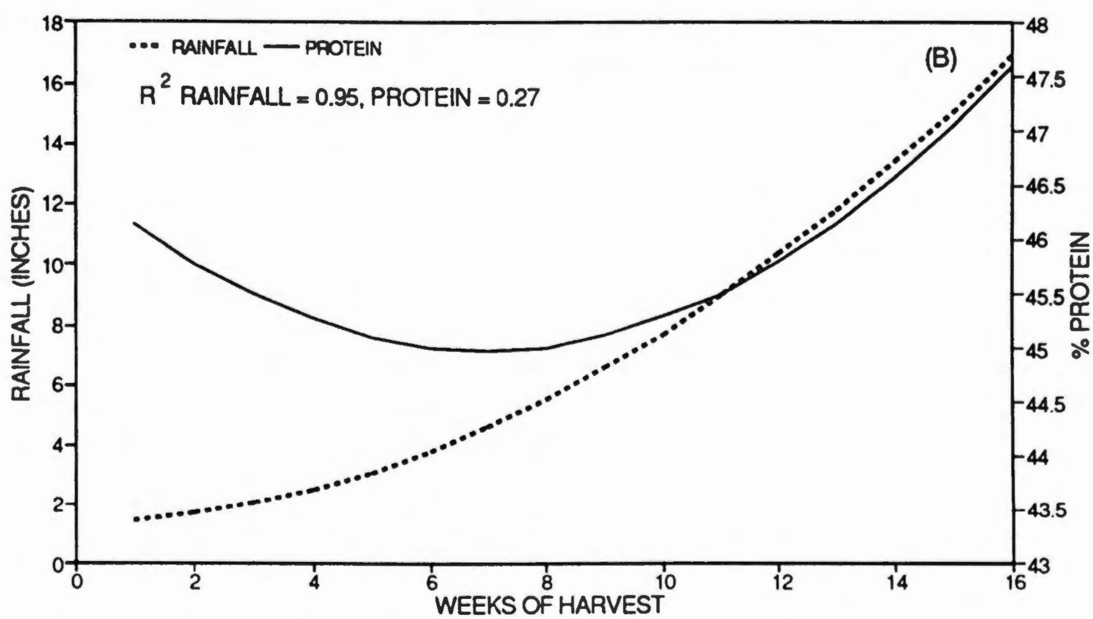
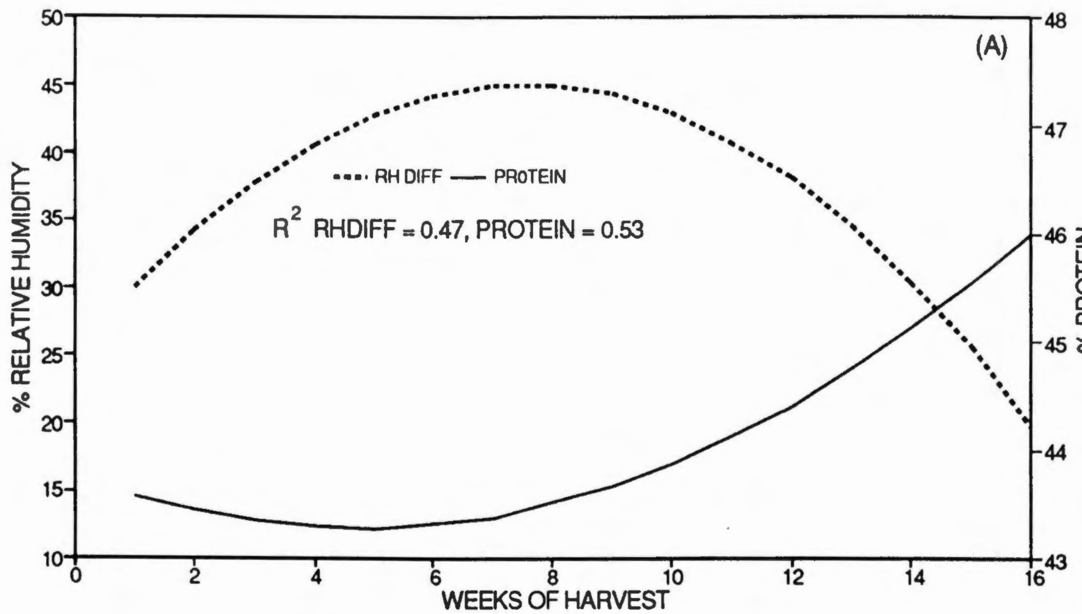




Figure B16. Predicted curves generated from the observed data showing the trends of changes in the protein (%, db) and cumulative rainfall (inches) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



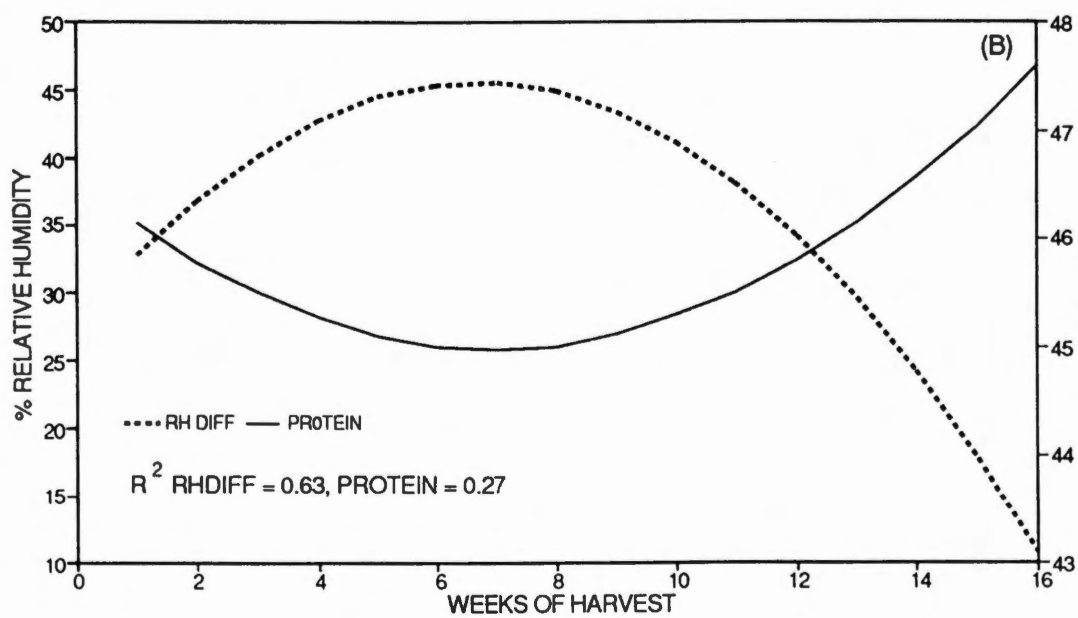
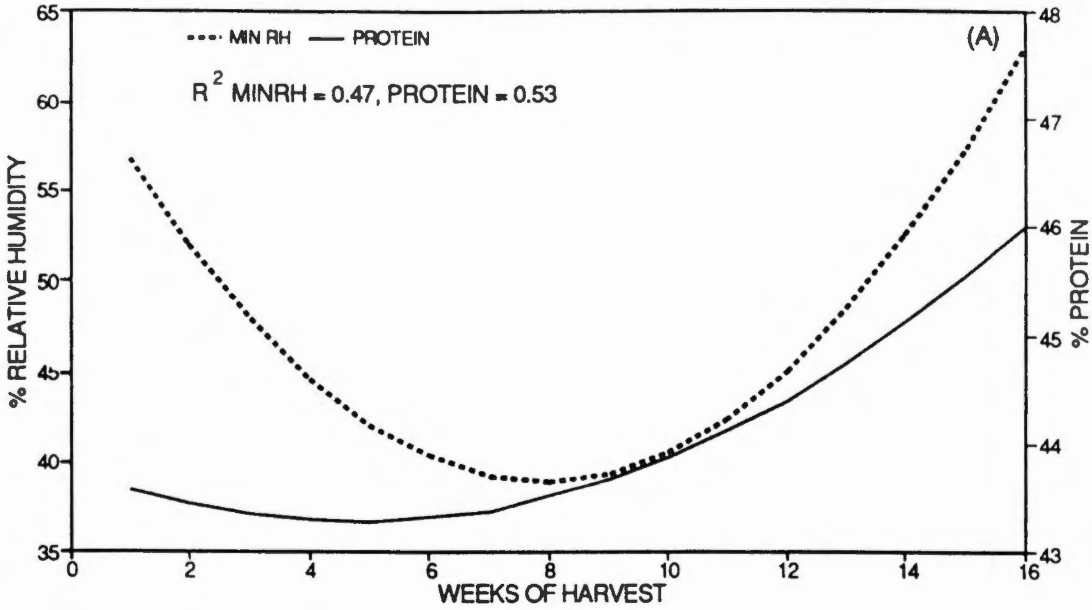




Figure B17. Predicted curves generated from the observed data showing the trends of changes in the protein (%, db) and the differences in the maximum and minimum relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



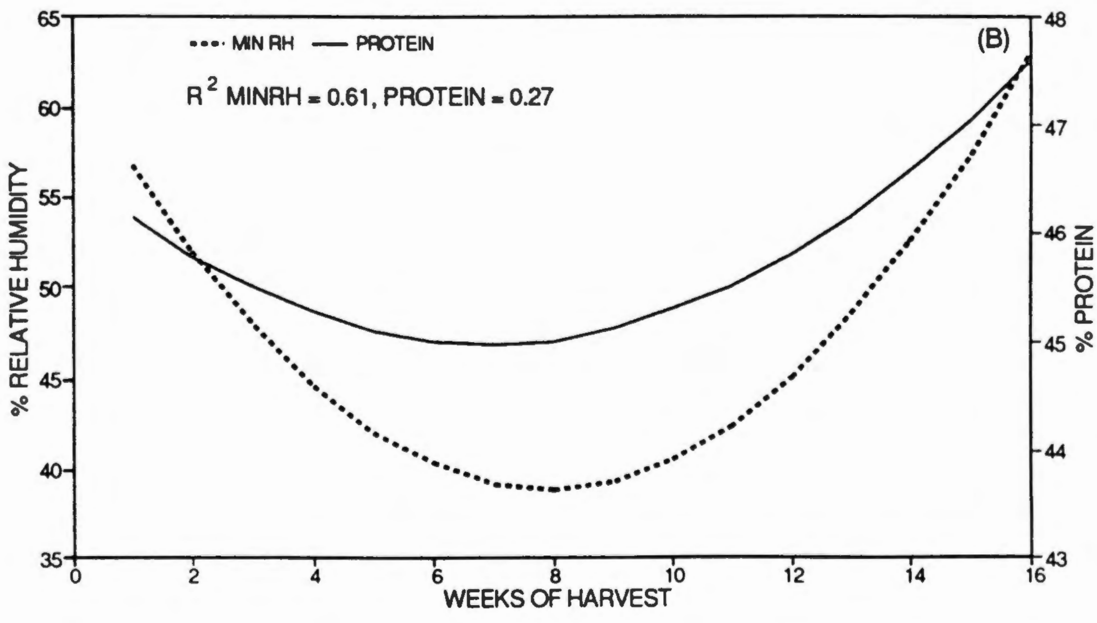
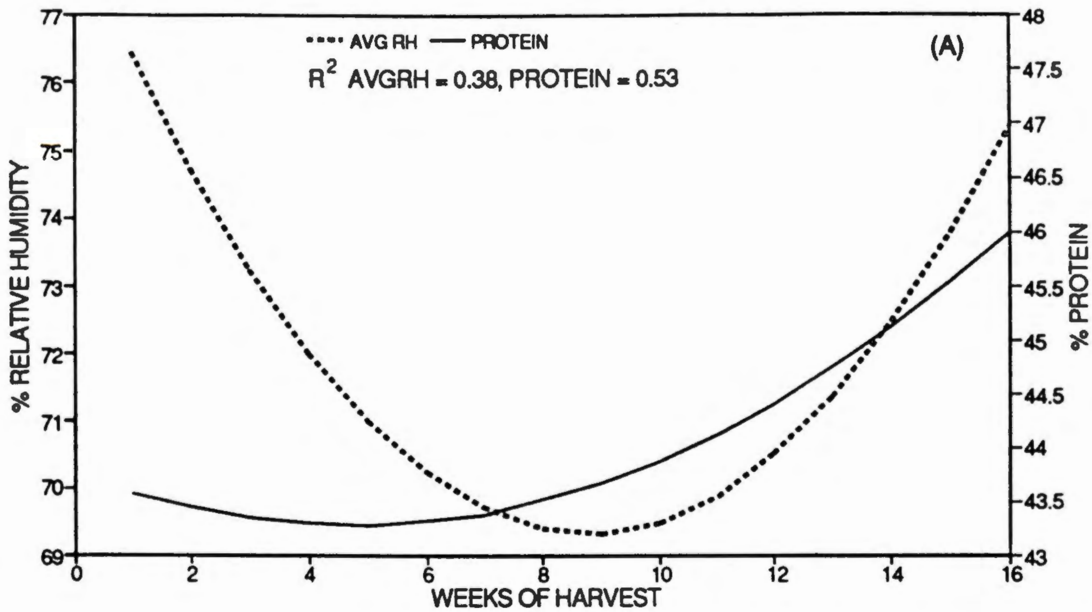




Figure B18. Predicted curves generated from the observed data showing the trends of changes in the protein (%, db) and the minimum relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



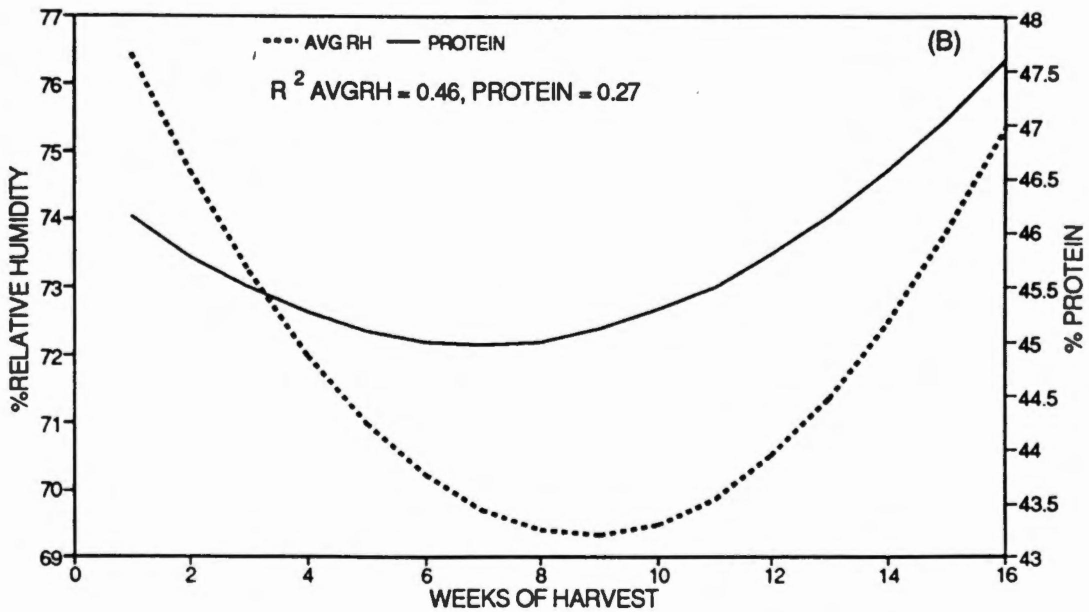




Figure B19. Predicted curves generated from the observed data showing the trends of changes in the protein (%, db) and the average relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

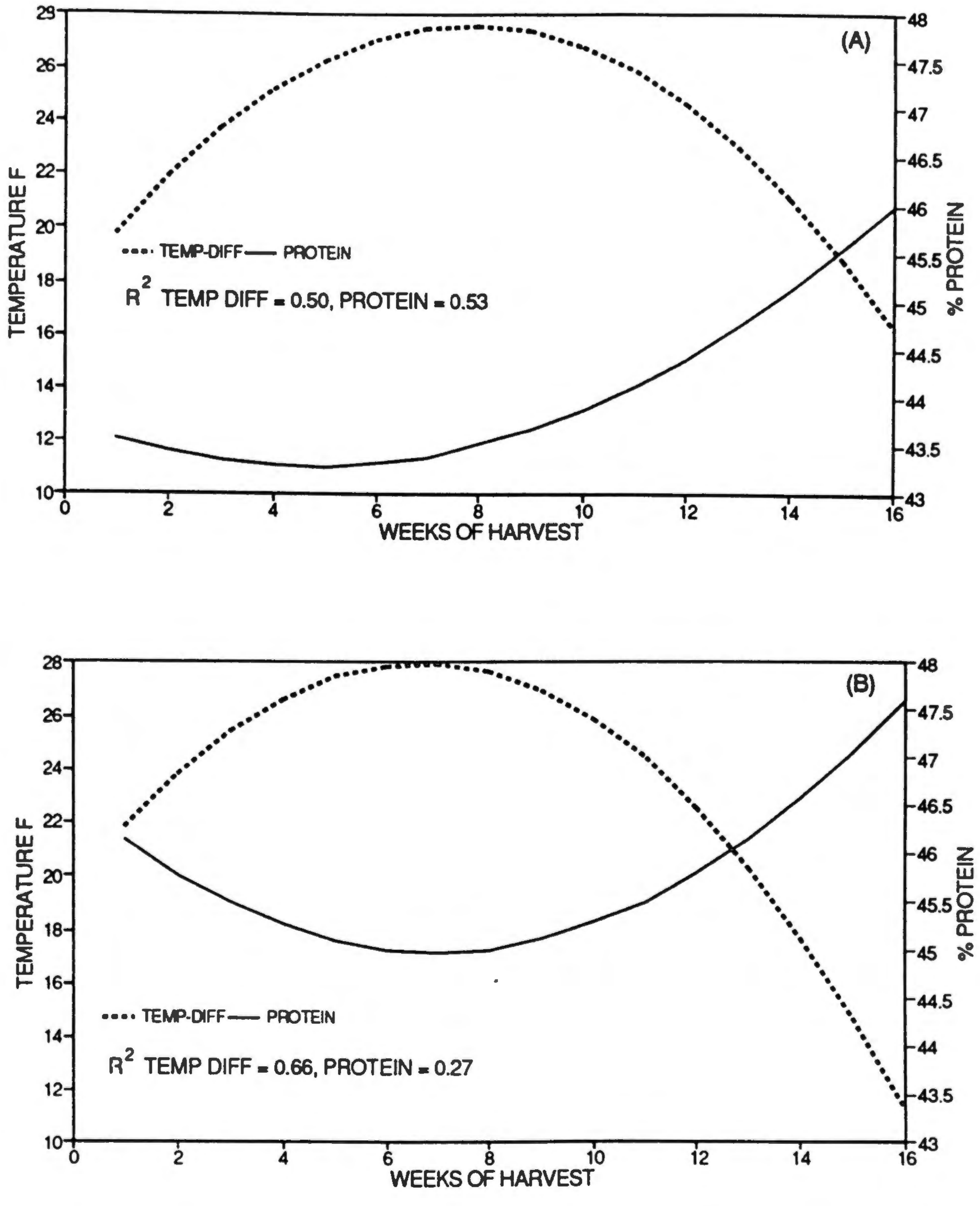



Figure B20. Predicted curves generated from the observed data showing the trends of changes in the protein (%, db) and the difference in the maximum and minimum temperature (°F) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

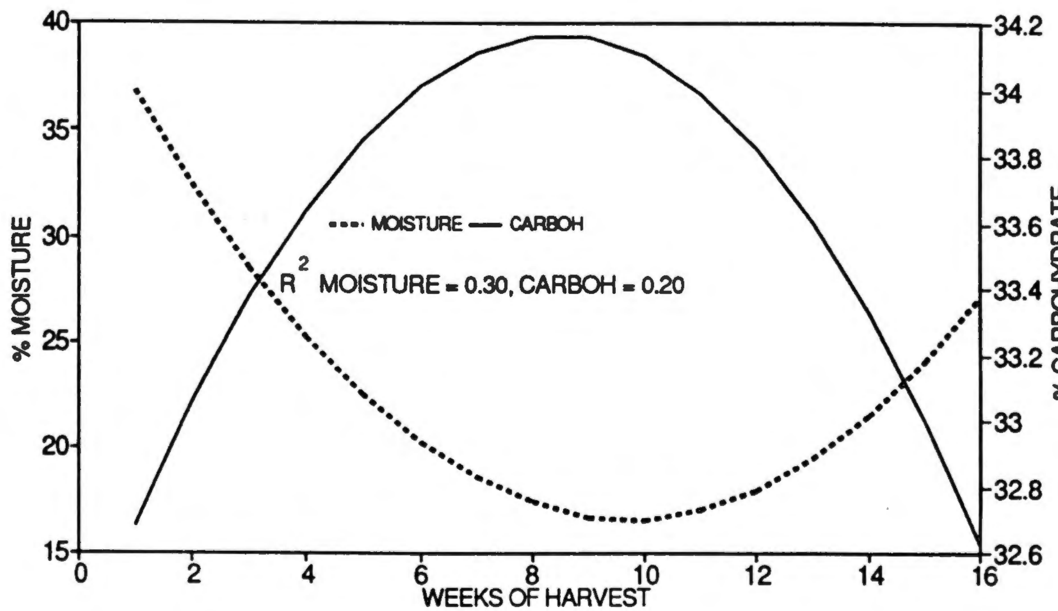
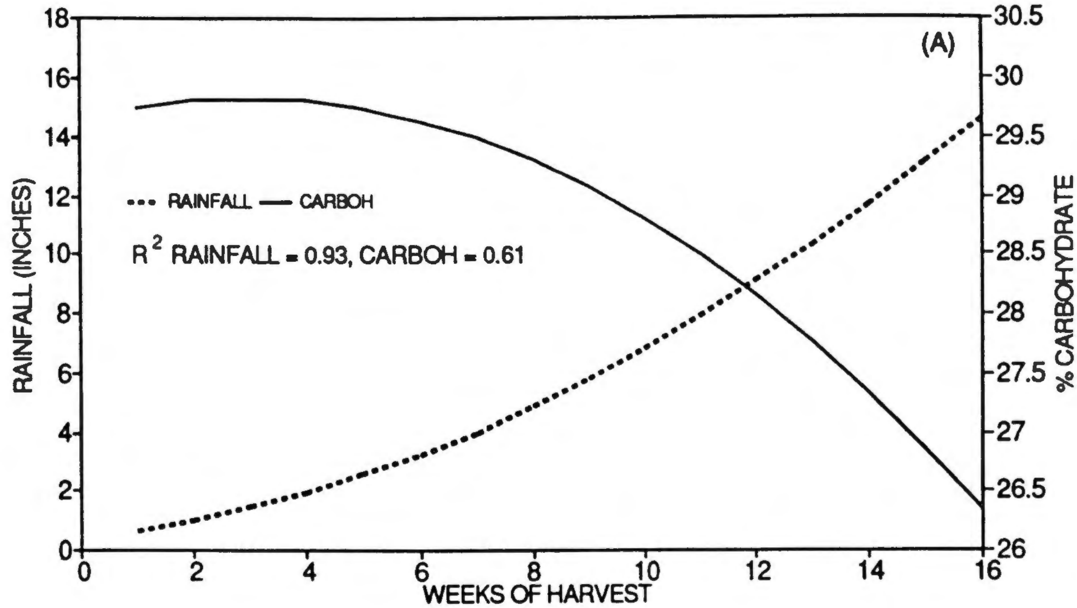



Figure B21. Predicted curves generated from the observed data showing the trends of changes in the carbohydrates (%, db) and bean moisture at harvest (%, wb) for soybean Leflore during the 1990 season.



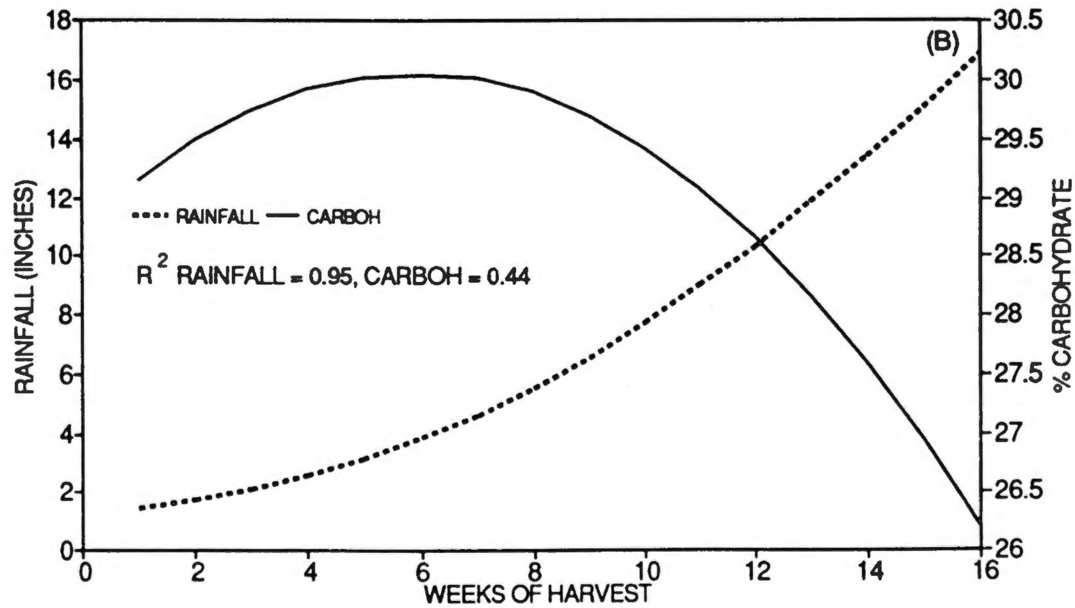
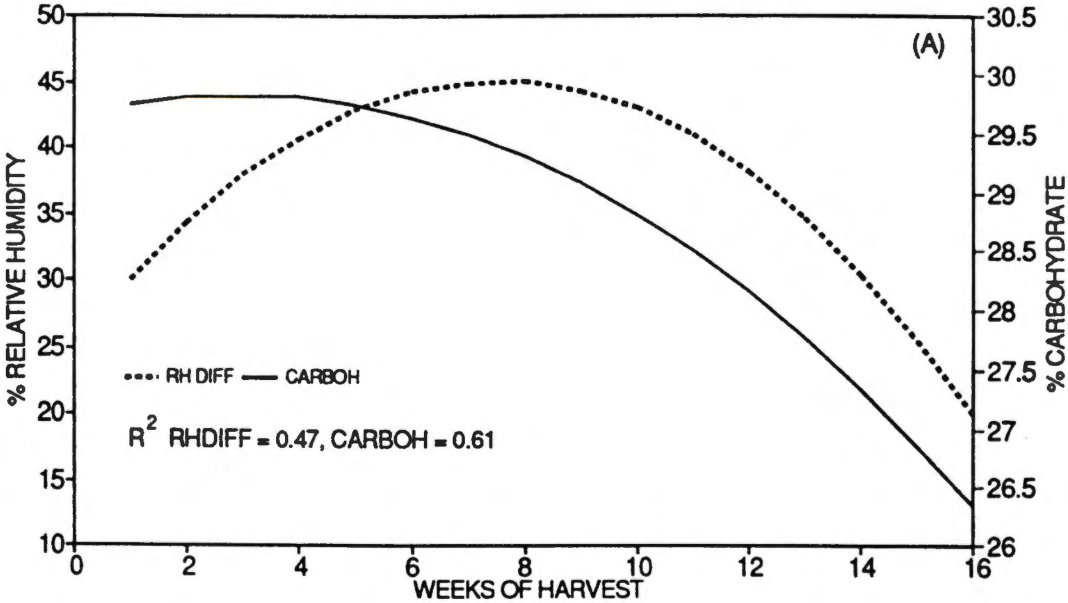




Figure B22. Predicted curves generated from the observed data showing the trends of changes in the carbohydrates (%, db) and cumulative rainfall (inches) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



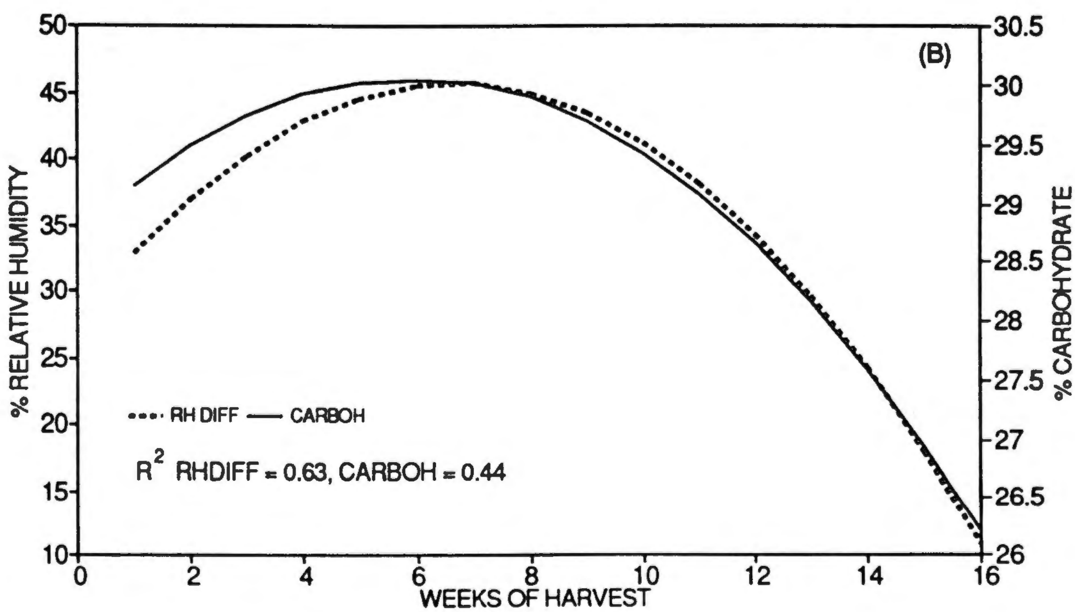
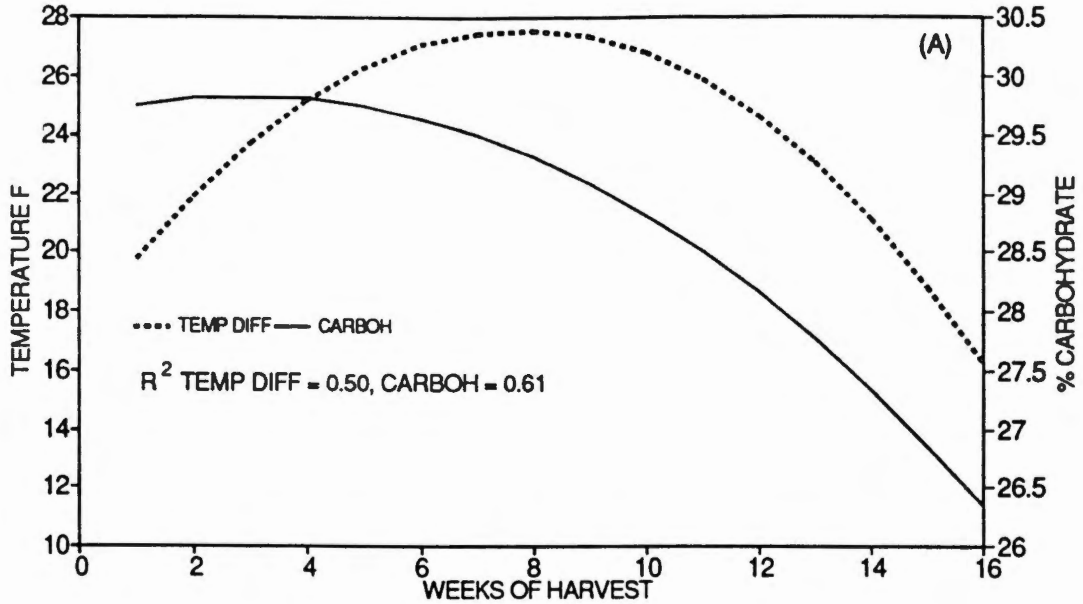




Figure B23. Predicted curves generated from the observed data showing the trends of changes in the carbohydrates (%, db) and the differences in the maximum and minimum relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



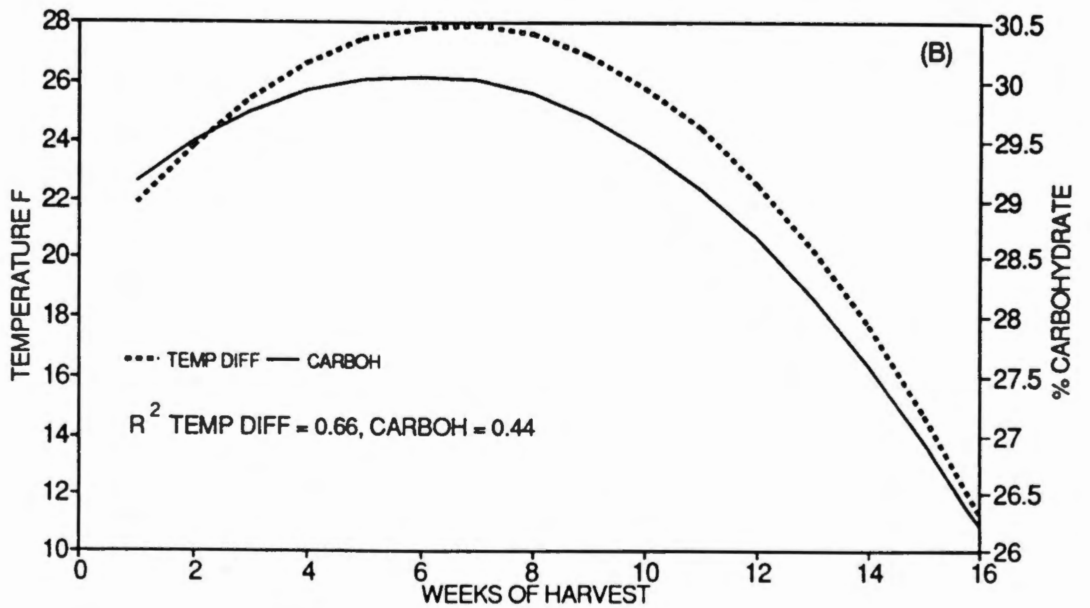




Figure B24. Predicted curves generated from the observed data showing the trends of changes in the carbohydrates (%, db) and the difference in the maximum and minimum temperature (°F) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

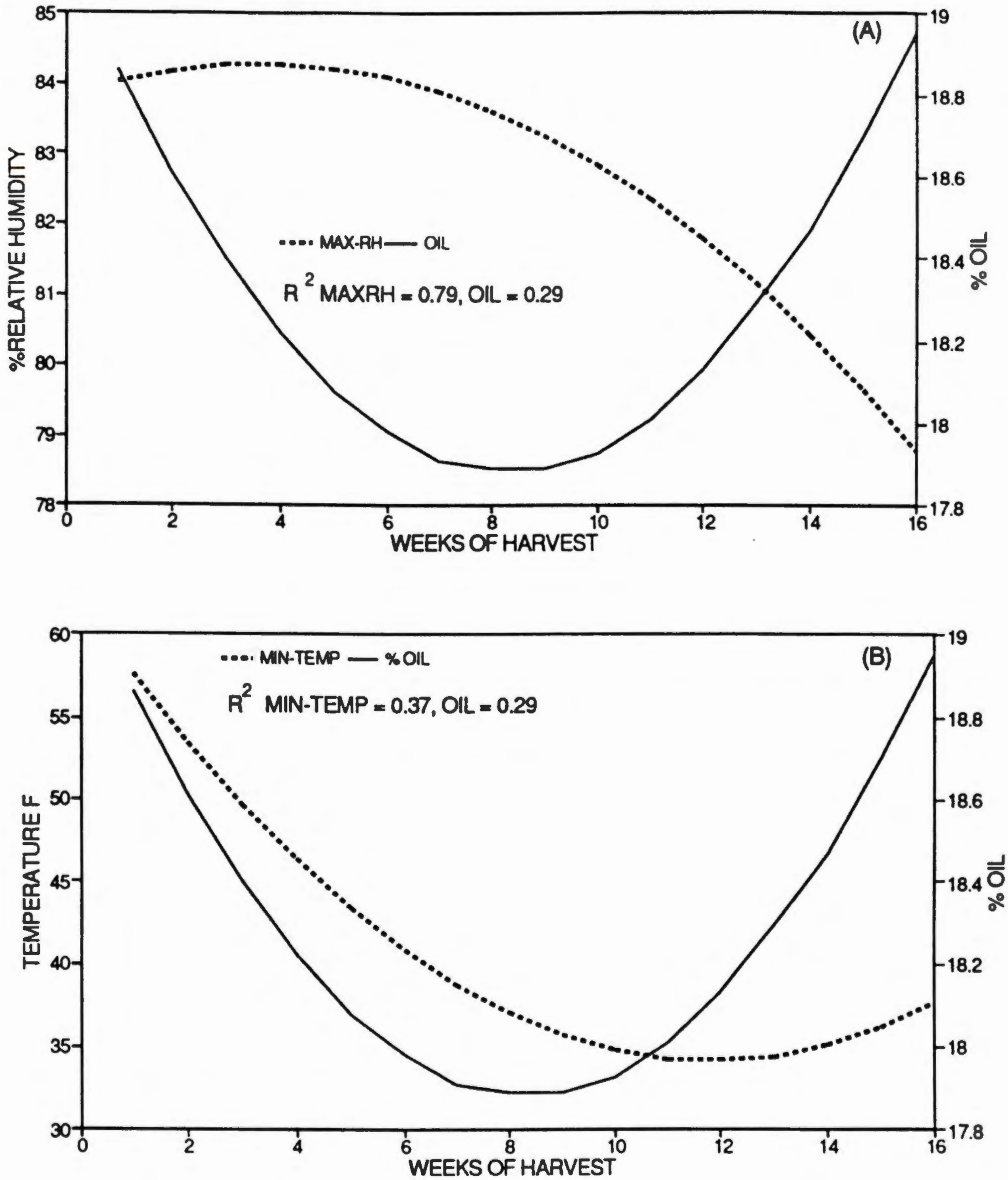



Figure B25. Predicted curves generated from the observed data showing the trends of changes in the total oil (%, db) and (A) maximum relative humidity (%), (B) minimum temperature (°F) for soybean Leflore during the 1990 season.

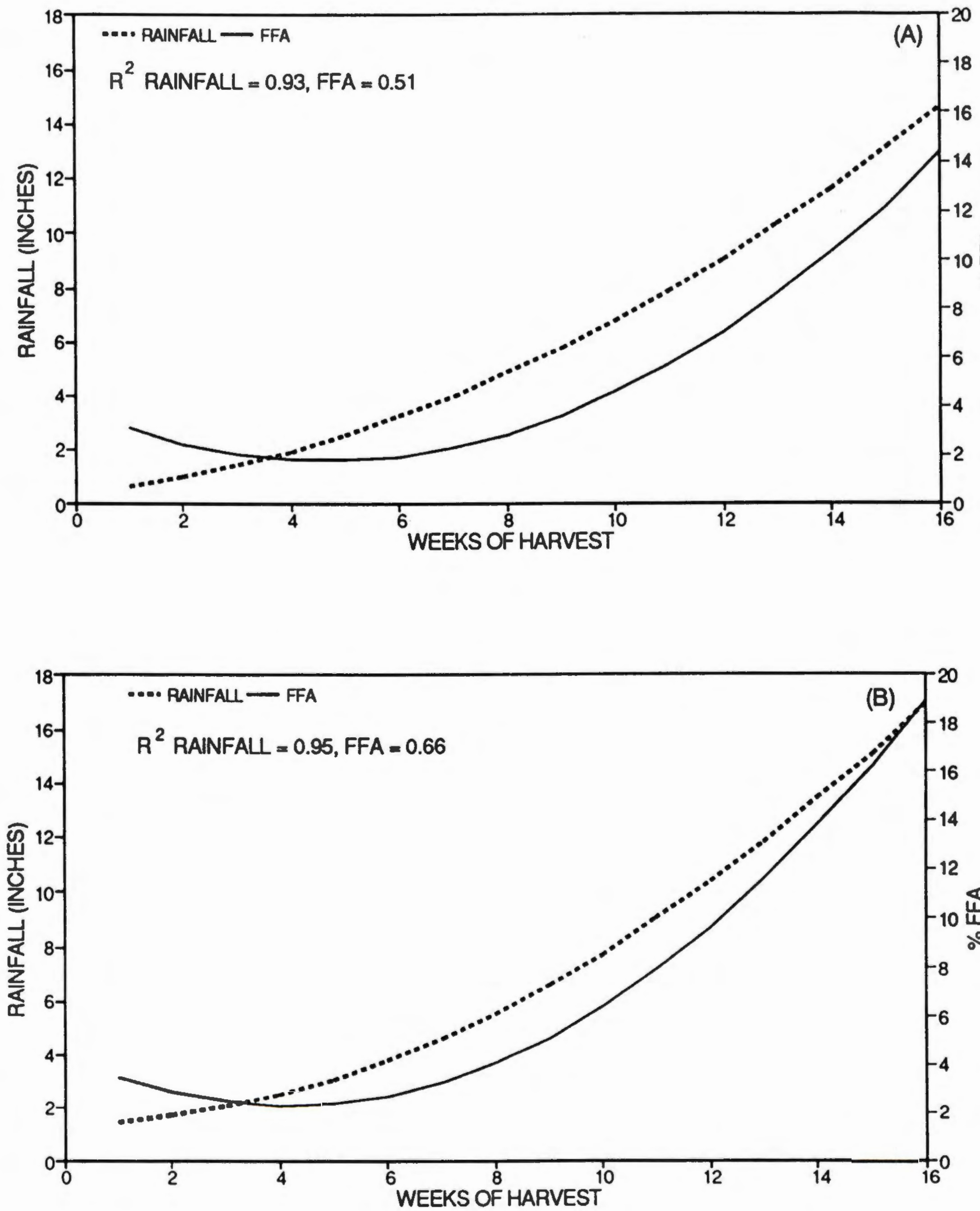
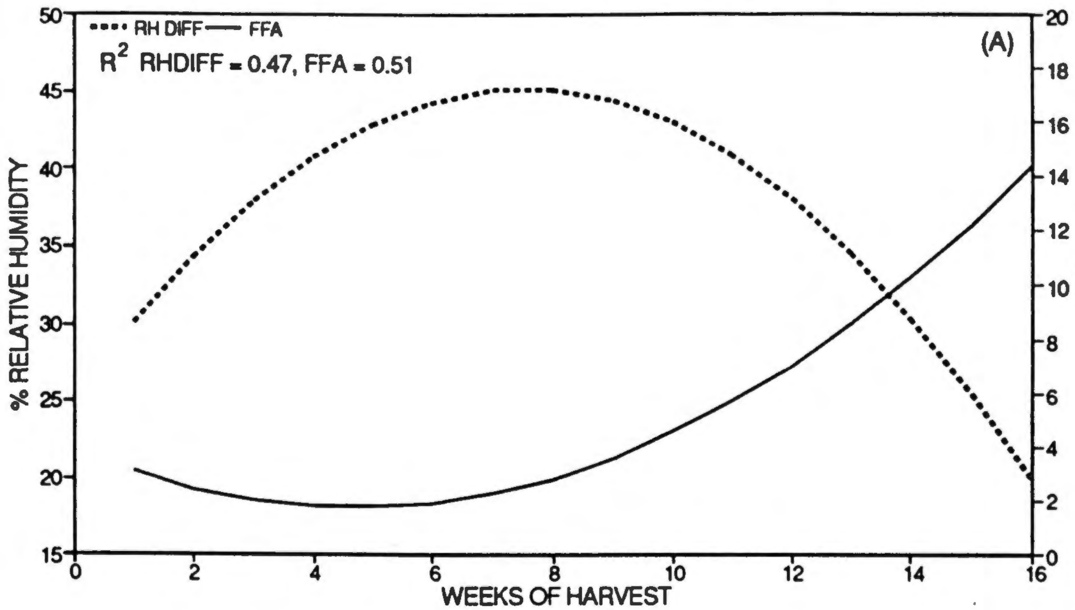



Figure B26. Predicted curves generated from the observed data showing the trends of changes in the free fatty acids (as percent oleic acid) and the cumulative rainfall (inches) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



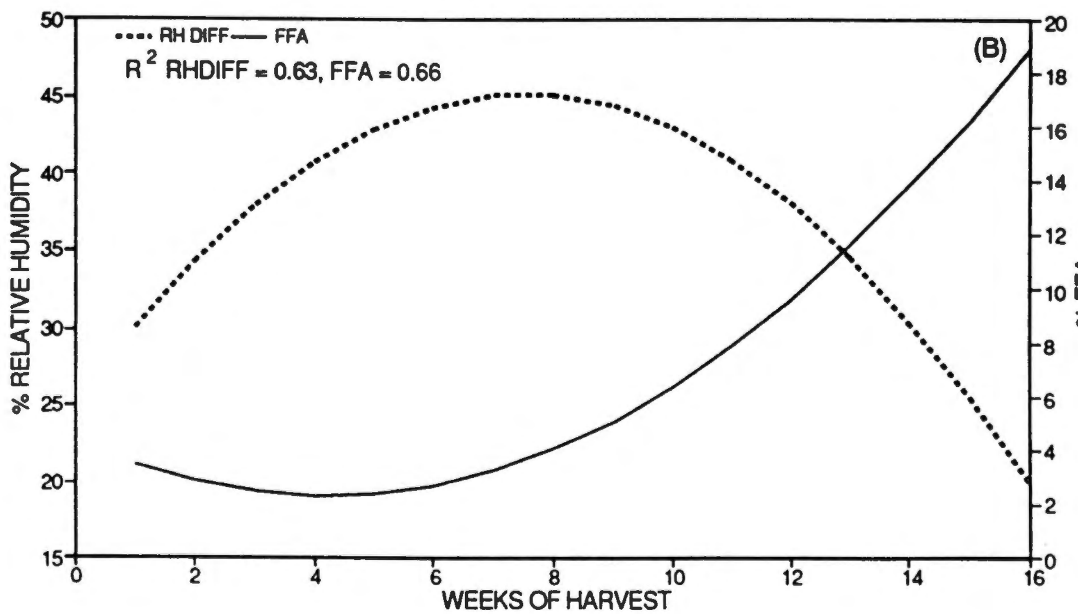




Figure B27. Predicted curves generated from the observed data showing the trends of changes in the free fatty acids (as percent oleic acid) and the differences in the maximum and the minimum relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

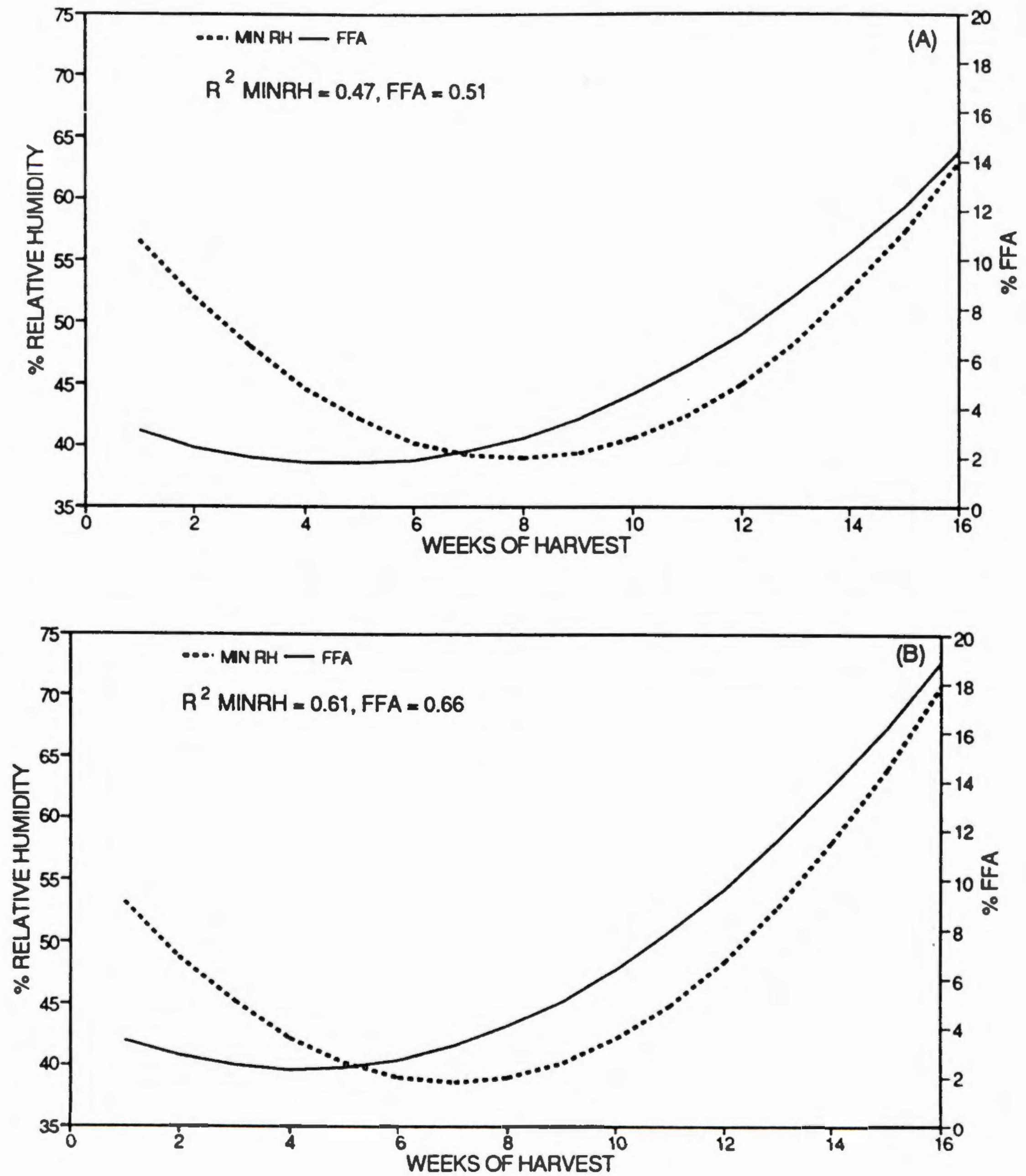
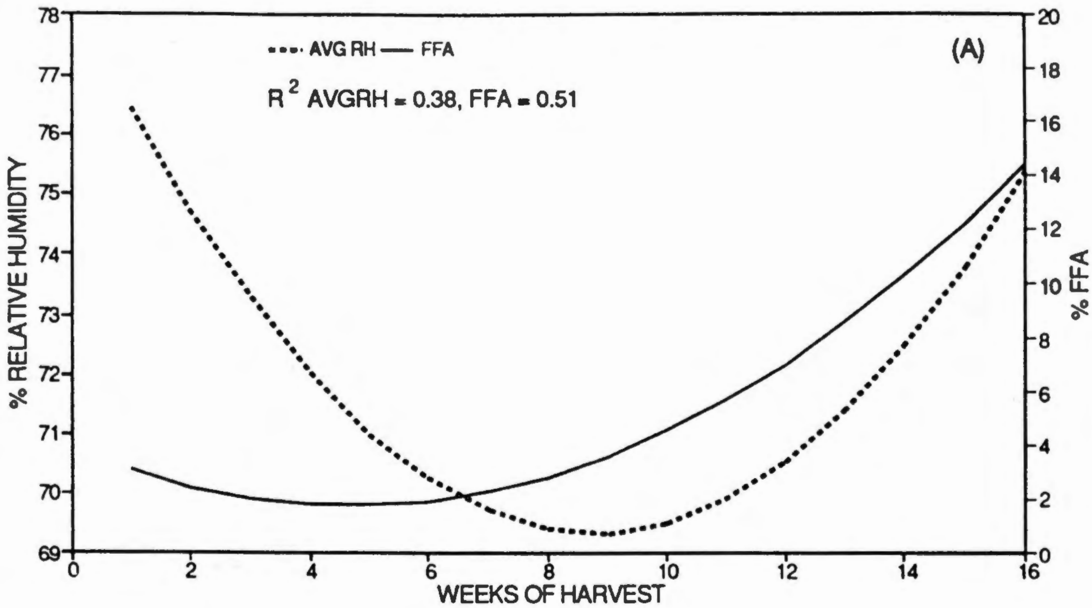



Figure B28. Predicted curves generated from the observed data showing the trends of changes in the free fatty acids (as percent oleic acid) and the minimum relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



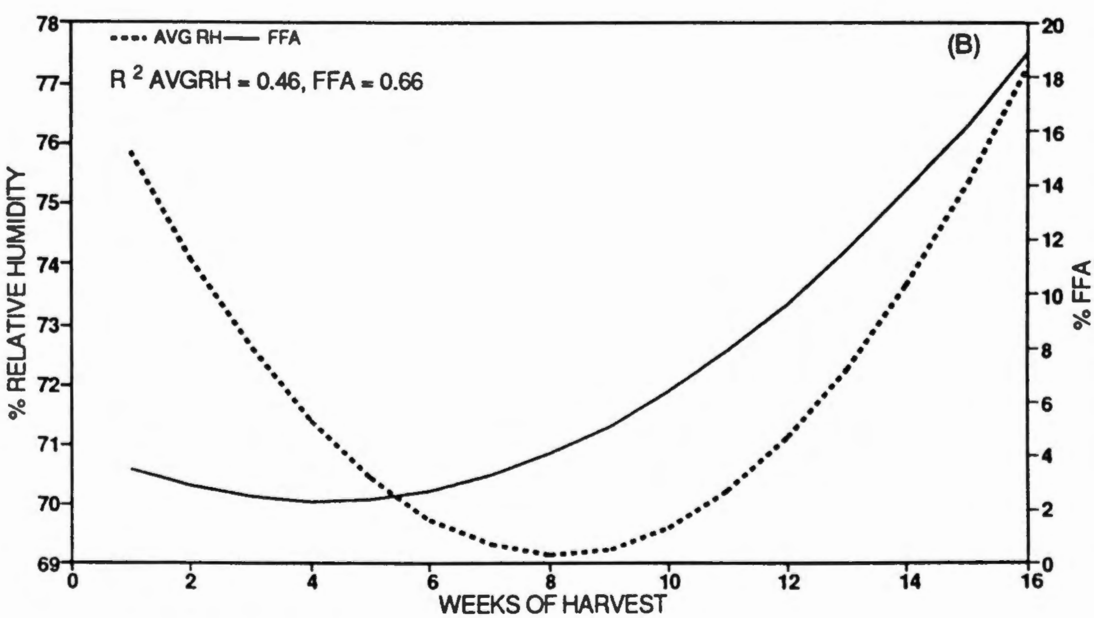
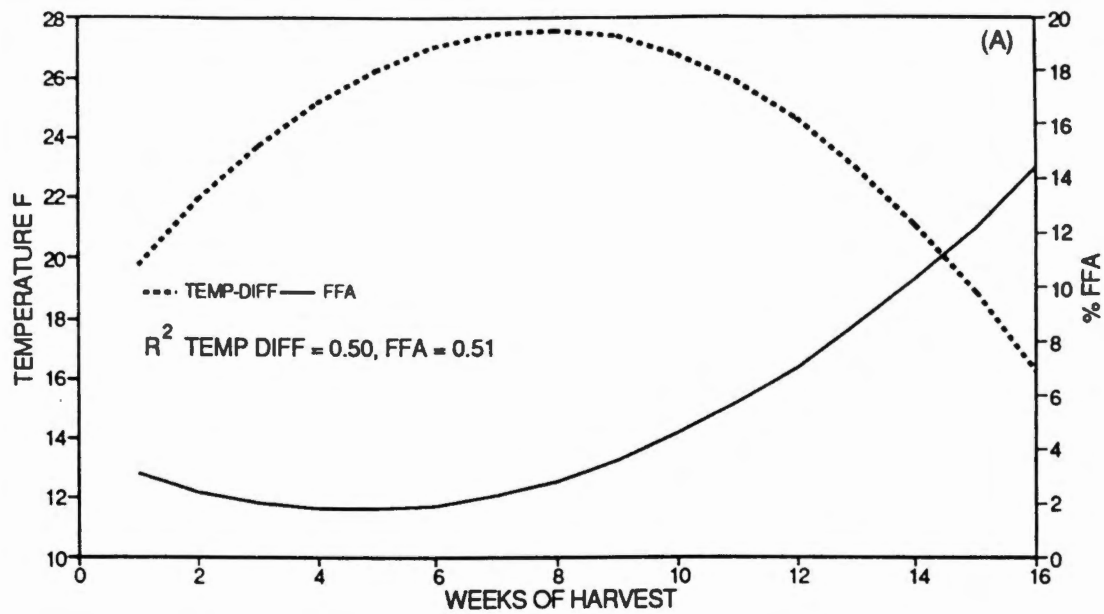




Figure B29. Predicted curves generated from the observed data showing the trends of changes in the free fatty acids (as percent oleic acid) and the average relative humidity (%) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.



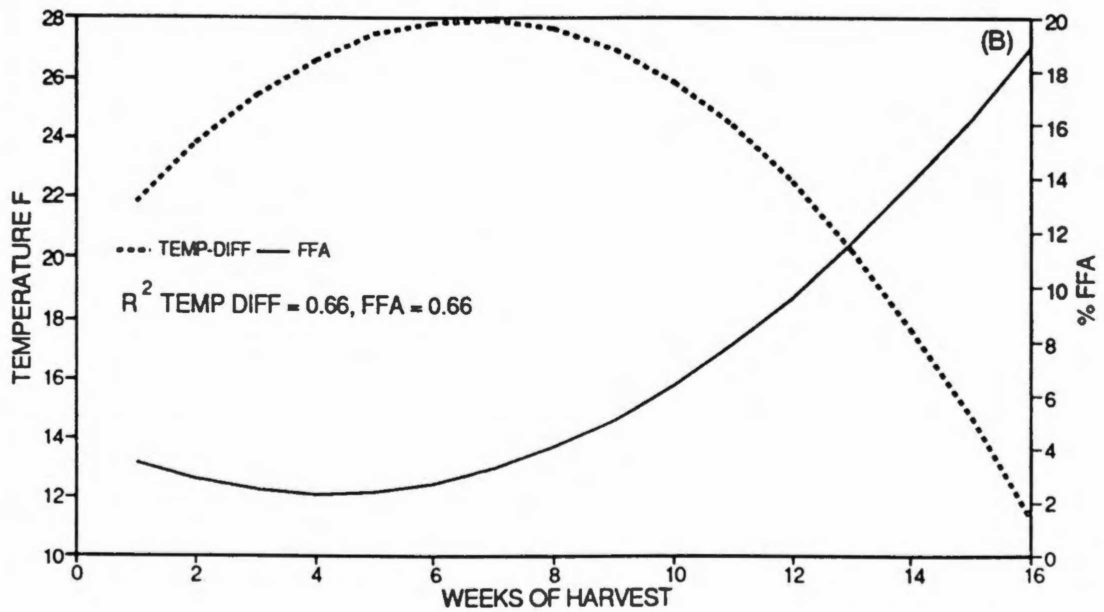




Figure B30. Predicted curves generated from the observed data showing the trends of changes in the free fatty acid (as percent oleic acid) and the differences in the maximum and minimum temperature (°F) for soybeans (A) TN4-86 and (B) Essex during the 1990 season.

# APPENDIX 'C'

Tables of Analysis of Variance and Simple Correlations analysis for field weathering experiment

TABLE C1. Analysis of variance for the effects of weeks of harvest and soybean cultivars (TN4-86, Essex and Leflore) on the total oil (%, db) and protein (%, db) during the 1989 season.

General Linear Models Procedure

Dependent Variable: OIL

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 74 | 212.69364 | 2.87424 | 23.85 | 0.0001 |
| Error | 50 | 6.02444 | 0.12049 | | |
| Corrected Total | 124 | 218.71808 | | | |

| R-Square | C.V. | Root MSE | OIL Mean |
|---|---|---|---|
| 0.972456 | 1.678961 | 0.3471 | 20.674 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 1.14884 | 0.57442 | 4.77 | 0.0127 |
| WEEK | 15 | 6.88196 | 0.45880 | 3.81 | 0.0002 |
| REP*WEEK | 30 | 8.12774 | 0.27092 | 2.25 | 0.0055 |
| Cultivar | 2 | 152.73474 | 76.36737 | 633.81 | 0.0001 |
| WEEK*Cultivar | 25 | 13.77801 | 0.55112 | 4.57 | 0.0001 |

Tests of Hypotheses using the Type III MS for REP*WEEK as an error term

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 15 | 6.8819607 | 0.4587974 | 1.69 | 0.1070 |

Dependent Variable: PROTEIN

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 74 | 559.76683 | 7.56442 | 11.59 | 0.0001 |
| Error | 50 | 32.62389 | 0.65248 | | |
| Corrected Total | 124 | 592.39072 | | | |

| R-Square | C.V. | Root MSE | PROTEIN Mean |
|---|---|---|---|
| 0.944928 | 1.854228 | 0.8078 | 43.563 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 18.63037 | 9.31519 | 14.28 | 0.0001 |
| WEEK | 15 | 9.47185 | 0.63146 | 0.97 | 0.5010 |
| REP*WEEK | 30 | 25.32557 | 0.84419 | 1.29 | 0.2066 |
| Cultivar | 2 | 379.26187 | 189.63094 | 290.63 | 0.0001 |
| WEEK*Cultivar | 25 | 31.45346 | 1.25814 | 1.93 | 0.0241 |

Tests of Hypotheses using the Type III MS for REP*WEEK as an error term

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 15 | 9.4718498 | 0.6314567 | 0.75 | 0.7192 |

TABLE C2. Analysis of variance for the effects of weeks of harvest and soybean cultivars (TN4-86, Essex and Leflore) on the free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) during the 1989 season.

General Linear Models Procedure

Dependent Variable: FFA

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 49 | 933.69831 | 19.05507 | 5.61 | 0.0001 |
| Error | 33 | 112.07639 | 3.39625 | | |
| Corrected Total | 82 | 1045.77470 | | | |

| R-Square | C.V. | Root MSE | FFA Mean |
|---|---|---|---|
| 0.892829 | 41.59916 | 1.8429 | 4.4301 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 7.82950 | 3.91475 | 1.15 | 0.3282 |
| WEEK | 10 | 156.08712 | 15.60871 | 4.60 | 0.0004 |
| REP*WEEK | 20 | 42.04639 | 2.10232 | 0.62 | 0.8697 |
| Cultivar | 2 | 114.89893 | 57.44947 | 16.92 | 0.0001 |
| WEEK*Cultivar | 15 | 571.62685 | 38.10846 | 11.22 | 0.0001 |

Tests of Hypotheses using the Type III MS for REP*WEEK as an error term

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 156.08712 | 15.60871 | 7.42 | 0.0001 |

Dependent Variable: BEAN

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 79 | 15166.914 | 191.986 | 15.53 | 0.0001 |
| Error | 64 | 791.276 | 12.364 | | |
| Corrected Total | 143 | 15958.190 | | | |

| R-Square | C.V. | Root MSE | BEAN Mean |
|---|---|---|---|
| 0.950416 | 14.86243 | 3.5162 | 23.658 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 1.8129 | 0.9065 | 0.07 | 0.9294 |
| WEEK | 15 | 6830.1656 | 455.3444 | 36.83 | 0.0001 |
| REP*WEEK | 30 | 365.8249 | 12.1942 | 0.99 | 0.5024 |
| Cultivar | 2 | 651.9554 | 325.9777 | 26.37 | 0.0001 |
| WEEK*Cultivar | 30 | 7317.1557 | 243.9052 | 19.73 | 0.0001 |

Tests of Hypotheses using the Type III MS for REP*WEEK as an error term

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 15 | 6830.1656 | 455.3444 | 37.34 | 0.0001 |

TABLE C3. Analysis of variance for the effects of weeks of harvest (for full sixteen weeks) on the total oil (%, db), protein (%, db), free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) for soybean Essex during the 1989 season.

---------------------------- Cultivar=E ------------------------------

General Linear Models Procedure

Dependent Variable: OIL

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 15 | 4.6002734 | 0.3066849 | 3.46 | 0.0030 |
| Error | 25 | 2.2158242 | 0.0886330 | | |
| Corrected Total | 40 | 6.8160976 | | | |
| | R-Square | C.V. | Root MSE | | OIL Mean |
| | 0.674913 | 1.404953 | 0.2977 | | 21.190 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| REP | 2 | 0.2308425 | 0.1154212 | 1.30 | 0.2897 |
| WEEK | 13 | 4.3435165 | 0.3341167 | 3.77 | 0.0022 |

Dependent Variable: PROTEIN

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 15 | 23.434427 | 1.562295 | 2.14 | 0.0452 |
| Error | 25 | 18.289963 | 0.731599 | | |
| Corrected Total | 40 | 41.724390 | | | |
| | R-Square | C.V. | Root MSE | | PROTEIN Mean |
| | 0.561648 | 1.891518 | 0.8553 | | 45.220 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| REP | 2 | 12.343370 | 6.171685 | 8.44 | 0.0016 |
| WEEK | 13 | 11.354103 | 0.873393 | 1.19 | 0.3388 |

Dependent Variable: FFA

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 75.688148 | 7.568815 | 1.98 | 0.1075 |
| Error | 16 | 61.128148 | 3.820509 | | |
| Corrected Total | 26 | 136.816296 | | | |
| | R-Square | C.V. | Root MSE | | FFA Mean |
| | 0.553210 | 38.86195 | 1.9546 | | 5.0296 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| REP | 2 | 46.138519 | 23.069259 | 6.04 | 0.0111 |
| WEEK | 8 | 29.549630 | 3.693704 | 0.97 | 0.4940 |

Dependent Variable: BEAN

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 17 | 6258.2917 | 368.1348 | 76.91 | 0.0001 |
| Error | 30 | 143.5883 | 4.7863 | | |
| Corrected Total | 47 | 6401.8800 | | | |
| | R-Square | C.V. | Root MSE | | BEAN Mean |
| | 0.977571 | 8.875279 | 2.1878 | | 24.650 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| REP | 2 | 0.7850 | 0.3925 | 0.08 | 0.9215 |
| WEEK | 15 | 6257.5067 | 417.1671 | 87.16 | 0.0001 |

TABLE C4. Analysis of variance for the effects of weeks of harvest (for full sixteen weeks) on the total oil (%, db), protein (%, db), free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) for soybean Leflore during the 1989 season.

---------------------------- Cultivar=L ----------------------------

General Linear Models Procedure

Dependent Variable: OIL

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 17 | 16.881683 | 0.993040 | 5.13 | 0.0001 |
| Error | 27 | 5.222762 | 0.193436 | | |
| Corrected Total | 44 | 22.104444 | | | |

| R-Square | C.V. | Root MSE | OIL Mean |
|---|---|---|---|
| 0.763723 | 2.301348 | 0.4398 | 19.111 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 2.882238 | 1.441119 | 7.45 | 0.0027 |
| WEEK | 15 | 12.995232 | 0.866349 | 4.48 | 0.0004 |

Dependent Variable: PROTEIN

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 17 | 32.890230 | 1.934719 | 2.11 | 0.0400 |
| Error | 27 | 24.732881 | 0.916033 | | |
| Corrected Total | 44 | 57.623111 | | | |

| R-Square | C.V. | Root MSE | PROTEIN Mean |
|---|---|---|---|
| 0.570782 | 2.336406 | 0.9571 | 40.964 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 15.727119 | 7.863560 | 8.58 | 0.0013 |
| WEEK | 15 | 19.369024 | 1.291268 | 1.41 | 0.2122 |

Dependent Variable: FFA

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 12 | 155.44111 | 12.95343 | 8.45 | 0.0001 |
| Error | 19 | 29.14108 | 1.53374 | | |
| Corrected Total | 31 | 184.58219 | | | |

| R-Square | C.V. | Root MSE | FFA Mean |
|---|---|---|---|
| 0.842124 | 44.47831 | 1.2384 | 2.7844 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 8.15226 | 4.07613 | 2.66 | 0.0960 |
| WEEK | 10 | 138.86074 | 13.88607 | 9.05 | 0.0001 |

Dependent Variable: BEAN

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 17 | 2004.5869 | 117.9169 | 112.58 | 0.0001 |
| Error | 30 | 31.4229 | 1.0474 | | |
| Corrected Total | 47 | 2036.0098 | | | |

| R-Square | C.V. | Root MSE | BEAN Mean |
|---|---|---|---|
| 0.984566 | 4.943660 | 1.0234 | 20.702 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 2.5704 | 1.2852 | 1.23 | 0.3075 |
| WEEK | 15 | 2002.0165 | 133.4678 | 127.42 | 0.0001 |

TABLE C5. Analysis of variance for the effects of weeks of harvest (for full sixteen weeks) on the total oil (%, db), protein (%, db), free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) for soybean TN4-86 during the 1989 season.

----------------------------- Cultivar=T ------------------------------

General Linear Models Procedure

Dependent Variable: OIL

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 4.0953846 | 0.2925275 | 2.55 | 0.0212 |
| Error | 24 | 2.7543590 | 0.1147650 | | |
| Corrected Total | 38 | 6.8497436 | | | |

| R-Square | C.V. | Root MSE | OIL Mean |
|---|---|---|---|
| 0.597889 | 1.544362 | 0.3388 | 21.936 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 1.4789744 | 0.7394872 | 6.44 | 0.0058 |
| WEEK | 12 | 2.6164103 | 0.2180342 | 1.90 | 0.0874 |

Dependent Variable: PROTEIN

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 14 | 10.038974 | 0.717070 | 3.47 | 0.0037 |
| Error | 24 | 4.964615 | 0.206859 | | |
| Corrected Total | 38 | 15.003590 | | | |

| R-Square | C.V. | Root MSE | PROTEIN Mean |
|---|---|---|---|
| 0.669105 | 1.014753 | 0.4548 | 44.821 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 0.1620513 | 0.0810256 | 0.39 | 0.6802 |
| WEEK | 12 | 9.8769231 | 0.8230769 | 3.98 | 0.0019 |

Dependent Variable: FFA

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 9 | 558.27000 | 62.03000 | 60.77 | 0.0001 |
| Error | 14 | 14.29000 | 1.02071 | | |
| Corrected Total | 23 | 572.56000 | | | |

| R-Square | C.V. | Root MSE | FFA Mean |
|---|---|---|---|
| 0.975042 | 16.97990 | 1.0103 | 5.9500 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 5.89000 | 2.94500 | 2.89 | 0.0893 |
| WEEK | 7 | 552.38000 | 78.91143 | 77.31 | 0.0001 |

Dependent Variable: BEAN

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 17 | 5901.9798 | 347.1753 | 10.78 | 0.0001 |
| Error | 30 | 966.3650 | 32.2122 | | |
| Corrected Total | 47 | 6868.3448 | | | |

| R-Square | C.V. | Root MSE | BEAN Mean |
|---|---|---|---|
| 0.859302 | 22.15039 | 5.6756 | 25.623 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 14.1817 | 7.0908 | 0.22 | 0.8037 |
| WEEK | 15 | 5887.7981 | 392.5199 | 12.19 | 0.0001 |

TABLE C6. Analysis of variance for the effects of weeks of harvest and soybean cultivars (TN4-86, Essex, and Leflore) on the total oil (%, db) and carbohydrates (%, db) during the 1990 season.

**General Linear Models Procedure**

**Dependent Variable: OILDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 79 | 304.51695 | 3.85464 | 14.32 | 0.0001 |
| Error | 64 | 17.23058 | 0.26923 | | |
| Corrected Total | 143 | 321.74753 | | | |
| | R-Square | C.V. | Root MSE | | OILDB Mean |
| | 0.946447 | 2.631575 | 0.5189 | | 19.717 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 0.36669 | 0.18335 | 0.68 | 0.5097 |
| WEEK | 15 | 15.81251 | 1.05417 | 3.92 | 0.0001 |
| REP*WEEK | 30 | 23.68473 | 0.78949 | 2.93 | 0.0002 |
| Cultivar | 2 | 246.19992 | 123.09996 | 457.23 | 0.0001 |
| WEEK*Cultivar | 30 | 18.45310 | 0.61510 | 2.28 | 0.0029 |
| **Tests of Hypotheses using the Type III MS for REP*WEEK as an error term** | | | | | |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 15 | 15.812510 | 1.054167 | 1.34 | 0.2425 |

**Dependent Variable: CARBDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 79 | 960.91680 | 12.16350 | 14.91 | 0.0001 |
| Error | 64 | 52.22480 | 0.81601 | | |
| Corrected Total | 143 | 1013.14160 | | | |
| | R-Square | C.V. | Root MSE | | CARBDB Mean |
| | 0.948453 | 2.932427 | 0.9033 | | 30.805 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 10.41845 | 5.20923 | 6.38 | 0.0030 |
| WEEK | 15 | 125.25147 | 8.35010 | 10.23 | 0.0001 |
| REP*WEEK | 30 | 24.95441 | 0.83181 | 1.02 | 0.4606 |
| Cultivar | 2 | 711.81502 | 355.90751 | 436.15 | 0.0001 |
| WEEK*Cultivar | 30 | 88.47745 | 2.94925 | 3.61 | 0.0001 |
| **Tests of Hypotheses using the Type III MS for REP*WEEK as an error term** | | | | | |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 15 | 125.25147 | 8.35010 | 10.04 | 0.0001 |

TABLE C7. Analysis of variance for the effects of weeks of harvest and soybean cultivars (TN4-86, Essex, and Leflore) on ash (%, db) and protein (% db) during the 1990 season.

**General Linear Models Procedure**

**Dependent Variable: ASHDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 79 | 21.730400 | 0.275068 | 2.93 | 0.0001 |
| Error | 64 | 6.006489 | 0.093851 | | |
| Corrected Total | 143 | 27.736889 | | | |
| | R-Square | C.V. | Root MSE | ASHDB Mean | |
| | 0.783448 | 5.843929 | 0.3064 | 5.2422 | |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 0.123260 | 0.061630 | 0.66 | 0.5220 |
| WEEK | 15 | 4.216711 | 0.281114 | 3.00 | 0.0012 |
| REP*WEEK | 30 | 2.540318 | 0.084677 | 0.90 | 0.6129 |
| Cultivar | 2 | 10.103310 | 5.051655 | 53.83 | 0.0001 |
| WEEK*Cultivar | 30 | 4.746801 | 0.158227 | 1.69 | 0.0407 |
| **Tests of Hypotheses using the Type III MS for REP*WEEK as an error term** | | | | | |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 15 | 4.2167111 | 0.2811141 | 3.32 | 0.0025 |

**Dependent Variable: PROTDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 79 | 378.65997 | 4.79316 | 8.35 | 0.0001 |
| Error | 64 | 36.75309 | 0.57427 | | |
| Corrected Total | 143 | 415.41306 | | | |
| | R-Square | C.V. | Root MSE | PROTDB Mean | |
| | 0.911526 | 1.712611 | 0.7578 | 44.248 | |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 9.96008 | 4.98004 | 8.67 | 0.0005 |
| WEEK | 15 | 70.25035 | 4.68336 | 8.16 | 0.0001 |
| REP*WEEK | 30 | 53.06256 | 1.76875 | 3.08 | 0.0001 |
| Cultivar | 2 | 191.23832 | 95.61916 | 166.51 | 0.0001 |
| WEEK*Cultivar | 30 | 54.14866 | 1.80496 | 3.14 | 0.0001 |
| **Tests of Hypotheses using the Type III MS for REP*WEEK as an error term** | | | | | |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 15 | 70.250353 | 4.683357 | 2.65 | 0.0113 |

TABLE C8. Analysis of variance for the effects of weeks of harvest and soybean cultivars (TN4-86, Essex, and Leflore) on free fatty acids (as percent oleic acid), dry matter (g/100g), and bean moisture percentage at harvest (%, wb) during the 1990 season.

**General Linear Models Procedure**

**Dependent Variable: FFA**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 79 | 8704.2263 | 110.1801 | 2.42 | 0.0002 |
| Error | 63 | 2864.7200 | 45.4717 | | |
| Corrected Total | 142 | 11568.9462 | | | |
| | R-Square | C.V. | Root MSE | | FFA Mean |
| | 0.752378 | 121.9260 | 6.7433 | | 5.5306 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 44.1220 | 22.0610 | 0.49 | 0.6179 |
| WEEK | 15 | 3476.4582 | 231.7639 | 5.10 | 0.0001 |
| REP*WEEK | 30 | 1322.4408 | 44.0814 | 0.97 | 0.5243 |
| Cultivar | 2 | 794.5541 | 397.2771 | 8.74 | 0.0004 |
| WEEK*Cultivar | 30 | 3082.3484 | 102.7449 | 2.26 | 0.0033 |
| **Tests of Hypotheses using the Type III MS for REP*WEEK as an error term** | | | | | |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 15 | 3476.4582 | 231.7639 | 5.26 | 0.0001 |

**General Linear Models Procedure**

**Dependent Variable: MOISTURE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 79 | 13573.743 | 171.820 | 12.93 | 0.0001 |
| Error | 63 | 837.322 | 13.291 | | |
| Corrected Total | 142 | 14411.066 | | | |
| | R-Square | C.V. | Root MSE | | MOISTURE Mean |
| | 0.941897 | 16.96848 | 3.6457 | | 21.485 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 114.9091 | 57.4546 | 4.32 | 0.0174 |
| WEEK | 15 | 7066.1620 | 471.0775 | 35.44 | 0.0001 |
| REP*WEEK | 30 | 5849.5401 | 194.9847 | 14.67 | 0.0001 |
| Cultivar | 2 | 68.8329 | 34.4165 | 2.59 | 0.0830 |
| WEEK*Cultivar | 30 | 471.3907 | 15.7130 | 1.18 | 0.2834 |
| **Tests of Hypotheses using the Type III MS for REP*WEEK as an error term** | | | | | |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 15 | 7066.1620 | 471.0775 | 2.42 | 0.0194 |

**Dependent Variable: DM**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 79 | 3303.5582 | 41.8172 | 0.95 | 0.5837 |
| Error | 63 | 2765.2711 | 43.8932 | | |
| Corrected Total | 142 | 6068.8293 | | | |
| | R-Square | C.V. | Root MSE | | DM Mean |
| | 0.544349 | 7.092686 | 6.6252 | | 93.409 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 101.3742 | 50.6871 | 1.15 | 0.3217 |
| WEEK | 15 | 678.7575 | 45.2505 | 1.03 | 0.4371 |
| REP*WEEK | 30 | 1212.0628 | 40.4021 | 0.92 | 0.5887 |
| Cultivar | 2 | 82.4326 | 41.2163 | 0.94 | 0.3964 |
| WEEK*Cultivar | 30 | 1219.2873 | 40.6429 | 0.93 | 0.5814 |
| **Tests of Hypotheses using the Type III MS for REP*WEEK as an error term** | | | | | |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 15 | 678.75754 | 45.25050 | 1.12 | 0.3813 |

TABLE C9. Analysis of variance for the effects of weeks of harvest (from first to fifth week) on ash (%, db), protein (%, db), total oil (%, db) and carbohydrates (%, db) for soybean TN4-86 during the 1990 season.

------------------------------- **Cultivar=T** -------------------------------

General Linear Models Procedure

**Dependent Variable: ASHDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 0.2265733 | 0.0566433 | 1.09 | 0.4118 |
| Error | 10 | 0.5190000 | 0.0519000 | | |
| Corrected Total | 14 | 0.7455733 | | | |
| | R-Square | C.V. | Root MSE | | ASHDB Mean |
| | 0.303891 | 4.457070 | 0.2278 | | 5.1113 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 0.2265733 | 0.0566433 | 1.09 | 0.4118 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 0.2265733 | 0.0566433 | 1.09 | 0.4118 |

**Dependent Variable: PROTDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 2.9249333 | 0.7312333 | 1.02 | 0.4419 |
| Error | 10 | 7.1592000 | 0.7159200 | | |
| Corrected Total | 14 | 10.0841333 | | | |
| | R-Square | C.V. | Root MSE | | PROTDB Mean |
| | 0.290053 | 1.946746 | 0.8461 | | 43.463 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 2.9249333 | 0.7312333 | 1.02 | 0.4419 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 2.9249333 | 0.7312333 | 1.02 | 0.4419 |

**Dependent Variable: OILDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 2.8609333 | 0.7152333 | 1.82 | 0.2012 |
| Error | 10 | 3.9246000 | 0.3924600 | | |
| Corrected Total | 14 | 6.7855333 | | | |
| | R-Square | C.V. | Root MSE | | OILDB Mean |
| | 0.421622 | 2.942998 | 0.6265 | | 21.287 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 2.8609333 | 0.7152333 | 1.82 | 0.2012 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 2.8609333 | 0.7152333 | 1.82 | 0.2012 |

**Dependent Variable: CARBDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 0.6236267 | 0.1559067 | 0.19 | 0.9395 |
| Error | 10 | 8.3092667 | 0.8309267 | | |
| Corrected Total | 14 | 8.9328933 | | | |
| | R-Square | C.V. | Root MSE | | CARBDB Mean |
| | 0.069812 | 3.022119 | 0.9116 | | 30.163 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 0.6236267 | 0.1559067 | 0.19 | 0.9395 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 0.6236267 | 0.1559067 | 0.19 | 0.9395 |

TABLE C10. Analysis of variance for the effects of weeks of harvest (from sixth to sixteenth week) on ash (%, db), protein (%, db), total oil (%, db) and carbohydrates (%, db) for soybean TN4-86 during the 1990 season.

---------------------------- **Cultivar=T** ----------------------------

General Linear Models Procedure

**Dependent Variable: ASHDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 2.5965212 | 0.2596521 | 2.59 | 0.0300 |
| Error | 22 | 2.2032667 | 0.1001485 | | |
| Corrected Total | 32 | 4.7997879 | | | |
| | R-Square | C.V. | Root MSE | | ASHDB Mean |
| | 0.540966 | 5.702649 | 0.3165 | | 5.5494 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 2.5965212 | 0.2596521 | 2.59 | 0.0300 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 2.5965212 | 0.2596521 | 2.59 | 0.0300 |

**Dependent Variable: PROTDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 37.993824 | 3.799382 | 9.10 | 0.0001 |
| Error | 22 | 9.189800 | 0.417718 | | |
| Corrected Total | 32 | 47.183624 | | | |
| | R-Square | C.V. | Root MSE | | PROTDB Mean |
| | 0.805233 | 1.458563 | 0.6463 | | 44.312 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 37.993824 | 3.799382 | 9.10 | 0.0001 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 37.993824 | 3.799382 | 9.10 | 0.0001 |

**Dependent Variable: OILDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 7.6164000 | 0.7616400 | 2.38 | 0.0430 |
| Error | 22 | 7.0293333 | 0.3195152 | | |
| Corrected Total | 32 | 14.6457333 | | | |
| | R-Square | C.V. | Root MSE | | OILDB Mean |
| | 0.520042 | 2.628286 | 0.5653 | | 21.507 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 7.6164000 | 0.7616400 | 2.38 | 0.0430 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 7.6164000 | 0.7616400 | 2.38 | 0.0430 |

**Dependent Variable: CARBDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 52.212588 | 5.221259 | 8.93 | 0.0001 |
| Error | 22 | 12.860400 | 0.584564 | | |
| Corrected Total | 32 | 65.072988 | | | |
| | R-Square | C.V. | Root MSE | | CARBDB Mean |
| | 0.802370 | 2.669636 | 0.7646 | | 28.639 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 52.212588 | 5.221259 | 8.93 | 0.0001 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 52.212588 | 5.221259 | 8.93 | 0.0001 |

TABLE C11. Analysis of variance for the effects of weeks of harvest (from first to fifth week) on ash (%, db), protein (%, db), total oil (%, db) and carbohydrates (%, db) for soybean Essex during the 1990 season.

------------------------------ **Cultivar=E** ------------------------------

General Linear Models Procedure

**Dependent Variable: ASHDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 0.0813333 | 0.0203333 | 0.26 | 0.9000 |
| Error | 10 | 0.7968000 | 0.0796800 | | |
| Corrected Total | 14 | 0.8781333 | | | |
| | R-Square | C.V. | Root MSE | | ASHDB Mean |
| | 0.092621 | 5.352904 | 0.2823 | | 5.2733 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 0.0813333 | 0.0203333 | 0.26 | 0.9000 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 0.0813333 | 0.0203333 | 0.26 | 0.9000 |

**Dependent Variable: PROTDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 0.9817067 | 0.2454267 | 0.12 | 0.9717 |
| Error | 10 | 20.2480667 | 2.0248067 | | |
| Corrected Total | 14 | 21.2297733 | | | |
| | R-Square | C.V. | Root MSE | | PROTDB Mean |
| | 0.046242 | 3.111966 | 1.4230 | | 45.725 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 0.9817067 | 0.2454267 | 0.12 | 0.9717 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 0.9817067 | 0.2454267 | 0.12 | 0.9717 |

**Dependent Variable: OILDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 2.2271333 | 0.5567833 | 0.63 | 0.6548 |
| Error | 10 | 8.8954000 | 0.8895400 | | |
| Corrected Total | 14 | 11.1225333 | | | |
| | R-Square | C.V. | Root MSE | | OILDB Mean |
| | 0.200236 | 4.960489 | 0.9432 | | 19.013 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 2.2271333 | 0.5567833 | 0.63 | 0.6548 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 2.2271333 | 0.5567833 | 0.63 | 0.6548 |

**Dependent Variable: CARBDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 4.5773600 | 1.1443400 | 0.68 | 0.6207 |
| Error | 10 | 16.8021333 | 1.6802133 | | |
| Corrected Total | 14 | 21.3794933 | | | |
| | R-Square | C.V. | Root MSE | | CARBDB Mean |
| | 0.214100 | 4.322593 | 1.2962 | | 29.987 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 4.5773600 | 1.1443400 | 0.68 | 0.6207 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 4.5773600 | 1.1443400 | 0.68 | 0.6207 |

TABLE C12. Analysis of variance for the effects of weeks of harvest (from sixth to sixteenth week) on ash (%, db), protein (%, db), total oil (%, db) and carbohydrates (%, db) for soybean Essex during the 1990 season.

------------------------------ **Cultivar=E** ------------------------------

General Linear Models Procedure

**Dependent Variable: ASHDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 1.0251515 | 0.1025152 | 0.66 | 0.7490 |
| Error | 22 | 3.4226667 | 0.1555758 | | |
| Corrected Total | 32 | 4.4478182 | | | |
| | R-Square | C.V. | Root MSE | | AS DB Mean |
| | 0.230484 | 7.139609 | 0.3944 | | 5.5245 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 1.0251515 | 0.1025152 | 0.66 | 0.7490 |

**Dependent Variable: PROTDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 55.386285 | 5.538628 | 4.83 | 0.0010 |
| Error | 22 | 25.214667 | 1.146121 | | |
| Corrected Total | 32 | 80.600952 | | | |
| | R-Square | C.V. | Root MSE | | PROTDB Mean |
| | 0.687167 | 2.339471 | 1.0706 | | 45.761 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 55.386285 | 5.538628 | 4.83 | 0.0010 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 55.386285 | 5.538628 | 4.83 | 0.0010 |

**Dependent Variable: OILDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 6.9470242 | 0.6947024 | 1.29 | 0.2926 |
| Error | 22 | 11.8062000 | 0.5366455 | | |
| Corrected Total | 32 | 18.7532242 | | | |
| | R-Square | C.V. | Root MSE | | OILDB Mean |
| | 0.370444 | 3.730231 | 0.7326 | | 19.638 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 6.9470242 | 0.6947024 | 1.29 | 0.2926 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 6.9470242 | 0.6947024 | 1.29 | 0.2926 |

**Dependent Variable: CARBDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 82.925358 | 8.292536 | 6.21 | 0.0002 |
| Error | 22 | 29.372067 | 1.335094 | | |
| Corrected Total | 32 | 112.297424 | | | |
| | R-Square | C.V. | Root MSE | | CARBDB Mean |
| | 0.738444 | 3.975423 | 1.1555 | | 29.065 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 82.925358 | 8.292536 | 6.21 | 0.0002 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 82.925358 | 8.292536 | 6.21 | 0.0002 |

TABLE C13. Analysis of variance for the effects of weeks of harvest (from first to fifth week) on ash (%, db), protein (%, db), total oil (%, db) and carbohydrates (%, db) for soybean Leflore during the 1990 season.

------------------------------ **Cultivar=L** ---------------------------------

General Linear Models Procedure

**Dependent Variable: ASHDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 1.3930933 | 0.3482733 | 21.61 | 0.0001 |
| Error | 10 | 0.1612000 | 0.0161200 | | |
| Corrected Total | 14 | 1.5542933 | | | |
| | R-Square | C.V. | Root MSE | | ASHDB Mean |
| | 0.896287 | 2.624681 | 0.1270 | | 4.8373 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 1.3930933 | 0.3482733 | 21.61 | 0.0001 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 1.3930933 | 0.3482733 | 21.61 | 0.0001 |

**Dependent Variable: PROTDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 5.7490267 | 1.4372567 | 0.90 | 0.4998 |
| Error | 10 | 15.9835333 | 1.5983533 | | |
| Corrected Total | 14 | 21.7325600 | | | |
| | R-Square | C.V. | Root MSE | | PROTDB Mean |
| | 0.264535 | 2.926934 | 1.2643 | | 43.194 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 5.7490267 | 1.4372567 | 0.90 | 0.4998 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 5.7490267 | 1.4372567 | 0.90 | 0.4998 |

**Dependent Variable: OILDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 5.3364933 | 1.3341233 | 5.88 | 0.0107 |
| Error | 10 | 2.2690000 | 0.2269000 | | |
| Corrected Total | 14 | 7.6054933 | | | |
| | R-Square | C.V. | Root MSE | | OILDB Mean |
| | 0.701663 | 2.596237 | 0.4763 | | 18.347 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 5.3364933 | 1.3341233 | 5.88 | 0.0107 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 5.3364933 | 1.3341233 | 5.88 | 0.0107 |

**Dependent Variable: CARBDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 20.522827 | 5.130707 | 5.88 | 0.0106 |
| Error | 10 | 8.723867 | 0.872387 | | |
| Corrected Total | 14 | 29.246693 | | | |
| | R-Square | C.V. | Root MSE | | CARBDB Mean |
| | 0.701714 | 2.774636 | 0.9340 | | 33.663 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 20.522827 | 5.130707 | 5.88 | 0.0106 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 4 | 20.522827 | 5.130707 | 5.88 | 0.0106 |

TABLE C14. Analysis of variance for the effects of weeks of harvest (from sixth to sixteenth week) on ash (%, db), protein (%, db), total oil (%, db) and carbohydrates (%, db) for soybean Leflore during the 1990 season.

------------------------------ **Cultivar=L** ------------------------------

General Linear Models Procedure

**Dependent Variable: ASHDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 0.9904182 | 0.0990418 | 1.39 | 0.2482 |
| Error | 22 | 1.5671333 | 0.0712333 | | |
| Corrected Total | 32 | 2.5575515 | | | |
| | R-Square | C.V. | Root MSE | | ASHDB Mean |
| | 0.387252 | 5.466799 | 0.2669 | | 4.8821 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 0.9904182 | 0.0990418 | 1.39 | 0.2482 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 0.9904182 | 0.0990418 | 1.39 | 0.2482 |

**Dependent Variable: PROTDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 12.620939 | 1.262094 | 1.26 | 0.3086 |
| Error | 22 | 21.980467 | 0.999112 | | |
| Corrected Total | 32 | 34.601406 | | | |
| | R-Square | C.V. | Root MSE | | PROTDB Mean |
| | 0.364752 | 2.333363 | 0.9996 | | 42.838 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 12.620939 | 1.262094 | 1.26 | 0.3086 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 12.620939 | 1.262094 | 1.26 | 0.3086 |

**Dependent Variable: OILDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 4.6191515 | 0.4619152 | 1.38 | 0.2521 |
| Error | 22 | 7.3574667 | 0.3344303 | | |
| Corrected Total | 32 | 11.9766182 | | | |
| | R-Square | C.V. | Root MSE | | OILDB Mean |
| | 0.385681 | 3.171292 | 0.5783 | | 18.235 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 4.6191515 | 0.4619152 | 1.38 | 0.2521 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 4.6191515 | 0.4619152 | 1.38 | 0.2521 |

**Dependent Variable: CARBDB**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 18.413891 | 1.841389 | 3.51 | 0.0067 |
| Error | 22 | 11.529933 | 0.524088 | | |
| Corrected Total | 32 | 29.943824 | | | |
| | R-Square | C.V. | Root MSE | | CARBDB Mean |
| | 0.614948 | 2.124537 | 0.7239 | | 34.075 |
| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 18.413891 | 1.841389 | 3.51 | 0.0067 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 10 | 18.413891 | 1.841389 | 3.51 | 0.0067 |

TABLE C15. Analysis of variance for the effects of weeks of harvest (from first to fifth week) on dry matter (g/100g db), free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) for soybean TN4-86 during the 1990 season.

---------------------------- **Cultivar=T** ----------------------------

General Linear Models Procedure

**Dependent Variable: DM**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 0.0696000 | 0.0174000 | 0.60 | 0.6694 |
| Error | 10 | 0.2886000 | 0.0288600 | | |
| Corrected Total | 14 | 0.3582000 | | | |

| R-Square | C.V. | Root MSE | DM Mean |
|---|---|---|---|
| 0.194305 | 0.180745 | 0.1699 | 93.990 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 4 | 0.0696000 | 0.0174000 | 0.60 | 0.6694 |

**Dependent Variable: FFA**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 22.016000 | 5.504000 | 1.59 | 0.2520 |
| Error | 10 | 34.693333 | 3.469333 | | |
| Corrected Total | 14 | 56.709333 | | | |

| R-Square | C.V. | Root MSE | FFA Mean |
|---|---|---|---|
| 0.388225 | 68.81581 | 1.8626 | 2.7067 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 4 | 22.016000 | 5.504000 | 1.59 | 0.2520 |

**Dependent Variable: MOISTURE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 625.94000 | 156.48500 | 23.65 | 0.0001 |
| Error | 10 | 66.17333 | 6.61733 | | |
| Corrected Total | 14 | 692.11333 | | | |

| R-Square | C.V. | Root MSE | MOIS Mean |
|---|---|---|---|
| 0.904389 | 14.10832 | 2.5724 | 18.233 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 4 | 625.94000 | 156.48500 | 23.65 | 0.0001 |

TABLE C16. Analysis of variance for the effects of weeks of harvest (from sixth to sixteenth week) on dry matter (g/100g db), free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) for soybean TN4-86 during the 1990 season.

---------------------------- **Cultivar=T** ----------------------------

General Linear Models Procedure

**Dependent Variable: DM**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 1.9618061 | 0.1961806 | 2.64 | 0.0274 |
| Error | 22 | 1.6318000 | 0.0741727 | | |
| Corrected Total | 32 | 3.5936061 | | | |

| R-Square | C.V. | Root MSE | DM Mean |
|---|---|---|---|
| 0.545916 | 0.289154 | 0.2723 | 94.188 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 1.9618061 | 0.1961806 | 2.64 | 0.0274 |

**Dependent Variable: FFA**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 12 | 1254.2327 | 104.5194 | 169.18 | 0.0001 |
| Error | 20 | 12.3564 | 0.6178 | | |
| Corrected Total | 32 | 1266.5891 | | | |

| R-Square | C.V. | Root MSE | FFA Mean |
|---|---|---|---|
| 0.990244 | 11.87659 | 07860 | 6.6182 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 1245.2091 | 124.5209 | 201.55 | 0.0001 |

**Dependent Variable: MOISTURE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 4223.9678 | 422.3968 | 21.84 | 0.0001 |
| Error | 22 | 425.5664 | 19.3439 | | |
| Corrected Total | 32 | 4649.5342 | | | |

| R-Square | C.V. | Root MSE | MOIS Mean |
|---|---|---|---|
| 0.908471 | 19.05121 | 4.3982 | 23.086 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 4223.9678 | 422.3968 | 21.84 | 0.0001 |

TABLE C17. Analysis of variance for the effects of weeks of harvest (from first to fifth week) on dry matter (g/100g db), free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) for soybean Essex during the 1990 season.

---------------------------- **Cultivar=E** ----------------------------------

General Linear Models Procedure

**Dependent Variable: DM**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 0.8012400 | 0.2003100 | 6.62 | 0.0072 |
| Error | 10 | 0.3025333 | 0.0302533 | | |
| Corrected Total | 14 | 1.1037733 | | | |

| R-Square | C.V. | Root MSE | DM Mean |
|---|---|---|---|
| 0.725910 | 0.185449 | 0.1739 | 93.791 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 4 | 0.8012400 | 0.2003100 | 6.62 | 0.0072 |

**Dependent Variable: FFA**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 16.404000 | 4.101000 | 2.42 | 0.1174 |
| Error | 10 | 16.960000 | 1.696000 | | |
| Corrected Total | 14 | 33.364000 | | | |

| R-Square | C.V. | Root MSE | FFA Mean |
|---|---|---|---|
| 0.491668 | 47.87888 | 1.3023 | 2.7200 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 4 | 16.404000 | 4.101000 | 2.42 | 0.1174 |

**Dependent Variable: MOISTURE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 726.28667 | 181.57167 | 6.97 | 0.0060 |
| Error | 10 | 260.34667 | 26.03467 | | |
| Corrected Total | 14 | 986.63333 | | | |

| R-Square | C.V. | Root MSE | MOIS Mean |
|---|---|---|---|
| 0.736126 | 23.15772 | 5.1024 | 22.033 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 4 | 726.28667 | 181.57167 | 6.97 | 0.0060 |

TABLE C18. Analysis of variance for the effects of weeks of harvest (from sixth to sixteenth week) on dry matter (g/100g db), free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) for soybean Essex during the 1990 season.

------------------------------ **Cultivar=E** ------------------------------

General Linear Models Procedure

**Dependent Variable: DM**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 3.9890848 | 0.3989085 | 1.32 | 0.2824 |
| Error | 22 | 6.6716667 | 0.3032576 | | |
| Corrected Total | 32 | 10.6607515 | | | |

| R-Square | C.V. | Root MSE | DM Mean |
|---|---|---|---|
| 0.374184 | 0.586699 | 0.5507 | 93.862 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 3.9890848 | 0.3989085 | 1.32 | 0.2824 |

**Dependent Variable: FFA**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 12 | 1457.6145 | 121.4679 | 71.11 | 0.0001 |
| Error | 20 | 34.1642 | 1.7082 | | |
| Corrected Total | 32 | 1491.7788 | | | |

| R-Square | C.V. | Root MSE | FFA Mean |
|---|---|---|---|
| 0.977098 | 14.45878 | 1.3070 | 9.0394 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 1453.6121 | 145.3612 | 85.10 | 0.0001 |

**Dependent Variable: MOISTURE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 1850.9697 | 185.0970 | 33.04 | 0.0001 |
| Error | 22 | 123.2400 | 5.6018 | | |
| Corrected Total | 32 | 1974.2097 | | | |

| R-Square | C.V. | Root MSE | MOIS Mean |
|---|---|---|---|
| 0.937575 | 11.54715 | 2.3668 | 20.497 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 1850.9697 | 185.0970 | 33.04 | 0.0001 |

TABLE C19. Analysis of variance for the effects of weeks of harvest (from first to fifth week) on dry matter (g/100g db), free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) for soybean Leflore during the 1990 season.

---------------------------- **Cultivar=L** ---------------------------------

General Linear Models Procedure

**Dependent Variable: DM**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 0.2036667 | 0.0509167 | 2.42 | 0.1175 |
| Error | 10 | 0.2106667 | 0.0210667 | | |
| Corrected Total | 14 | 0.4143333 | | | |

| R-Square | C.V. | Root MSE | DM Mean |
|---|---|---|---|
| 0.491553 | 0.154419 | 0.1451 | 93.993 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 4 | 0.2036667 | 0.0509167 | 2.42 | 0.1175 |

**Dependent Variable: FFA**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 6.5426667 | 1.6356667 | 0.57 | 0.6884 |
| Error | 10 | 28.5333333 | 2.8533333 | | |
| Corrected Total | 14 | 35.0760000 | | | |

| R-Square | C.V. | Root MSE | FFA Mean |
|---|---|---|---|
| 0.186528 | 55.56517 | 1.6892 | 3.0400 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 4 | 6.5426667 | 1.6356667 | 0.57 | 0.6884 |

**Dependent Variable: MOISTURE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 3890.6240 | 972.6560 | 122.69 | 0.0001 |
| Error | 10 | 79.2800 | 7.9280 | | |
| Corrected Total | 14 | 3969.9040 | | | |

| R-Square | C.V. | Root MSE | MOIS Mean |
|---|---|---|---|
| 0.980030 | 10.32137 | 2.8157 | 27.280 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 4 | 3890.6240 | 972.6560 | 122.69 | 0.0001 |

TABLE C20. Analysis of variance for the effects of weeks of harvest (from sixth to sixteenth week) on dry matter (g/100g db), free fatty acids (as percent oleic acid) and bean moisture percentage at harvest (%, wb) for soybean Leflore during the 1990 season.

---------------------------- **Cultivar=L** ----------------------------------

General Linear Models Procedure

**Dependent Variable: DM**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 6.9022848 | 0.6902285 | 1.76 | 0.1284 |
| Error | 22 | 8.6096667 | 0.3913485 | | |
| Corrected Total | 32 | 15.5119515 | | | |

| | R-Square | C.V. | Root MSE | | DM Mean |
|---|---|---|---|---|---|
| | 0.444966 | 0.666564 | 0.6256 | | 93.851 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 6.9022848 | 0.6902285 | 1.76 | 0.1284 |

**Dependent Variable: FFA**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 12 | 28.715758 | 2.392980 | 8.15 | 0.0001 |
| Error | 20 | 5.873939 | 0.293697 | | |
| Corrected Total | 32 | 34.589697 | | | |

| | R-Square | C.V. | Root MSE | | FFA Mean |
|---|---|---|---|---|---|
| | 0.830182 | 20.86810 | 0.5419 | | 2.5970 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 28.649697 | 2.864970 | 9.75 | 0.0001 |

**Dependent Variable: MOISTURE**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 10 | 1055.4939 | 105.5494 | 122.04 | 0.0001 |
| Error | 22 | 19.0267 | 0.8648 | | |
| Corrected Total | 32 | 1074.5206 | | | |

| | R-Square | C.V. | Root MSE | | MOIS Mean |
|---|---|---|---|---|---|
| | 0.982293 | 4.531092 | 0.9300 | | 20.524 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 10 | 1055.4939 | 105.5494 | 122.04 | 0.0001 |

TABLE C21. Analysis of variance for the effects of weeks of harvest and soybean cultivars (TN4-86, Essex, and Leflore) on the undamaged beans (%) and cracked beans (%) during the 1990 season.

**General Linear Models Procedure**

**Dependent Variable: UNDAMAGED BEANS**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 29 | 19802.667 | 682.851 | 138.10 | 0.0001 |
| Error | 24 | 118.667 | 4.944 | | |
| Corrected Total | 53 | 19921.333 | | | |
| | R-Square | C.V. | Root MSE | | UNDAMAGED Mean |
| | 0.994043 | 3.013930 | 2.2236 | | 73.778 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 21.333 | 10.667 | 2.16 | 0.1375 |
| WEEK | 5 | 13651.333 | 2730.267 | 552.19 | 0.0001 |
| REP*WEEK | 10 | 170.000 | 17.000 | 3.44 | 0.0064 |
| Cultivar | 2 | 2220.333 | 1110.167 | 224.53 | 0.0001 |
| WEEK*Cultivar | 10 | 3739.667 | 373.967 | 75.63 | 0.0001 |

**Tests of Hypotheses using the Type III MS for REP*WEEK as an error term**

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 5 | 13651.333 | 2730.267 | 160.60 | 0.0001 |

**Dependent Variable: CRACKED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 29 | 4580.6667 | 157.9540 | 55.21 | 0.0001 |
| Error | 24 | 68.6667 | 2.8611 | | |
| Corrected Total | 53 | 4649.3333 | | | |
| | R-Square | C.V. | Root MSE | | CRACKED Mean |
| | 0.985231 | 13.96636 | 1.6915 | | 12.111 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 6.7778 | 3.3889 | 1.18 | 0.3232 |
| WEEK | 5 | 2055.3333 | 411.0667 | 143.67 | 0.0001 |
| REP*WEEK | 10 | 56.5556 | 5.6556 | 1.98 | 0.0833 |
| Cultivar | 2 | 1772.3333 | 886.1667 | 309.73 | 0.0001 |
| WEEK*Cultivar | 10 | 689.6667 | 68.9667 | 24.10 | 0.0001 |

**Tests of Hypotheses using the Type III MS for REP*WEEK as an error term**

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 5 | 2055.3333 | 411.0667 | 72.68 | 0.0001 |

TABLE C22. Analysis of variance for the effects of weeks of harvest and soybean cultivars (TN4-86, Essex, and Leflore) on the wrinkled (%) and split (%) beans during the 1990 season.

**General Linear Models Procedure**

**Dependent Variable: WRINKLED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 29 | 825.50000 | 28.46552 | 9.58 | 0.0001 |
| Error | 24 | 71.33333 | 2.97222 | | |
| Corrected Total | 53 | 896.83333 | | | |

| | R-Square | C.V. | Root MSE | WRINKLED Mean |
|---|---|---|---|---|
| | 0.920461 | 30.72499 | 1.7240 | 5.6111 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| REP | 2 | 6.33333 | 3.16667 | 1.07 | 0.3603 |
| WEEK | 5 | 364.83333 | 72.96667 | 24.55 | 0.0001 |
| REP*WEEK | 10 | 26.33333 | 2.63333 | 0.89 | 0.5589 |
| Cultivar | 2 | 116.33333 | 58.16667 | 19.57 | 0.0001 |
| WEEK*Cultivar | 10 | 311.66667 | 31.16667 | 10.49 | 0.0001 |

**Tests of Hypotheses using the Type III MS for REP*WEEK as an error term**

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 5 | 364.83333 | 72.96667 | 27.71 | 0.0001 |

**Dependent Variable: SPLIT**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 29 | 274.00000 | 9.44828 | 17.01 | 0.0001 |
| Error | 24 | 13.33333 | 0.55556 | | |
| Corrected Total | 53 | 287.33333 | | | |

| | R-Square | C.V. | Root MSE | SPLIT Mean |
|---|---|---|---|---|
| | 0.953596 | 95.83148 | 0.7454 | 0.7778 |

| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
|---|---|---|---|---|---|
| REP | 2 | 0.77778 | 0.38889 | 0.70 | 0.5064 |
| WEEK | 5 | 67.33333 | 13.46667 | 24.24 | 0.0001 |
| REP*WEEK | 10 | 5.88889 | 0.58889 | 1.06 | 0.4278 |
| Cultivar | 2 | 65.33333 | 32.66667 | 58.80 | 0.0001 |
| WEEK*Cultivar | 10 | 134.66667 | 13.46667 | 24.24 | 0.0001 |

**Tests of Hypotheses using the Type III MS for REP*WEEK as an error term**

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| WEEK | 5 | 67.333333 | 13.466667 | 22.87 | 0.0001 |

TABLE C23. Analysis of variance for the effects of weeks of harvest and soybean cultivars (TN4-86, Essex, and Leflore) on the cracked-Wrinkled (%) and total damaged beans (%) during the 1990 season.

**General Linear Models Procedure**

**Dependent Variable: CRKWRKL**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 29 | 5626.1667 | 194.0057 | 76.75 | 0.0001 |
| Error | 24 | 60.6667 | 2.5278 | | |
| Corrected Total | 53 | 5686.8333 | | | |
| | R-Square | C.V. | Root MSE | | CRKWRKL Mean |
| | 0.989332 | 20.58862 | 1.5899 | | 7.7222 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 4.1111 | 2.0556 | 0.81 | 0.4553 |
| WEEK | 5 | 2966.8333 | 593.3667 | 234.74 | 0.0001 |
| REP*WEEK | 10 | 43.2222 | 4.3222 | 1.71 | 0.1362 |
| Cultivar | 2 | 794.3333 | 397.1667 | 157.12 | 0.0001 |
| WEEK*Cultivar | 10 | 1817.6667 | 181.7667 | 71.91 | 0.0001 |
| **Tests of Hypotheses using the Type III MS for REP*WEEK as an error term** | | | | | |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 5 | 2966.8333 | 593.3667 | 137.28 | 0.0001 |

**Dependent Variable: BAD**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 29 | 19802.667 | 682.851 | 138.10 | 0.0001 |
| Error | 24 | 118.667 | 4.944 | | |
| Corrected Total | 53 | 19921.333 | | | |
| | R-Square | C.V. | Root MSE | | BAD Mean |
| | 0.994043 | 8.479871 | 2.2236 | | 26.222 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 21.333 | 10.667 | 2.16 | 0.1375 |
| WEEK | 5 | 13651.333 | 2730.267 | 552.19 | 0.0001 |
| REP*WEEK | 10 | 170.000 | 17.000 | 3.44 | 0.0064 |
| Cultivar | 2 | 2220.333 | 1110.167 | 224.53 | 0.0001 |
| WEEK*Cultivar | 10 | 3739.667 | 373.967 | 75.63 | 0.0001 |
| **Tests of Hypotheses using the Type III MS for REP*WEEK as an error term** | | | | | |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| WEEK | 5 | 13651.333 | 2730.267 | 160.60 | 0.0001 |

TABLE C24. Analysis of variance for the effects of weeks of harvest on the undamaged (%), cracked (%) and wrinkled (%) beans for soybean TN4-86 during the 1990 season.

-----------------------------Cultivar=TN4-86-----------------------------

**General Linear Models Procedure**

**Dependent Variable: UNDAMAGED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 12358.333 | 1765.476 | 111.98 | 0.0001 |
| Error | 10 | 157.667 | 15.767 | | |
| Corrected Total | 17 | 12516.000 | | | |
| | R-Square | C.V. | Root MSE | | UNDAMAGED Mean |
| | 0.987403 | 5.699607 | 3.9707 | | 69.667 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 12.333 | 6.167 | 0.39 | 0.6862 |
| WEEK | 5 | 12346.000 | 2469.200 | 156.61 | 0.0001 |

**Dependent Variable: CRACKED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 577.00000 | 82.42857 | 26.59 | 0.0001 |
| Error | 10 | 31.00000 | 3.10000 | | |
| Corrected Total | 17 | 608.00000 | | | |
| | R-Square | C.V. | Root MSE | | CRACKED Mean |
| | 0.949013 | 24.00930 | 1.7607 | | 7.3333 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 9.00000 | 4.50000 | 1.45 | 0.2796 |
| WEEK | 5 | 568.00000 | 113.60000 | 36.65 | 0.0001 |

**Dependent Variable: WRINKLED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 206.33333 | 29.47619 | 5.93 | 0.0062 |
| Error | 10 | 49.66667 | 4.96667 | | |
| Corrected Total | 17 | 256.00000 | | | |
| | R-Square | C.V. | Root MSE | | WRINKLED Mean |
| | 0.805990 | 29.06872 | 2.2286 | | 7.6667 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 10.33333 | 5.16667 | 1.04 | 0.3887 |
| WEEK | 5 | 196.00000 | 39.20000 | 7.89 | 0.0030 |

TABLE C25. Analysis of variance for the effects of weeks of harvest on the split (%), cracked-wrinkled (%) and total damaged (%) beans for soybean TN4-86 during the 1990 season.

**---------------------------- Cultivar=TN4-86 ----------------------------**

**General Linear Models Procedure**

**Dependent Variable: SPLIT**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 204.33333 | 29.19048 | 16.52 | 0.0001 |
| Error | 10 | 17.66667 | 1.76667 | | |
| Corrected Total | 17 | 222.00000 | | | |
| | R-Square | C.V. | Root MSE | | SPLIT Mean |
| | 0.920420 | 56.96401 | 1.3292 | | 2.3333 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 2.33333 | 1.16667 | 0.66 | 0.5378 |
| WEEK | 5 | 202.00000 | 40.40000 | 22.87 | 0.0001 |

**Dependent Variable: CRKWRKL**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 3716.3333 | 530.9048 | 95.37 | 0.0001 |
| Error | 10 | 55.6667 | 5.5667 | | |
| Corrected Total | 17 | 3772.0000 | | | |
| | R-Square | C.V. | Root MSE | | CRKWRKL Mean |
| | 0.985242 | 18.14906 | 2.3594 | | 13.000 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 2.3333 | 1.1667 | 0.21 | 0.8144 |
| WEEK | 5 | 3714.0000 | 742.8000 | 133.44 | 0.0001 |

**Dependent Variable: BAD**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 12358.333 | 1765.476 | 111.98 | 0.0001 |
| Error | 10 | 157.667 | 15.767 | | |
| Corrected Total | 17 | 12516.000 | | | |
| | R-Square | C.V. | Root MSE | | BAD Mean |
| | 0.987403 | 13.09031 | 3.9707 | | 30.333 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 12.333 | 6.167 | 0.39 | 0.6862 |
| WEEK | 5 | 12346.000 | 2469.200 | 156.61 | 0.0001 |

TABLE C26. Analysis of variance for the effects of weeks of harvest on the undamaged (%), cracked (%) and wrinkled (%) beans for soybean Essex during the 1990 season.

**---------------------------Cultivar=ESSEX ------------------------------**

**General Linear Models Procedure**

**Dependent Variable: UNDAMAGED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 3701.5000 | 528.7857 | 122.97 | 0.0001 |
| Error | 10 | 43.0000 | 4.3000 | | |
| Corrected Total | 17 | 3744.5000 | | | |
| | R-Square | C.V. | Root MSE | | UNDAMAGED Mean |
| | 0.988516 | 3.012558 | 2.0736 | | 68.833 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| REP | 2 | 9.0000 | 4.5000 | 1.05 | 0.3867 |
| WEEK | 5 | 3692.5000 | 738.5000 | 171.74 | 0.0001 |

**Dependent Variable: CRACKED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 1786.8333 | 255.2619 | 44.27 | 0.0001 |
| Error | 10 | 57.6667 | 5.7667 | | |
| Corrected Total | 17 | 1844.5000 | | | |
| | R-Square | C.V. | Root MSE | | CRACKED Mean |
| | 0.968736 | 11.90771 | 2.4014 | | 20.167 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| REP | 2 | 2.3333 | 1.1667 | 0.20 | 0.8201 |
| WEEK | 5 | 1784.5000 | 356.9000 | 61.89 | 0.0001 |

**Dependent Variable: WRINKLED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 238.83333 | 34.11905 | 13.29 | 0.0002 |
| Error | 10 | 25.66667 | 2.56667 | | |
| Corrected Total | 17 | 264.50000 | | | |
| | R-Square | C.V. | Root MSE | | WRINKLED Mean |
| | 0.902962 | 33.14652 | 1.6021 | | 4.8333 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| REP | 2 | 2.33333 | 1.16667 | 0.45 | 0.6472 |
| WEEK | 5 | 236.50000 | 47.30000 | 18.43 | 0.0001 |

TABLE C27. Analysis of variance for the effects of weeks of harvest on the cracked-wrinkled (%) and total damaged (%) beans for soybean Essex during the 1990 season.

----------------------------**Cultivar=ESSEX** ----------------------------

**General Linear Models Procedure**

**Dependent Variable: CRKWRKL**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 708.50000 | 101.21429 | 36.15 | 0.0001 |
| Error | 10 | 28.00000 | 2.80000 | | |
| Corrected Total | 17 | 736.50000 | | | |
| | R-Square | C.V. | Root MSE | | CRKWRKL Mean |
| | 0.961982 | 27.13492 | 1.6733 | | 6.1667 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 4.00000 | 2.00000 | 0.71 | 0.5129 |
| WEEK | 5 | 704.50000 | 140.90000 | 50.32 | 0.0001 |

**Dependent Variable: BAD**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 3701.5000 | 528.7857 | 122.97 | 0.0001 |
| Error | 10 | 43.0000 | 4.3000 | | |
| Corrected Total | 17 | 3744.5000 | | | |
| | R-Square | C.V. | Root MSE | | BAD Mean |
| | 0.988516 | 6.653404 | 2.0736 | | 31.167 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 9.0000 | 4.5000 | 1.05 | 0.3867 |
| WEEK | 5 | 3692.5000 | 738.5000 | 171.74 | 0.0001 |

TABLE C28. Analysis of variance for the effects of weeks of harvest on the undamaged (%), cracked (%), wrinkled (%) beans for soybean Leflore during the 1990 season.

-------------------------- **Cultivar=LEFLORE** ---------------------------

**General Linear Models Procedure**

**Dependent Variable: UNDAMAGED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 1366.8333 | 195.2619 | 26.51 | 0.0001 |
| Error | 10 | 73.6667 | 7.3667 | | |
| Corrected Total | 17 | 1440.5000 | | | |
| | R-Square | C.V. | Root MSE | | UNDAMAGED Mean |
| | 0.948860 | 3.276652 | 2.7142 | | 82.833 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 14.3333 | 7.1667 | 0.97 | 0.4111 |
| WEEK | 5 | 1352.5000 | 270.5000 | 36.72 | 0.0001 |

**Dependent Variable: CRACKED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 396.50000 | 56.64286 | 20.23 | 0.0001 |
| Error | 10 | 28.00000 | 2.80000 | | |
| Corrected Total | 17 | 424.50000 | | | |
| | R-Square | C.V. | Root MSE | | CRACKED Mean |
| | 0.934040 | 18.94325 | 1.6733 | | 8.8333 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 4.00000 | 2.00000 | 0.71 | 0.5129 |
| WEEK | 5 | 392.50000 | 78.50000 | 28.04 | 0.0001 |

**Dependent Variable: WRINKLED**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 253.00000 | 36.14286 | 51.63 | 0.0001 |
| Error | 10 | 7.00000 | 0.70000 | | |
| Corrected Total | 17 | 260.00000 | | | |
| | R-Square | C.V. | Root MSE | | WRINKLED Mean |
| | 0.973077 | 19.30754 | 0.8367 | | 4.3333 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 9.00000 | 4.50000 | 6.43 | 0.0160 |
| WEEK | 5 | 244.00000 | 48.80000 | 69.71 | 0.0001 |

TABLE C29. Analysis of variance for the effects of weeks of harvest on the cracked-wrinkled (%) and total damaged (%) beans for soybean Leflore during the 1990 season.

**---------------------------Cultivar=LEFLORE---------------------------**

**General Linear Models Procedure**

**Dependent Variable: CRKWRKL**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 370.33333 | 52.90476 | 38.71 | 0.0001 |
| Error | 10 | 13.66667 | 1.36667 | | |
| Corrected Total | 17 | 384.00000 | | | |
| | R-Square | C.V. | Root MSE | | CRKWRKL Mean |
| | 0.964410 | 29.22613 | 1.1690 | | 4.0000 |
| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| REP | 2 | 4.33333 | 2.16667 | 1.59 | 0.2523 |
| WEEK | 5 | 366.00000 | 73.20000 | 53.56 | 0.0001 |

**Dependent Variable: BAD**

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 7 | 1366.8333 | 195.2619 | 26.51 | 0.0001 |
| Error | 10 | 73.6667 | 7.3667 | | |
| Corrected Total | 17 | 1440.5000 | | | |
| | R-Square | C.V. | Root MSE | | BAD Mean |
| | 0.948860 | 15.81064 | 2.7142 | | 17.167 |
| **Source** | **DF** | **Type III SS** | **Mean Square** | **F Value** | **Pr > F** |
| REP | 2 | 14.3333 | 7.1667 | 0.97 | 0.4111 |
| WEEK | 5 | 1352.5000 | 270.5000 | 36.72 | 0.0001 |

TABLE C30. Estimates of correlation coefficients of total oil (%, db) and free fatty acids (as percent oleic acid) with protein (%, db), bean moisture at harvest (%, wb) and weather components for soybeans TN4-86, Essex and Leflore over sixteen weeks of harvest during the 1989 season.

| | | TOTAL OIL (%) | | | FREE FATTY ACID[1] (%) | | |
|---|---|---|---|---|---|---|---|
| | | TN4-86 | Essex | Leflore | TN4-86 | Essex | Leflore |
| Protein | % | -0.11 | -0.15 | -0.35 | | | |
| Bean moisture | % | x | x | x | x | x | 0.56 |
| Avg Temp | °F | x | x | 0.42 | x | x | 0.41 |
| Max Temp | °F | x | x | 0.42 | x | x | x |
| Min Temp | °F | x | x | 0.40 | x | x | 0.44 |
| Avg RH | % | x | x | x | x | x | x |
| Max RH | % | x | x | 0.40 | x | x | x |
| Min RH | % | x | x | x | x | x | x |

x = Non-significant at 99% level and/or less than 0.30 except with protein.
1. = Free fatty acids.

TABLE C31. Estimates of correlation coefficients of bean moisture percentage at harvest (%, wb) with chemical components (%, db), physical damage parameters (%) and weather components for soybeans TN4-86, Essex and Leflore over sixteen weeks of harvest during the 1990 season.

| | BEAN MOISTURE PERCENTAGE AT HARVEST | | | | | |
|---|---|---|---|---|---|---|
| | Full sixteen weeks | | | From week 6 through 16 | | |
| | TN4-86 | Essex | Leflore | TN4-86 | Essex | Leflore |
| Weeks of harvest | 0.46 | x | x | 0.60 | 0.87 | x |
| Chemical components (%) | | | | | | |
| a. Carbohydrates | -0.59 | -0.57 | -0.60 | -0.68 | -0.80 | -0.57 |
| b. Protein | 0.48 | 0.53 | x | 0.54 | 0.76 | 0.43 |
| c. Ash | -0.37 | x | 0.55 | x | x | x |
| d. Total oil | x | x | 0.43 | x | 0.43 | x |
| e. Free fatty acid[1] | 0.66 | 0.86 | x | 0.70 | 0.87 | 0.65 |
| Physical damage parameters[2] (%) | | | | | | |
| a. Cracked beans | 0.46 | x | -0.41 | x | x | x |
| b. Wrinkled beans | x | 0.44 | x | x | x | x |
| c. Cracked-wrinkled beans[3] | x | 0.44 | x | x | x | x |
| d. Split beans | 0.54 | x | x | x | x | x |
| e. Total damaged beans[4] | | | | x | x | x |
| Weather components | | | | | | |
| a. Temperature (°F) | | | | | | |
| i. Average | -0.47 | x | 0.49 | x | x | x |
| ii. Minimum | -0.40 | x | 0.66 | x | x | x |
| iii. Maximum | x | x | x | -0.59 | -0.71 | -0.51 |
| iv. Maximum - Minimum | -0.57 | -0.63 | -0.39 | -0.58 | -0.81 | -0.84 |
| b. Relative humidity (%) | | | | | | |
| i. Average | 0.40 | 0.55 | 0.64 | 0.57 | 0.83 | 0.92 |
| ii. Minimum | 0.57 | 0.66 | 0.51 | 0.62 | 0.87 | 0.90 |
| iii. Maximum | x | x | x | x | x | x |
| iv. Maximum - Minimum | -0.58 | -0.64 | -0.46 | -0.61 | -0.86 | -0.86 |
| c. Cumulative rainfall (inches) | 0.54 | 0.40 | x | 0.66 | 0.83 | 0.46 |

x = Non-significant at 99% level and/or less than 0.30.
1 = Free fatty acid as percent oleic acid.
2 = Analysis was not done for the harvest period from week 6 through 16.
3 = Beans with both cracks and wrinkles.
4 = Sum of cracked, wrinkled, cracked-wrinkled, and split beans.

TABLE C32. Estimates of correlation coefficients of total oil (%, db), protein (%, db), carbohydrates (%, db) and free fatty acids (as percent oleic acid) with different weather components, for soybeans TN4-86, Essex and Leflore (from first to sixteenth week) during the 1990 season.

| WEATHER COMPONENTS | TOTAL OIL ESSEX | TOTAL OIL LEFLORE | TOTAL OIL TN4-86 | CRUDE PROTEIN ESSEX | CRUDE PROTEIN LEFLORE | CRUDE PROTEIN TN4-86 |
|---|---|---|---|---|---|---|
| Weeks | 0.42 | x | x | 0.31 | x | 0.64 |
| Protein % | -0.15 | -0.39 | -0.09 | -- | -- | -- |
| Carbohy % | -0.50 | x | -0.49 | -0.84 | -0.76 | -0.78 |
| FFA % | 0.47 | 0.44 | 0.31 | 0.66 | x | 0.64 |
| Avg Temp °F | -0.35 | x | x | x | x | -0.42 |
| Max Temp °F | -0.44 | x | x | x | x | -0.52 |
| Min Temp °F | x | 0.30 | x | x | x | -0.34 |
| Temp Diff °F | -0.41 | x | x | -0.58 | x | -0.41 |
| Avg RH % | x | x | x | 0.57 | 0.34 | 0.35 |
| Max RH % | -0.34 | -0.31 | -0.31 | x | x | -0.36 |
| Min RH % | 0.38 | x | x | 0.66 | x | 0.46 |
| RH Diff % | -0.40 | x | | -0.63 | x | -0.50 |
| Cumul Rain " | 0.49 | x | x | 0.40 | x | 0.68 |

| WEATHER COMPONENTS | CARBOHYDRATES ESSEX | CARBOHYDRATES LEFLORE | CARBOHYDRATES TN4-86 | FREE FATTY ACIDS ESSEX | FREE FATTY ACIDS LEFLORE | FREE FATTY ACIDS TN4-86 |
|---|---|---|---|---|---|---|
| FFA | x | x | -0.52 | -- | -- | -- |
| Avg Temp °F | x | x | 0.54 | -0.41 | 0.41 | -0.37 |
| Max Temp °F | 0.45 | x | 0.66 | -0.62 | x | -0.53 |
| Min Temp °F | x | -0.40 | 0.45 | x | 0.55 | x |
| Temp Diff °F | 0.69 | 0.37 | 0.46 | -0.79 | -0.32 | -0.62 |
| Avg RH % | -0.56 | -0.44 | x | 0.53 | 0.42 | 0.36 |
| Max RH % | 0.43 | x | 0.56 | -0.60 | x | -0.49 |
| Min RH % | -0.71 | -0.45 | -0.50 | 0.75 | 0.41 | 0.59 |
| RH Diff % | 0.72 | 0.44 | 0.56 | -0.80 | -0.39 | -0.64 |
| Cumul Rain " | -0.62 | x | -0.78 | 0.79 | x | 0.64 |

x = Either the correlation coefficient was non-significant at 99% level of significance and/or < 0.30.

explanation of abbreviations used in the above table:

Avg = Average.
Max = Maximum.
Min = Minimum.
Diff = Difference between maximum and minimum.
Temp (°F) = Temperature in Fahrenheit.
RH = Relative humidity.
Cumul Rain " = Cumulative rainfall in inches.
Carbohy = Carbohydrates.
FFA = Free fatty acid (as percent oleic acid).

TABLE 33. Estimates of correlation coefficients of total oil (%, db), protein (%, db), carbohydrates (%, db) and free fatty acids (as percent oleic acid) with different weather components, for soybeans TN4-86, Essex and Leflore (from sixth to sixteenth week) during the 1990 season.

| WEATHER COMPONENTS | TOTAL OIL ESSEX | TOTAL OIL LEFLORE | TOTAL OIL TN4-86 | CRUDE PROTEIN ESSEX | CRUDE PROTEIN LEFLORE | CRUDE PROTEIN TN4-86 |
|---|---|---|---|---|---|---|
| Weeks | x | x | x | 0.60 | x | 0.74 |
| Protein % | -0.11 | -0.44 | -0.09 | -- | -- | -- |
| Carbohy % | -0.46 | x | -0.51 | -0.90 | -0.77 | -0.77 |
| FFA % | 0.49 | x | x | 0.82 | x | 0.64 |
| Avg Temp °F | x | x | x | x | x | x |
| Max Temp °F | -0.42 | x | x | x | x | -0.49 |
| Min Temp °F | x | x | x | x | x | x |
| Temp Diff °F | -0.51 | x | x | -0.67 | -0.41 | -0.55 |
| Avg RH % | 0.56 | x | x | 0.71 | 0.48 | 0.63 |
| Max RH % | x | -0.55 | x | x | x | x |
| Min RH % | 0.53 | x | x | 0.75 | 0.50 | 0.62 |
| RH Diff % | -0.53 | x | | -0.74 | -0.47 | -0.61 |
| Cumul Rain * | 0.50 | 0.41 | x | 0.61 | x | 0.72 |

| WEATHER COMPONENTS | CARBOHYDRATES ESSEX | CARBOHYDRATES LEFLORE | CARBOHYDRATES TN4-86 | FREE FATTY ACIDS ESSEX | FREE FATTY ACIDS LEFLORE | FREE FATTY ACIDS TN4-86 |
|---|---|---|---|---|---|---|
| Weeks | -0.52 | x | -0.71 | 0.76 | 0.46 | 0.65 |
| FFA | -0.86 | -0.53 | -0.79 | -- | -- | -- |
| Avg Temp °F | x | x | x | x | x | x |
| Max Temp °F | 0.45 | x | 0.54 | -0.56 | -0.43 | -0.46 |
| Min Temp °F | x | -0.40 | x | x | x | x |
| Temp Diff °F | 0.69 | 0.37 | 0.68 | -0.87 | -0.60 | -0.75 |
| Avg RH % | -0.56 | -0.44 | -0.68 | 0.89 | 0.43 | 0.63 |
| Max RH % | 0.43 | x | x | -0.54 | x | -0.42 |
| Min RH % | -0.71 | -0.45 | -0.75 | 0.92 | 0.62 | 0.73 |
| RH Diff % | 0.72 | 0.44 | 0.75 | -0.91 | -0.64 | -0.73 |
| Cumul Rain * | -0.62 | x | -0.77 | 0.77 | 0.48 | 0.61 |

x = Either the correlation coefficient was non-significant at 99% level of significance and/or < 0.30.

Explanation of abbreviations used in the above table:

Avg = Average.
Max = Maximum.
Min = Minimum.
Diff = Difference between maximum and minimum.
Temp (°F) = Temperature in Fahrenheit.
RH = Relative humidity.
Cumul Rain * = Cumulative rainfall in inches.
Carbohy = Carbohydrates.
FFA = Free fatty acid (as percent oleic acid).

TABLE C34. Estimates of correlation coefficients of physical damage parameters (%) with weeks of harvest, total oil (%, db), protein (%, db) and weather components over sixteen weeks of harvest for soybeans TN4-86, Essex and Leflore for the 1990 season.

| Weather Components | Good Beans | Crack Beans | Wrinkle Beans | Split Beans | Crack-Wrinkle | Bad Beans |
|---|---|---|---|---|---|---|
| | | | Cultivar TN4-86 | | | |
| Weeks | -0.89 | 0.79 | 0.85 | 0.81 | 0.88 | 0.89 |
| Total oil % | x | x | x | x | x | x |
| Protein % | x | x | x | x | x | x |
| Avg Temp °F | 0.73 | -0.63 | -0.75 | -0.65 | -0.73 | -0.73 |
| Max Temp °F | 0.87 | -0.77 | -0.83 | -0.77 | -0.88 | -0.87 |
| Min Temp °F | 0.64 | -0.54 | -0.70 | -0.56 | -0.64 | -0.64 |
| Temp Diff°F | x | x | x | x | x | x |
| AvgRH % | x | x | x | x | x | x |
| MaxRH % | 0.87 | -0.76 | -0.83 | -0.77 | -0.88 | -0.87 |
| MinRH % | x | x | x | x | x | x |
| RH Diff % | x | x | x | x | x | x |
| Cumul Rain* | -0.92 | 0.82 | 0.82 | 0.83 | 0.93 | 0.92 |
| | | | Cultivar ESSEX | | | |
| Week | -0.96 | 0.73 | 0.47 | x | 0.72 | 0.96 |
| Total oil % | -0.53 | 0.42 | x | x | 0.49 | 0.53 |
| Protein % | -0.44 | x | x | x | 0.56 | 0.44 |
| Avg Temp °F | 0.89 | -0.76 | -0.47 | x | -0.53 | -0.89 |
| Max Temp °F | 0.94 | -0.84 | x | x | -0.57 | -0.94 |
| Min Temp °F | 0.68 | -0.47 | -0.51 | x | -0.48 | -0.68 |
| Temp diff°F | 0.69 | -0.71 | x | x | x | -0.69 |
| Avg RH % | x | x | x | x | x | x |
| Max RH % | 0.86 | -0.83 | x | x | -0.53 | -0.86 |
| Min RH % | -0.66 | 0.67 | x | x | x | 0.66 |
| RH Diff % | 0.71 | -0.72 | x | x | x | -0.71 |
| Cumul Rain* | -0.93 | 0.87 | x | x | 0.54 | 0.93 |
| | | | Cultivar LEFLORE | | | |
| Week | -0.73 | 0.61 | x | x | 0.59 | 0.73 |
| Total oil % | x | x | x | x | x | x |
| Protein % | x | x | x | x | x | x |
| Avg Temp °F | 0.59 | -0.51 | x | x | -0.60 | -0.59 |
| Max Temp °F | 0.79 | -0.70 | x | x | -0.59 | -0.79 |
| Min Temp °F | x | x | x | x | -0.49 | x |
| Temp Diff°F | 0.71 | -0.68 | x | x | x | -0.71 |
| Avg RH % | x | x | x | x | x | x |
| Max RH % | 0.80 | -0.76 | x | x | -0.82 | -0.80 |
| Min RH % | -0.59 | 0.57 | 0.46 | x | x | 0.58 |
| RH Diff % | 0.70 | -0.68 | x | x | x | -0.70 |
| Cumul Rain* | -0.78 | 0.73 | x | x | 0.72 | 0.78 |

x = Either the correlation coefficient was non-significant at 99% level of significance and/or < 0.30.

Explanation of abbreviations in the above table:

Avg = Average.
Max = Maximum.
Min = Minimum.
Diff = Difference between maximum and minimum.
Temp (°F) = Temperature in Fahrenheit.
RH = Relative humidity.
Cumul Rain * = Cumulative rainfall in inches

# VITA

Harjeet Singh Sidhu was born on April 22, 1951, at Bathinda (Punjab), India. He received his Bachelor of Science degree in Agriculture in March, 1973, from Punjab Agricultural University, Ludhiana, India. He received his Master of Science degree in Horticulture and graduated second in the class from Agra University, Agra, India. He received his Master of Philosophy degree (post M.S. and pre Ph.D. Advanced Training) in Horticulture, received a merit scholarship and graduated first in the class from Meerut University, Meerut, India.

He served as a Lecturer in Horticulture at Khalsa College, Amritsar, India for two academic years from 1982 to 1984. He moved to United States of America in February, 1984 and lived at Virginia Beach, Virginia.

In May 1989, he started his graduate studies in the Department of Agricultural Engineering of the University of Tennessee, Knoxville. He became United States Citizen in March, 1990 and became a Graduate Research Assistant in May, 1990. He is a member of Gamma Sigma Delta, the Honor Society of Agriculture, American Society of Agricultural Engineers and Institute of Food Technologists. He plans to receive the Master of Science degree with a major in Agricultural Engineering Technology and minor in Food Science and Technology in December, 1992.

He has been accepted in Ph.D. program in Food Science and

Technology Department of the University of Tennessee, Knoxville, and has also been awarded a graduate research Assistantship.

He is married to the former Prabhjot Kaur Mann. They have a son Harmanjeet, 11 and a daughter Harmaneek, 5.