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ROOT RATING - CORN YIELD INTERACTIONS

BY

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ROOT RATING - CORN YIELD INTERACTIONS

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

The northern corn rootworm, Diabrotica longicornis barberi Smith and Lawrence (NCR) and the western corn rootworm D. virgifera virgifera LeConte (WCR) are the two species of rootworms of economic importance in South Dakota corn fields. NCRs infest both first year corn fields and continuous corn whereas WCRs generally infest continuous corn fields. Damage can occur from larval feeding on roots which inhibits nutrient and moisture uptake, increases propensity for lodging or by adult feeding on silks which causes losses in pollination and seed set.

Adult emergence begins in early July and continues until early September. Female rootworm adults mate and then lay eggs in cracks in the soil. Rootworms overwinter as eggs in the soil with egg hatch occurring in June and continuing until early July. The larval stage of the rootworm feeds on corn roots until pupation occurs in August. One generation of rootworms per year occurs in South Dakota.

Control of rootworms is attempted through application of granular insecticides at planting and crop rotation. Yield increases from the use of insecticides was first shown by Cox and Lilly (1953). Resistance to insecticides was first noted in Nebraska and recorded by Ball and Weekman (1962). Crop rotation is the first recommendation by extension entomologists in the North Central Region (Walgenbach, 1985).

Root ratings developed in 1971 by Hills and Peters are the standard for checking insecticide efficacy. Using this rating system and pooled agronomic and edaphic factors, Turpin et al. (1972) determined a rating of 2.5 as the economic injury level.

No investigations have been published that correlate root ratings to yields on an individual plant or field basis. With this in mind, the objectives of my research were three fold. The first objective was to assess corn root damage by Diabrotica larvae and their relationship to corn yield losses; secondly, to determine if correlations exist between corn root damage ratings and yields; and third to potentially serve as an insight for establishing a method of damage rating that will provide a positive correlation between root ratings and yields on a field basis.

LITERATURE REVIEW

Three species of corn rootworm occur in South Dakota. They include the northern corn rootworm, *Diabrotica longicornis barberi* Smith and Lawrence (NCR); the western corn rootworm, *D. virgifera virgifera* LeConte (WCR); and the southern corn rootworm, *D. undecimpunctata howardi* Barber (SCR). Only the NCR and WCR are economic pests of corn in South Dakota and their population dynamics are closely related to the continuous corn acreage. The NCR has also been shown to cause first year damage to corn following small grains and flax.

The NCR adult is pale green to yellow and about 0.64 cm long. The NCR was first recorded in Colorado in 1824 (Chiang 1973) and has been a pest for the last 100 years. The NCR expanded its range eastward from Illinois and was found in Indiana by 1885 (Webster 1908). The NCR's westward expansion is not well documented. The NCR was first recorded as being injurious to corn by Charles Riley in 1880 (Hill et al. 1948). There is no record of when the NCR first entered or damaged corn in South Dakota but was the dominant rootworm in South Dakota until 1961 (Kantack 1965).

The WCR adult is pale, yellowgreen with black stripes on its back and about 0.64 cm long. The WCR was described in Colorado in 1909 (Fitzgerald and Ortman 1964). Damage to corn was reported in Colorado in 1909 (Gillette 1912); in Nebraska in 1929 (Tate and Bare 1946) and in Kansas in 1945 (Bryson et al. 1953).

WCRs were first collected in South Dakota in Jones County in 1922 and Butte County in 1930 (Kantack 1965). From 1955 to 1970 the WCR expanded its range to include Ohio and other areas growing continuous corn. Significant rootworm damage was not reported for the WCR until 1955 when chlorinated hydrocarbon resistance developed (Chiang 1973).

In Nebraska, adult emergence occurs in mid-summer as indicated by Pruess et al. (1974). Ninety percent of the WCR adults had emerged from July 29 to August 6. In South Dakota, adults began emerging in early July and continued until early September (Kantack et al. 1975). NCR emergence was observed to start August 1 with a peak period of August 15 and then declining until completion on September 10 (Howe et al. 1963). Holm (1976) observed initial WCR emergence on July 8 in 1975.

Male WCR emergence peaked before female emergence in caged studies (Chiang 1973). Hill (1975) in laboratory observations found that no female WCRs mated more than once but that males may mate several times. Branson et al. (1977) observed that adult male WCRs mated an average of 8.2 times during their mean lifetime of 41.6 days. They observed that WCR females may mate more than once but not when they were actively laying eggs.

Hill (1975) noted that field collected WCR females lived an average of 78.2 days and had an average reproductive period of 76.4 days in the laboratory. In this study, WCR females laid an average of 1023 eggs with 51.2 eggs laid during the first five days of oviposition and 245 eggs laid by the 10th day. The rate decreased to 65 eggs during the last 10 days of oviposition. Some WCR females will lay eggs until death while others cease oviposition three weeks before they die (Branson and Johnson 1973).

Forbes (1883) observed that NCR females laid their eggs in clusters of 3 to 10 in the top 2.54 cm of soil but could be found as deep as 15.24 cm. Sisson and Chiang (1964) observed NCR eggs laid at the base of corn plants and also noticed that the greatest concentrations of eggs were on the side the corn was leaning in lodged fields. Patel and Apple (1967) found NCR eggs in the corn rows next to the base of the corn plants. They observed 92.8% of the NCR eggs in the top 15.24 cm of soil but this level is dependent upon the depth of drought cracks, and that egg numbers decreased 10.16, 20.32 and 25.40 cm from the base of the plant. Foster et al. (1979) also observed that the depth NCR eggs were found was dependent upon the depth of the drought cracks.

WCR females lay their eggs in cracks in the soil and the eggs are commonly found among the brace roots of the corn plant (Webster 1913). Ball (1957) observed that 80% of the WCR eggs were laid in the top 15.24 cm, 58% in the top 10.16 cm and 23% in the top 5.08 cm of soil. Kirk et al. (1968) found that WCRs prefer to lay their eggs on soil particles 1 mm in size or larger and that they also prefer clumps of foxtail over cornstalks and surface trash as oviposition sites: WCR females laying eggs in a moist soil have a 9.3 times better chance of egg survival than those in dry soils (Kirk et al. 1968).

Forbes (1883) found that adult WCRs leave the corn fields when food becomes scarce. He noticed that they fed on volunteer oats and then proceeded to lay eggs in the oats. He determined that the concentration of rootworms in the adjacent cornfield would have to be quite high for this to occur. Webster (1913) observed the same situation in corn following clover. Tate and Bare (1946) observed that volunteer corn in small grain stubble is a suitable oviposition site for the NCR, especially if the corn is present during August and September. Later maturing cornfields have a better chance as oviposition sites (Howe et al. 1963). Brooks (1967) observed that when food becomes scarce in corn fields, rootworms will begin dispersing and will feed on other crops in bloom. Hedrick (1978) found more adults in stubble fields that contained weeds 20 cm or taller than in weeds 20 cm or shorter. Vassalotti (1982) found that NCRs were the primary rootworm species found infesting corn following soybeans and small grain in South Dakota.

A threshold temperature of 11°C for egg development of the NCR was reported by Chiang and Sisson (1968). They also found that first hatch occurred 400 degree days above 11°C. Apple et al. (1971) in Wisconsin and Wilde (1971) in Kansas were able to show similar results. Fifty percent of the eggs from South Dakota and Minnesota require fewer days for hatch than do eggs from Iowa, Kansas, Missouri and Nebraska (Wilde et al. 1972).

The hatching of WCR eggs depends partially upon the intensity of their diapause (Krysan and Branson 1977). Beck (1968) defined diapause as a genetically determined state of suppressed development. This dormant state is characterized by a temporary cessation of growth and diapause enhances the organisms resistance of adverse climatic conditions.

There are two theories on the termination of diapause. Ball (1957), Howe and George (1966), Wilde (1971), Wilde et al. (1972) and Chiang (1973) reported that diapause could artificially be broken or terminated by subjecting the eggs to a chill period. Krysan (1972), Branson et al. (1975), Krysan et al. (1977) and Branson (1976) feel that chilling only synchronized hatch and has no influence on diapause.

Patel and Apple (1967) found that 21.4% of NCR eggs did not enter diapause. Chiang (1965) determined that NCR eggs can survive two winters without hatching. He observed that even though the eggs received enough heat units the first year to hatch, eggs at depths in the soil of 10.16-20.32 cm may not hatch until the second year.

Temperature, moisture, and tillage practices are all interrelated in affecting the survival of eggs. Matteson et al. (1972) indicated that soil manipulations can cause physical damage. It could also expose the eggs to adverse conditions near the surface. Chiang (1965) found that NCR eggs located near the surface had a 10% less chance for survival than those deeper in the soil. Patel and Apple (1967) noted that if temperatures reach -2^{o}C or below for two weeks, NCR survival is reduced. George in 1972 as stated by Chiang (1973) observed that mortality of WCR eggs after exposure to -10°C for one week was 50%, and no hatching occurred after exposure to -15°C or lower. Mihm et al. (1974) observed that contact moisture was important for egg hatch and that as humidity decreased so did egg survival. Gustin (1980) determined that in laboratory tests, WCR egg hatch declined significantly at -7.5°C and -10°C over a period of four weeks. Gustin also stated that the soil habitat in eastern South Dakota insulates the WCR eggs from warm spells and allows post diapause development to be inhibited until spring.

George and Hintz (1966) found three instars during the larval period of the rootworm. The average length of the WCR larvae were 1.50, 3.73 and 7.12 mm for the first, second and third instars respectively. They also determined the average head capsule lengths and widths to be 250 by 200 mm for first instars, 325 by 325 mm for second instars and 550 mm by 500 mm for the third instar larvae.

Kuhlman et al. (1970) determined that a positive correlation existed between temperature, growth and development. At 15.6°C larvae reached maturity in 70.8 days; at 22.2°C the average duration was 38.2 days; and at 29.4°C the average was 26.6 days as an immature.

Corn roots are the major food source of the WCR larvae but Branson and Ortman (1967A) showed that in laboratory studies there were several alternate hosts for WCR larvae. They found that WCR larvae could survive at least ten days on nine different grass species. Branson and Ortman (1967B) determined that certain plants could sustain the WCR from larvae to adult and that the adults could still produce viable eggs without reducing fertility. These plants included green and yellow foxtail, Minter and Selkirk wheat, Omugi barley and Oahe intermediate wheatgrass as well as corn. Branson and Ortman (1970) later found that there are at least 18 plants that larvae can survive on and that at least 13 of those 18 can be used to complete the WCR life cycle. No investigations were conducted in the field to determine the impact of these species under natural conditions.

Bryson et al. (1953) determined that WCR larvae feed from mid June until late July on corn roots in the field. Turpin and Peters (1971) found that larvae will move from sandy to clay soils but not from clay to sandy soils. When WCR larvae were placed in petri dishes containing sand and clay soils, 50% of the larvae migrated to the clay from the sandy soils but only 8% migrated from the clay to the sandy soils. Using data from Kuhlman et al. (1970) and George and Hintz (1966), Chiang (1973) devised a temperature-duration regression. These regressions showed that younger instars are more sensitive, with a higher temperature coefficient than older instars. He surmised that this is due to the young larvae normally being exposed to lower temperatures.

Food uptake increases as the larvae mature. They first bore into the cortical parenchyma (Chiang 1973). Once the cortex of the root develops a tough exodermis, Apple and Patel (1963) determined that the larvae move toward the new areas of root growth. Short and Luedtke (1970) observed that larvae can migrate up to 81.3 cm in the soil to obtain food. They also determined that as the distance from the food source increased from 81.3 to 203.2 cm adult emergence and root damage decreased.

Sechriest (1969) and Short (1970) stated that the greatest concentrations of larvae in the fields are found in the areas that had corn the previous season. Sechriest (1969) found that 98% of the rootworm larvae were found within 10.16 cm of the base of the corn stalk and 90% were in the upper 10.16 cm of soil. Chiang et al. (1971) determined that corn plants midway between the old rows in minimum tillage fields reduced larval damage.

Chiang (1973) found that pupal sampling is difficult because it is a very fragile stage and of short duration. He also showed that pupation occurred in the soil as far as 63.5 cm away from the main roots and as deep as 22.86 cm. Sechriest (1969) observed 98% of the pupae 10.16 cm from the plant and 90% 10.16 cm deep in the soil.

Damage to the corn plant can occur by larval feeding on roots or adult silk and leaf feeding. Larval feeding on the roots inhibits the uptake of nutrients and water by the plant. Apple and Patel (1963) observed that the majority of the feeding occurs on whorls 3-7 with the worst damage occurring on whorls

4, 5, and 6. Of those plants that had severe feeding on whorls 4, 5 and 6, 68.7% had severe lodging.

Adult corn rootworms are primarily pollen feeders but also feed on earsilks and leaves of the corn plant. Silk feeding could reduce yield only if feeding occurs during the green silk stage (Anonymous 1970). Chiang (1973) stated that adult feeding is important by preventing pollination or causing kernel damage. Turpin and Leva (1984) determined that adult silk feeding caused yield reduction when silks were shortened to within 1.27 cm of the plant or less and if 5 or more adults were present on this ear.

Control practices include crop rotation and insecticides applied at planting to control the larvae of the corn rootworm. Muma et al. (1949) showed that benzene hexachloride applied in the spring would control the WCR for two generations. Cox and Lilly (1953) tested aldrin, gamma benzene hexachloride, chlordane and dieldrin for rootworm control. They found that these chemicals reduced lodging 90-100 percent as well as increasing yields 13.68 quintals per hectare.

WCR resistance to chlorinated hydrocarbon insecticides was first reported by Ball and Weekman (1962) to have occurred in Nebraska during the late 1950's. They showed that adult WCRs obtained from irrigated continuous corn fields were 100 times more tolerant to aldrin and heptachlor than those from non-continuous corn. Hamilton (1965) showed that aldrin resistance by adult rootworms had developed in Iowa, Kansas, Missouri, Minnesota and

South Dakota. He noted that the LD_{50} levels for adults decreased significantly at each location from adults collected early to adults collected later in the season.

Ball (1973) evaluated WCR adults for diazinon and phorate resistance. He found an increase in the LD_{50} level to the chemicals but the results were statistically insignificant with a slight reversion in susceptibility to diazinon being observed. Walgenbach and Sutter (1977) used organophosphates and carbamates in field studies for LD_{50} tests and showed that early hatching WCR larvae were more resistant than late hatching WCR larvae. They also had circumstantial field evidence that resistance to bufencarb occurred in fields where used 3-5 years. Kuhlman and Wedburg (1977) observed carbofuran failure in four of 11 fields with two or more years of consecutive use. Kuhlman (1978) stated that two years of other chemicals or a rotation of crops would be needed before going back to carbofuran. Kantack (1974) stated that a rotation of carbamates and organophosphates was needed for rootworm control.

Research has been done on timing, method of applying and emergency applications of insecticides. Hill et al. (1948) observed that post planting applications were better than at planting applications in 1947. Hills and Peters (1972) in 1968 and 1969 applied bufencarb, fonofos, phorate, diazinon, carbofuran and fensulfothion at planting and at three post planting dates. They showed that diazinon at the last post planting application performed better than diazinon applied at planting. Hills and

Peters (1972) stated that using less than the recommended amount of insecticide resulted in a significant decrease in the amount of control. They observed that using liquid insecticide formulations with fertilizers gave good control but that granular formulations whether broadcasted, banded or applied post-planting also gave good control.

Mayo (1976) observed that emergency insecticide treatments may be economically beneficial but that the damage and yield reduction may have already occurred. He observed that in dryland plots the untreated area yielded 11.6 quintals per hectare and that fensulfothion and diazinon treated plots yielded less than the untreated plots. Walgenbach and Sutter (1977) stated that weather, cultural operations and planting dates may influence rootworm susceptibility to insecticides. They noticed an increase in tolerance by WCR larvae from several locations to carbofuran and these buildups were consistent with individual chemical failures in those fields.

Enhanced microbial degradation of pesticides in the soil has caused problems in corn rootworm control. Kaufman et al. (1981) and Kaufman and Edwards (1983) showed that carbofuran degraded at a 40% higher rate in carbofuran history soils than in nonhistory soils. In the first ten days of soil incubation, the carbofuran history soil reached 80% degradation while the nonhistory soil reached 5% degradation. They showed that active microbial populations in the soil were responsible for the chemical breakdown.

Other methods of corn rootworm control have been attempted. Forbes (1894) stated that certain fertilizers such as potash salts may kill larvae in the soil while Hill et al. (1948) found that nitrogen fertilizers didn't affect rootworm populations but increased root regrowth. Weekman (1965) suggested that fertilizer-insecticide combinations gave adequate control. Apple (1968) stated that to make the fertilizer-insecticide combinations work they had to be placed on both sides of the corn row.

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Genetic resistance by the plant has also been attempted. Lonnquist and Kisselbach (1948) determined that there were two types of heritable resistance. The first type is root regrowth after injury; the second is antibiosis or the substance within the plant tissue that causes rootworm mortality. Antibiosis has not been found to be a major factor in corn resistance. Fitzgerald and Ortman (1964) found four factors involved in resistance, (a) possession of a strong, well developed root system; (b) plants ability to regenerate roots; (c) the time of insect attack in relation to the stage of plant development; and (d) the environmental conditions, especially moisture supply and soil fertility. Fitzgerald and Ortman concluded that immunity to larval attack and protection under heavy infestations were not likely. Resistant varieties have not been developed.

Several tillage practices were evaluated on their influence on rootworm populations by Graham and Tate (1944). They observed that rootworm damage was less in fall disked or tilled fields than it was in spring disked or tilled fields. They reasoned that the fall tillage breaks soil into clumps which exposes more soil surface and lowers the soil temperature. Calkins and Kirk (1969) determined that if winter precipitation was plentiful then fall or spring plowing doesn't afford significant changes in rootworm control. They also stated that spring plowing was better for rootworm control when there was less snow cover. This may be due to soil texture more than clumping of the soil. They reasoned that light soils crumble after plowing and plowing moves the eggs to greater depths.

Calkins et al. (1970) tried early cutting of corn for silage as a method of rootworm control. They observed that corn cut before September 1 caused rootworm populations the next year to be below economic levels and thus not have to apply chemicals. Holm (1976) showed that in South Dakota fields an earlier cutting date of August 13 would give rootworm numbers below economic levels the next season.

Hill and Mayo (1974) used trap cropping as a method of controlling rootworms. They planted small areas of corn adjacent to larger corn fields. They found that later planted small areas would attract female beetles for feeding and oviposition and thus reduce the area needed for insecticide application.

Ortman et al. (1968) attempted to devise a method of evaluating root damage by using the pounds of pull required to remove the corn plant from the soil. They determined that variations in the amount of pull required could be due to soil moisture, soil type, time of sampling and root damage.

Musick and Fairchild (1968) developed a root rating system in which the plants were pulled and the damage on different nodes assessed to determine insecticide efficacy. After removing the soil from the roots they rated the root system on a 1-6 scale. A rating of one indicated no damage while a rating of six indicated at least one node of roots chewed to the base of the corn plant. The same plant was rated again using the first and second nodes of roots below the soil surface. These nodes of roots were rated on a 1-5 scale indicating (1) no pruning damage; (2) 0-25% pruning damage; (3) 26-50% pruning damage; (4) 51-75% pruning damage and (5) 76-100% pruning damage. They then combined the two ratings from each plant and came up with an overall rating.

Apple et al. (1977) used a 1-9 root damage rating scale to determine insecticide efficacy. Insecticides used today are rated on a damage scale developed by Hills and Peters (1971). Turpin et al. (1972) determined from pooled edaphic and agronomic characteristics for 526 Iowa corn fields that the economics threshold level for rootworm damage was 2.5. They stated that for each increase of 1.0 in the damage rating, a 6.28 quintal per hectare yield reduction occurred. The data did not take into consideration factors such as the amount of nitrogen available to the plant, weed control and farming practices. Yield root rating analysis was not conducted for each field.

Hill et al. (1948) observed a decrease in the amount of damage to corn when .44 or 1.78 kg of lindane per hectare was applied in preplow broadcast sprays. In a 10 year survey of continuous cornfields in Iowa, Peters (1975) determined that aldrin and heptachlor treatments increased yields 5 quintals per hectare over untreated fields. Apple (1971) showed that carbofuran could reduce the number of NCR larvae from 19.1 to 1.5 per root mass while increasing yield from 63.3 to 73.0 quintals per hectare. Petty et al. (1969) showed an average increase of 1.88 quintals per hectare in treated corn over untreated corn. Owens et al. (1974) found that when testing terbufos, fonofos, ethoprop, phorate, carbofuran, fensulfothion, trimethocarb and bufencarb against the untreated areas, the benefit of treatment was an increase of 1.57 to 5.71 quintals per hectare. Smith (1979) observed that untreated plots averaged 6.3 larvae per plant and had yield reductions of 0.7 tons per hectare while treated plots had 2.9 larvae per plant and yield increases of 14.2% over the untreated plots.

Chiang et al. (1980) found that 600-1200 WCR eggs per plant caused no yield reduction compared to untreated areas in artifically infested plots, however, 2400 eggs per plant averaged a 44.9% reduction in yield. WCR adult emergence was 6.52%, 4.92% and 2.27% in the 600, 1200 and 2400 eggs per plant treatments respectively. No root ratings were taken but they reasoned that heavy feeding pressure caused some larvae to die because of lack of food.

Sutter et al. (1981) showed that artifical infestations of 100, 300, 600, 1200 and 2400 eggs per plant caused a significant reduction in yield. They also showed that a positive correlation existed between high egg numbers and the amount of root damage but there was no significant difference in yield.

Rogers et al. (1976) tested 64 unselected hybrids and observed that rootworm feeding depressed yields in untreated plots by 2.73 quintals per hectare and all hybrids sustained the same yield reduction from rootworm feeding. Matteson et al. (1972) observed that increasing the amount of tillage accounted for an increase in corn height but did not give significant differences in yields or number of larvae present.

MATERIALS AND METHODS

In 1982 six plots were established on farmer cooperative fields that showed evidence of larval rootworm feeding damage during July and August. Two plots were located near Fairview, South Dakota on the Arlyn and Dave Olsen farms; one plot near Alcester, South Dakota on the Verlyn Lapour farm; near Sinai, South Dakota on the Glen Langum farm; near Onida, South Dakota on the John West farm; and one plot at the Southeast Experiment Station near Beresford, South Dakota. All plots were dryland corn fields except the West location and all were insecticide failure fields except for West field which was untreated for rootworms and the Southeast Experiment Station plot which was an insecticide evaluation plot.

Evaluation areas were established after the corn had reached physiological maturity and rootworm damage was evident. Soil classifications varied by location but all soils were fine silty, mixed mesic soils except Lapour which was fine silty, mixed calcareous mesic soil. Plot dimensions were limited to 10 corn rows by 61 meters. Location of the plots in the fields varied by location but all plots were at least 91 meters from any field borders or end rows. Corn plants were chosen randomly within the plot area with all plants the same approximate size and height. Only plants not showing damage by corn borer were selected and one half of the plants dug were standing erect, half were lodged at 45^{o} or more. The plants were tagged prior to digging, the ear removed, bagged and marked with a corresponding number. The number of plants evaluated varied by location. An attempt was made to obtain twenty plants that would meet the criteria for each root rating in the scale developed by Hills and Peters (1971). If this wasn't accomplished on the initial digging, the field was reentered and more plants were evaluated until 20 plants in each category were obtained.

The corn roots were washed under high pressure and then rated using the one to six rating scale developed by Hills and Peters (1971). The rating scale is:

1. no noticable or minor feeding damage.
2. feeding scars present, but no root pruning *
3. at least one root pruned, but less than an entire node of roots pruned.
4. one full node or equivalent of roots pruned.
5. two full nodes or equivalent of roots pruned.
6. three or more nodes or equivalent of roots pruned.

* to qualify as a root pruned, the root must be chewed off to within 3.81 cm of the base of the plant.

The corn was dried to 15.5 percent moisture, shelled and the grain from each ear weighed. Corn hybrids varied by location because of farmer preference. The root ratings and corresponding grain weights were then analyzed by computer using discriminatory analysis (Fryar 1966) and Least Square Means at the .10 probability level. This analysis was conducted because of uneven sampling sizes across the ratings.

Soil samples were taken from 0-15.24 cm depth and from the 15.24 to 60.96 cm depth using a 2.54 cm diameter core sampler and soil sampling methods recommended by the Soil Testing Laboratory at South Dakota State University. Ten samples from each location were taken, composited and the samples analyzed by the Soil Testing Laboratory at South Dakota State University. The 0-15.24 cm samples were tested for nitrogen, phosphorus and potassium content, pH and organic matter content while the 15.24-60 cm samples were analyzed for nitrate nitrogen levels. Climatological data was obtained from the Water Resources Institute at South Dakota State University for each location.

In 1983, four plots were established. All locations were insecticide evaluation plots and three locations were the same as the previous year. These locations were John West, Dave Olsen and the Southeast Experiment Station. An additional plot was established near Pierre, South Dakota on the Paul Bonhorst farm. Soil at this location is a fine montmorillonitic mesic soil. The same information and procedures were used as in 1982, the only difference being that the same corn hybrid was planted at each location and 500 plants were dug per plot to help assure an adequate number of plants in each root rating.

In 1984, two locations were used; John West and Verlyn Lapour. Information, climatological data and procedures were the same as 1983 with 500 plants dug per plot.

Table 1. 1982 Field, Climatological and Soil Information.

	Arlyn Olson	Dave Olsen
Location	Fairview, SD	Fairview, SD
Hybrid	Dekalb XL32A	Dekalb XL55A
Hybrid Maturity	104 days	108 days
Planted	5/7/82	5/8/82
Fertilizer		
kg N/ha	78.4 granular	78.4 granular
kg P/ha	33.6 granular	33.6 granular
kg K/ha	56.0 granular	56.0 granular
Herbicide	None	metolachlor 2.24 kg Ai/ha
Manure	2.24 metric tons/ha disced in	2.24 metric tons/ha disced in
Insecticide	carbofuran 1.12 kg Ai/ha	carbofuran 1.12 kg Ai/ha
Tillage Type	Spring plow	Spring plow
Previous Crop	Corn	Corn
Plant Pop.	50,141/ha	50,141/ha
Soil Class	Udic Haplustoll	Udic Haplustoll
Soil Type	Moody-Nora silty clay loam	Moody silty clay loam
pH	6.3	6.3
Organic Matter	2.3%	3.1%
0-15.24 cm		
kg N/ha	6.05	5.26
kg P/ha	42.56	28.0
kg K/ha	436.8	459.2
15.24-60.96 cm		
kg N/ha	16.9	25.42
Precipitation		
May - August	43.92 cm	43.92 cm
# plants dug	100	250
Date dug	10/28/82	11/2/82

Table 2. 1982 Field, Climatological and Soil Information.

	Verlyn Lapour	Glen Langum
Location	Alcester, SD	Sinai, SD
Hybrid	Pride 5578	PAG 5X 181
Hybrid Maturity	115 days	100 days
Planted	5/19/82	5/10/82
Fertilizer		
kg N/ha	72.8 granular	89.6 granular
kg P/ha	22.4 granular	33.6 granular
kg K/ha	11.2 granular	22.4 granular
Herbicide	Liquid alachlor 3.36 kg Ai/ha	None
Manure	None	2.24 metric tons disced in
Insecticide	carbofuran 1.12 kg Ai/ha	None
Tillage Type	Spring plow	Fall chisel plow
Previous Crop	Corn	Oats
Plant Pop.	43,255/ha	44,460/ha
Soil Class	Cumulic Hapliquoll	Udic Haplaboroll
Soil Type	Calco silty clay loam	Poinsett clay loam
pH	6.6	6.8
Organic Matter	2.0%	3.3%
0-15.24 cm		
kg N/ha	8.06	12.88
kg P/ha	53.76	44.8
kg K/ha	470.4	828.8
15.24-60.96 cm		
kg N/ha	30.24	70.11
Precipitation		
May - August	45.36 cm	42.72 cm
# plants dug	97	197
Date dug	10/28/82	9/21/82

Table 3. 1982 Field, Climatological and Soil Information.

	John West	S.E. Exper. Station
Location	Onida, SD	Beresford, SD
Hybrid	Pioneer 3732	Northrup King PX39
Hybrid Maturity	101 days	104 days
Planted	5/19/82	5/4/82
Fertilizer		
kg N/ha	168 anhydrous ammonia	None
kg P/ha	None	None
kg K/ha	None	None
Herbicide	2.24 kg atrazine/ha	2.24 kg atrazine + 1.06 liters oil/ha
Manure		
Insecticide	None	Labeled compounds
Tillage Type	Disced twice	Fall plow
Previous Crop	Corn	Trap crop corn
Plant Pop.	62,491/ha	49,400/ha
Soil Class	Typic Argiustoll	Pachic Haplustoll
Soil Type	Agar silt loam	Trent silty clay loam
pH	7.2	6.8
Organic Matter	2.7%	3.3%
0-15.24 cm		
kg N/ha	10.53	38.75
kg P/ha	17.92	75.04
kg K/ha	795.2	504
15.24-60.96 cm		
kg N/ha	44.8	147.62
Precipitation		
May - August	32.18 cm	45.36 cm
Irrigation	25.4 cm	None
# plants dug	218	239
Date dug	10/5/82	10/6/82

Table 4. 1983 Field, Climatological and Soil Information

	John West	Paul Bonhorst
Location	Onida, SD	Pierre, SD
Hybrid	Sokota 680	Sokota 680
Hybrid Maturity	110 days	110 days
Planted	5/5/83	5/10/83
Fertilizer		
kg N/ha	78.4 anhydrous ammonia	148.96 (granular) 33.6 liq.
kg P/ha	None	49.28 granular
kg K/ha	None	98.56 granular
Herbicide	2.24 kg Ai/ha alachlor liquid 2.24 kg Ai/ha atrazine 3.36 kg Ai/ha alachlor	3.36 kg Ai/ha alachlor 2.69 kg Ai/ha atrazine
Insecticide	Labeled compounds	Labeled compounds
Tillage Type	Offset, light discing	Chisel, tandem disc
Previous Crop	Corn	Corn
Plant Pop.	49,400/ha	49,400/ha
Soil Class	Typic Argiustoll	Vertic Argiustoll
Soil Type	Agar silt loam	Millboro silty clay loam
pH	7.2	6.8
Organic Matter	2.4%	2.6%
0-15.24 cm		
kg N/ha	12.32	77.28
kg P/ha	33.6	39.2
kg K/ha	1120	1120
15.24-60.96 cm		
kg N/ha	40.32	95.2
Precipitation		
May - August	36.8 cm	31.75 cm
Irrigation	10.61 cm	25.4 cm
# plants dug	472	486
Date dug	10/4/83	10/18/83

Table 5. 1983 Field, Climatological and Soil Information

	S.E, Exper. Station	Dave Olsen
Location	Beresford, SD	Fairview, SD
Hybrid	Sokota 680	Sokota 680
Hybrid Maturity	110 days	110 days
Planted	5/23/83	5/17/83
Fertilizer		
kg N/ha	None	89,6 granular
kg P/ha	None	33.6 granular
kg K/ha	None	22.4 granular
Herbicide	2,24 kg atrazine + 1,06 liter oil/ha	2,24 kg alachlor 3.36 kg alachlor bnd.
Manure	None	2.24 metric tons/ha
Insecticide	Labeled compounds	Labeled compounds
Tillage Type	Fall plow	Disced twice
Previous Crop	Trap crop corn	Corn
Plant Pop.	49,400/ha	49.400/ha
Soil Class	Pachic Haplustoll	Udic Haplustoll
Soil Type	Trent silty clay loam	Moody silty clay loam
pH	6.8	6.5
Organic Matter	3.0%	3.2%
0-15.24 cm		
kg N/ha	39.98	5.04
kg P/ha	75.04	24.64
kg K/ha	448,00	448.00
15.24-60.96 cm		
kg N/ha	145,82	23.86
Precipitation		
May - August	44.09 cm	44.12 cm
# plants dug	496	486
Date dug	10/12/83	10/13/83

Table 6. 1984 Field, Climatological and Soil Information

	John West	Verlyn Lapour
Location	Onida, SD	Alcester, SD
Hybrid	Sokota 680	Sokota 680
Hybrid Maturity	110 days	110 days
Planted	5/9/84	5/21/84
Fertilizer		
kg N/ha	112 anhydrous ammonia	89.6 granular
kg P/ha	None	67.2 granular
kg K/ha	None	33,6 granular
Herbicide	3,36 kg Ai/ha atrazine	2,24 kg Ai/ha cyanazine
	0,28 kg Ai/ha dicamba	2,24 kg Ai/ha liquid alachlor
	3,36 kg/ha alachlor	3.36 kg Ai/ha alachlor
Insecticide	Labeled compounds	Labeled compounds
Tillage Type	Offset, light discing	Disced
Previous Crop	Corn	Corn
Plant Pop.	49.400/ha	49,400/ha
Soil Class	Typic Argiustoll	Cumulic Hapliquoll
Soil Type	Agar silt loam	Calco silty clay loam
pH	6,6	6.0
Organic Matter	2.2%	2.9%
0-15.24 cm		
kg N/ha	34.27	12.32
kg P/ha	31.36	100.8
kg K/ha	1142.4	660.8
15.24-60.96 cm		
kg N/ha	55,66	70.11
Precipitation		
May - August	45,69 cm	52.05 cm
Irrigation	20,32 cm	None
# plants dug	500	497
Date dug	10/9/84	10/17/84

RESULTS AND DISCUSSION

1982 Results

Glen Langum, Sinai, SD (Field A); Verlyn Lapour, Alcester, SD (Field B1); Arlyn Olsen, Fairview, SD (Field C)

Three locations were grouped based on plant yield response to rootworm damage. Field A was in a corn-oats rotation with no rootworm insecticide applied in 1982. Fields B1 and C were in the third year of corn and were carbofuran insecticide failure sites in 1982. Severe lodging occurred in fields B1 and C with all plants in the 4, 5 and 6 root rating categories. Johnson (1969) showed from 37 cornfields in Iowa that as the root rating increased, so did the percentage of lodging and over a two year period, 48, 90 and 100 percent lodging occurred for plants given a 4, 5 or 6 rating respectively. All root ratings were found in field A with 27% of the plants in the three root rating category (Table 7) and approximately 50% of the plants showed severe lodging.

Planting dates were May 10, 19 and 7 for A, B1 and C, respectively (Tables 1 and 2) and plant maturity should not have interacted with rootworm development. May rainfall for these locations was over 12.5 cm and gave good moisture for germination and July and August rainfall was adequate (Table 8) and would have not inhibited ear formation, silking or pollination (Hanway 1966). Soil testing results obtained after the corn reached physiological maturity showed major elements to be adequate for plant needs (Ron Gelderman, 1984).

Table 7

Number of Plants per Root Rating by Location and Year

1982

Root Rating	A	B1	C	D1	E1	F1
1	25			21	22	22
2	32			32	47	46
3	54			81	95	98
4	33	33	37	36	40	34
5	27	44	28	23	25	19
6	26	20	23	25	21	20
TOTAL	197	97	88	218	250	239

1983

Root Rating	D2	E2	F2	G
1	38	22	42	34
2	198	144	146	156
3	168	169	166	121
4	61	82	80	100
5	5	41	53	50
6	2	22	8	25
TOTAL	472	480	495	486

1984

Root Rating	D3	B2
1	69	43
2	137	101
3	155	123
4	65	94
5	44	109
6	30	29
TOTAL	500	497

Table 8

Monthly Growing Season Rainfall by Location and Year in Centimeters

1982

Month	A	B1	C	D1	E1	F1
April	2.79	2.95	3.20	3.35	3.20	2.95
May	13.89	23.72	12.78	14.00	12.78	23.72
June	6.35	4.29	4.75	6.35	4.75	4.29
July	4.55	7.65	8.48	19.53*	8.48	7.65
August	15.14	6.76	14.71	14.35*	14.71	6.76
TOTAL	42.72	45.37	43.92	57.58	43.92	45.37

1983

Month	D2	E2	F2	G
April	2.57	6.07	5.08	3.05
May	9.53	7.80	8.03	7.01
June	9.63	26.52	27.84	12.50
July	24.74*	9.78	7.49	5.79*
August	2.85*	0.03	0.74	6.45*
TOTAL	49.32	50.20	49.18	34.80

1984

Month	D3	B2
April	6.93	16.33
May	6.25	10.31
June	16.08	20.17
July	16.87*	5.23
August	15.67*	2.92
TOTAL	61.80	54.96

* Includes irrigation water

Table 9

Plot Yield Average and Field Yield Average by Location and Year

1982
quintals/hectare

	A1	B1	C	D1	E1	F1
Plot Average	73	81	75	81	58	72
Field Average	71	41	38	79	45	

1983
quintals/hectare

	D2	E2	F2	G
Plot Average	87	77	72	74
Field Average	77	84		81

1984
quintals/hectare

	D3	B2
Plot Average	89	100
Field Average	88	97

Yields were analyzed by the Least Square Means method (LS Means) to determine differences between yields and their associated root ratings. Yields from plants with root ratings of (1) minor damage to those of (6) 3 nodes destroyed, were not shown to be different from each other at these locations. Differences were determined at the .10 level of probability (Appendix A). Yield results from these locations (figures 1-3) resembled results found by Sutter et al. (1981), who found that in artificial infestation studies there were no differences between yields in insecticide treated fields containing different levels of eggs. They did not report the relationship between these yields and root ratings. Data did not resemble the rootworm-yield relationship found by Turpin et al. (1972). After analyzing data from 526 fields, they stated that root ratings greater than 2.5 reduced yields by as much as 6.3 quintals per hectare. This value was determined on the average yields from estimated ratings of the field and not from yields from individual plants.

Hand harvested yields at these locations were close to the yield goals set by the farmers in the spring, but the actual yields for fields B1 and C, which were roughly determined from the number of wagon loads taken from the field were one-half of the expected yield (Table 9). This is due largely to the severe lodging associated with plants in the 4, 5 and 6 rating categories. Root regrowth was observed on plants in the 4, 5 and 6 root rating categories of field A, although no difference in the amount of

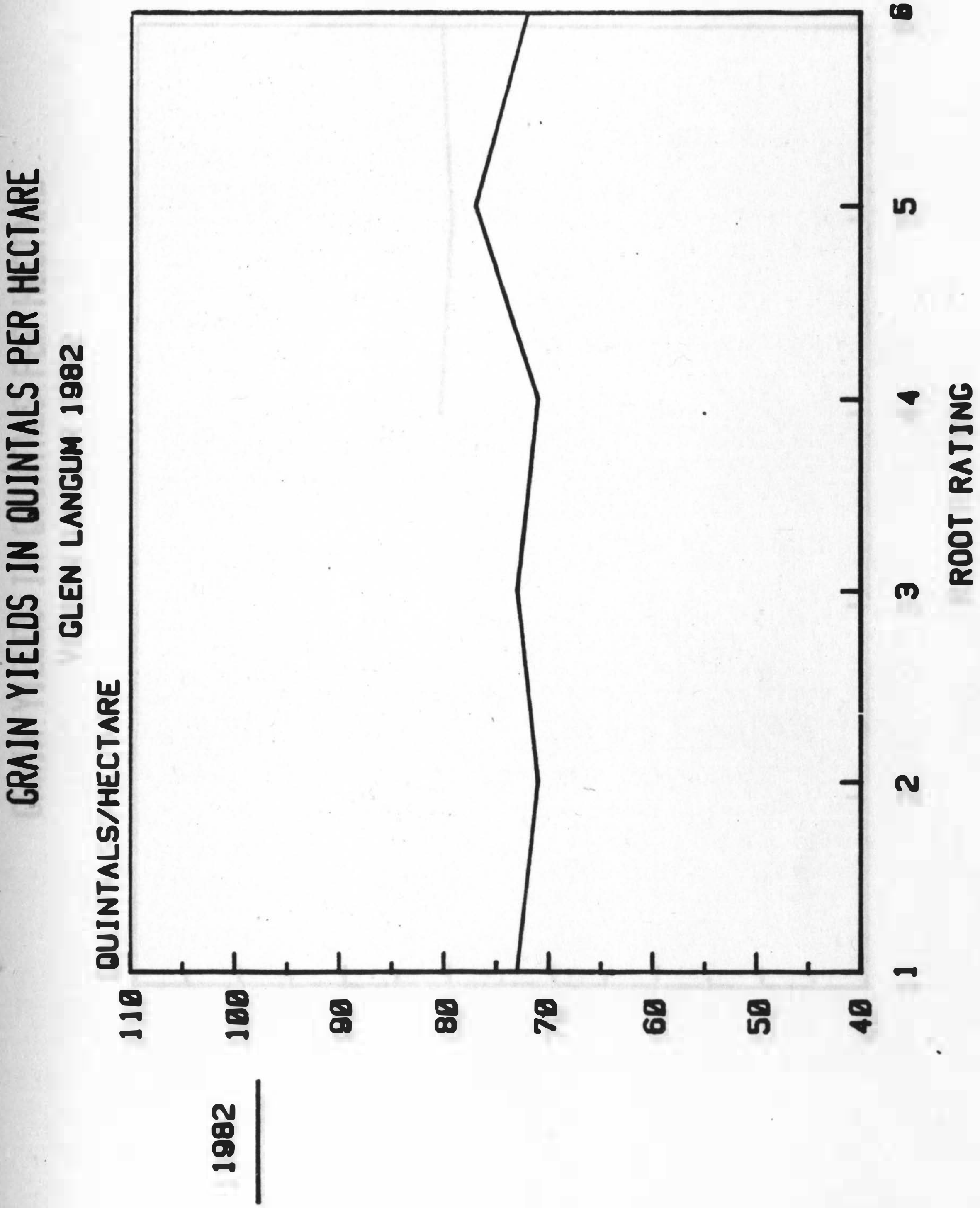

Figure 1. Grain yields in quintals per hectare - Glen Langum 1982.

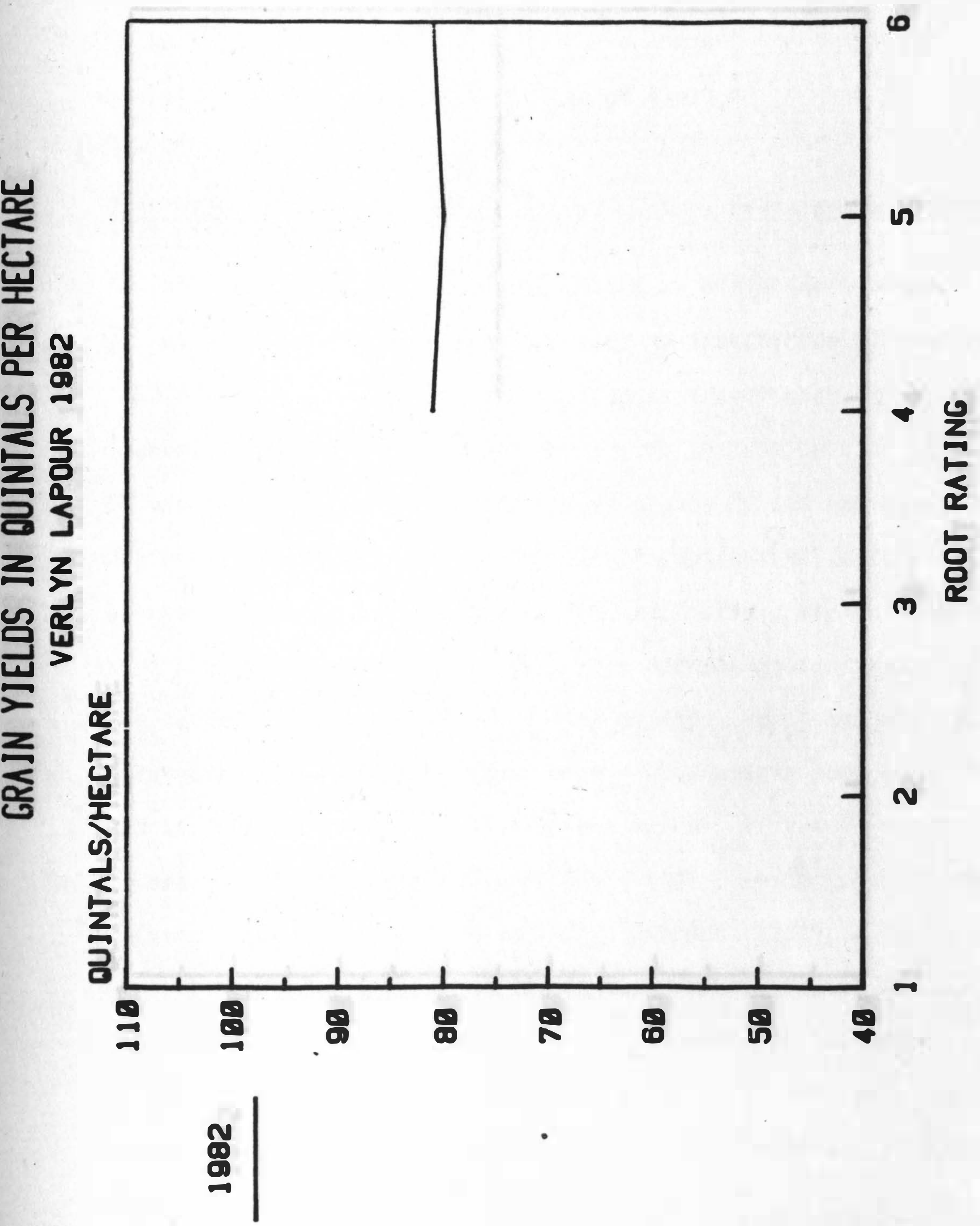

Figure 2. Grain yields in quintals per hectare - Verlyn Lapour 1982

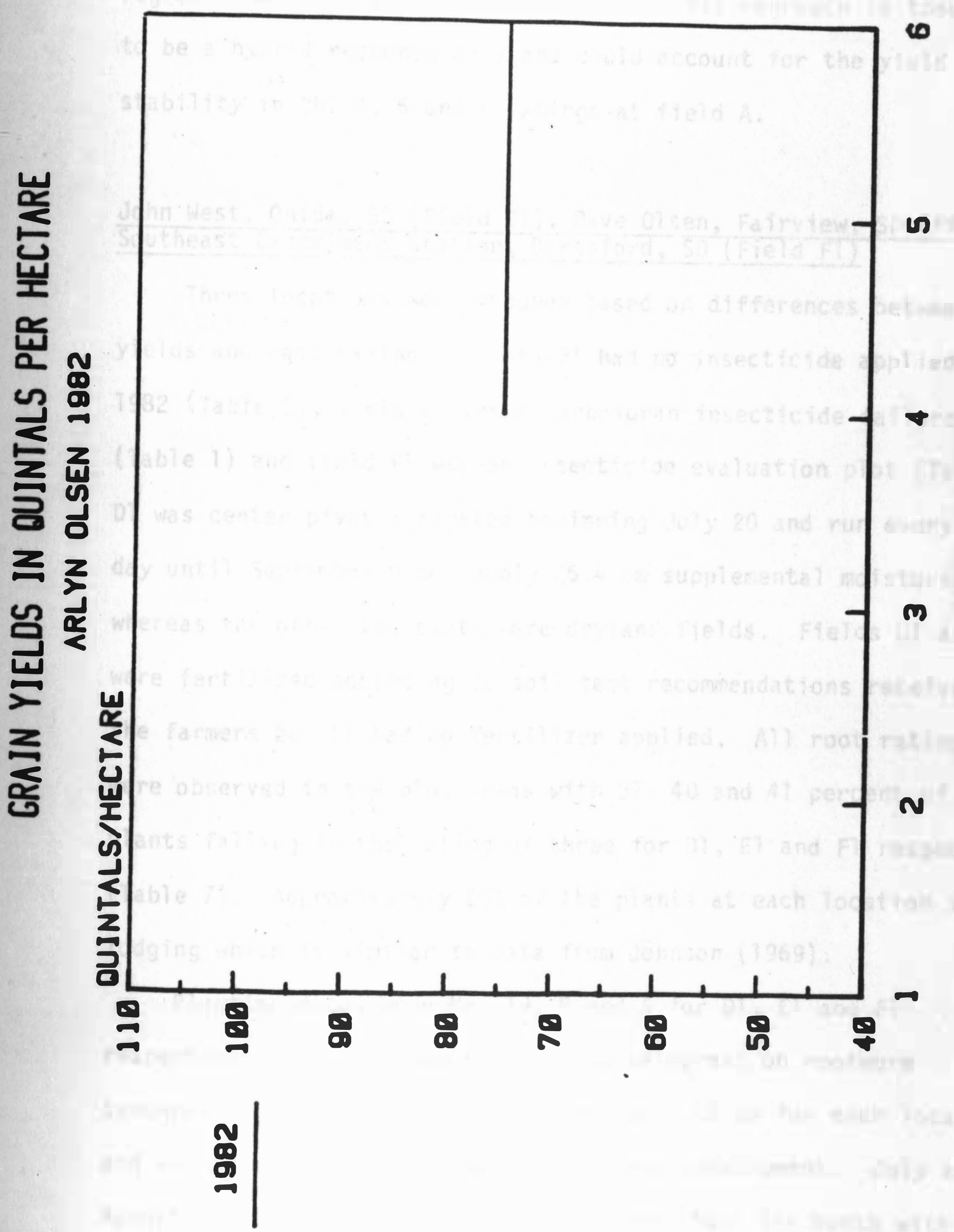

Figure 3. Grain yields in quintals per hectare - Arlyn Olsen 1982

regrowth was apparent between ratings. This regrowth is thought to be a hybrid response only and could account for the yield stability in the 4, 5 and 6 ratings at field A.

John West, Onida, SD (Field D1); Dave Olsen, Fairview, SD (Field E1); Southeast Experiment Station, Beresford, SD (Field F1)

Three locations were grouped based on differences between yields and root ratings. Field D1 had no insecticide applied in 1982 (Table 3), field E1 was a carbofuran insecticide failure field (Table 1) and field F1 was an insecticide evaluation plot (Table 3). D1 was center pivot irrigated beginning July 20 and run every fifth day until September 9 to supply 25.4 cm supplemental moisture, whereas the other two plots were dryland fields. Fields D1 and E1 were fertilized according to soil test recommendations received by the farmers but F1 had no fertilizer applied. All root ratings were observed in the plot areas with 37, 40 and 41 percent of the plants falling in the rating of three for D1, E1 and F1 respectively (Table 7). Approximately 50% of the plants at each location showed lodging which is similar to data from Johnson (1969).

Planting dates were May 19, 8 and 4 for D1, E1 and F1 respectively with no impact of corn development on rootworm synchrony. May monthly moisture was above 12 cm for each location and was adequate for good germination and development. July and August rainfall was well distributed throughout the month with few moisture stress days during pollination and seed set (Table 8). Fertility levels in the soil was not limiting to plant growth

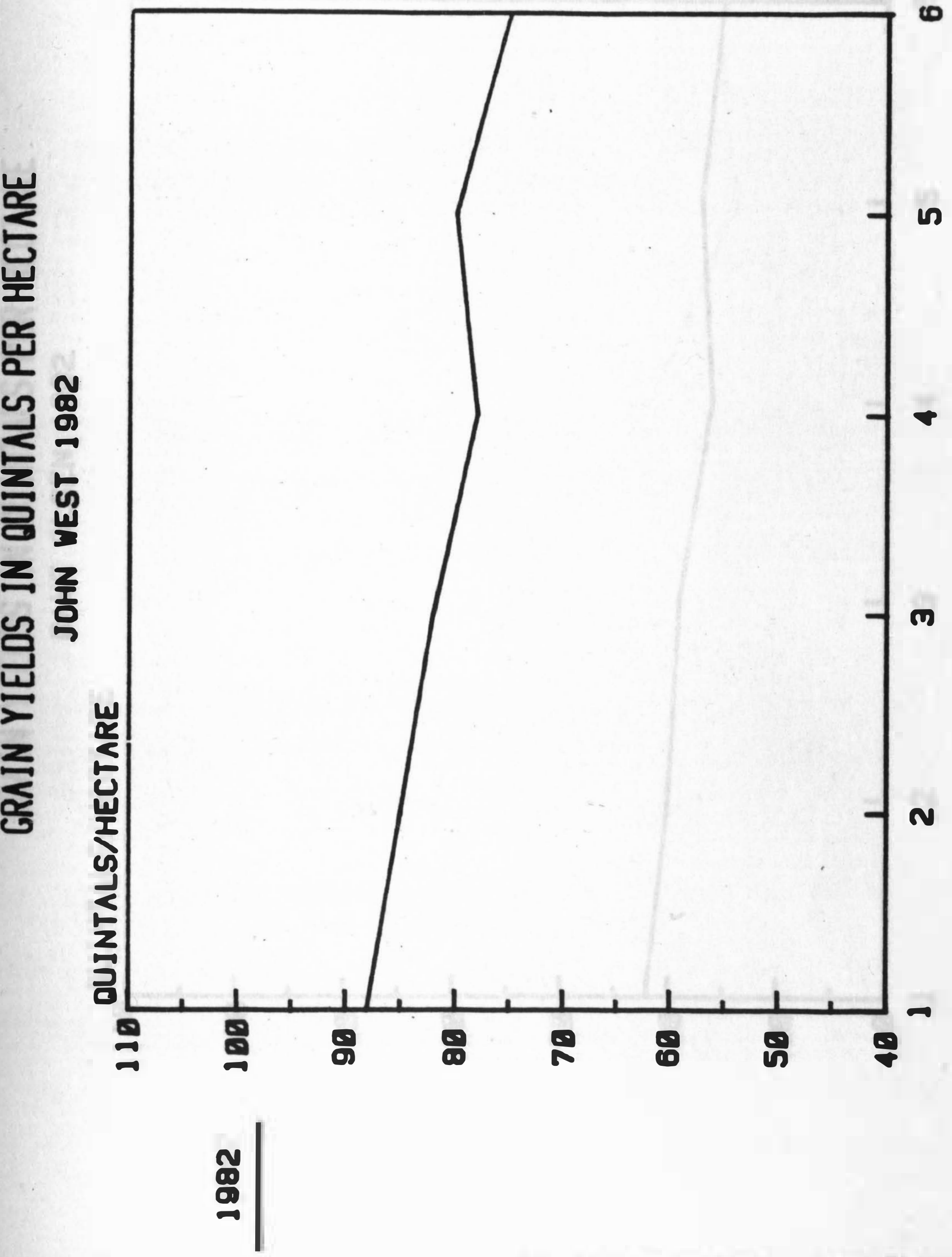

Figure 4. Grain yields in quintals per hectare - John West 1982

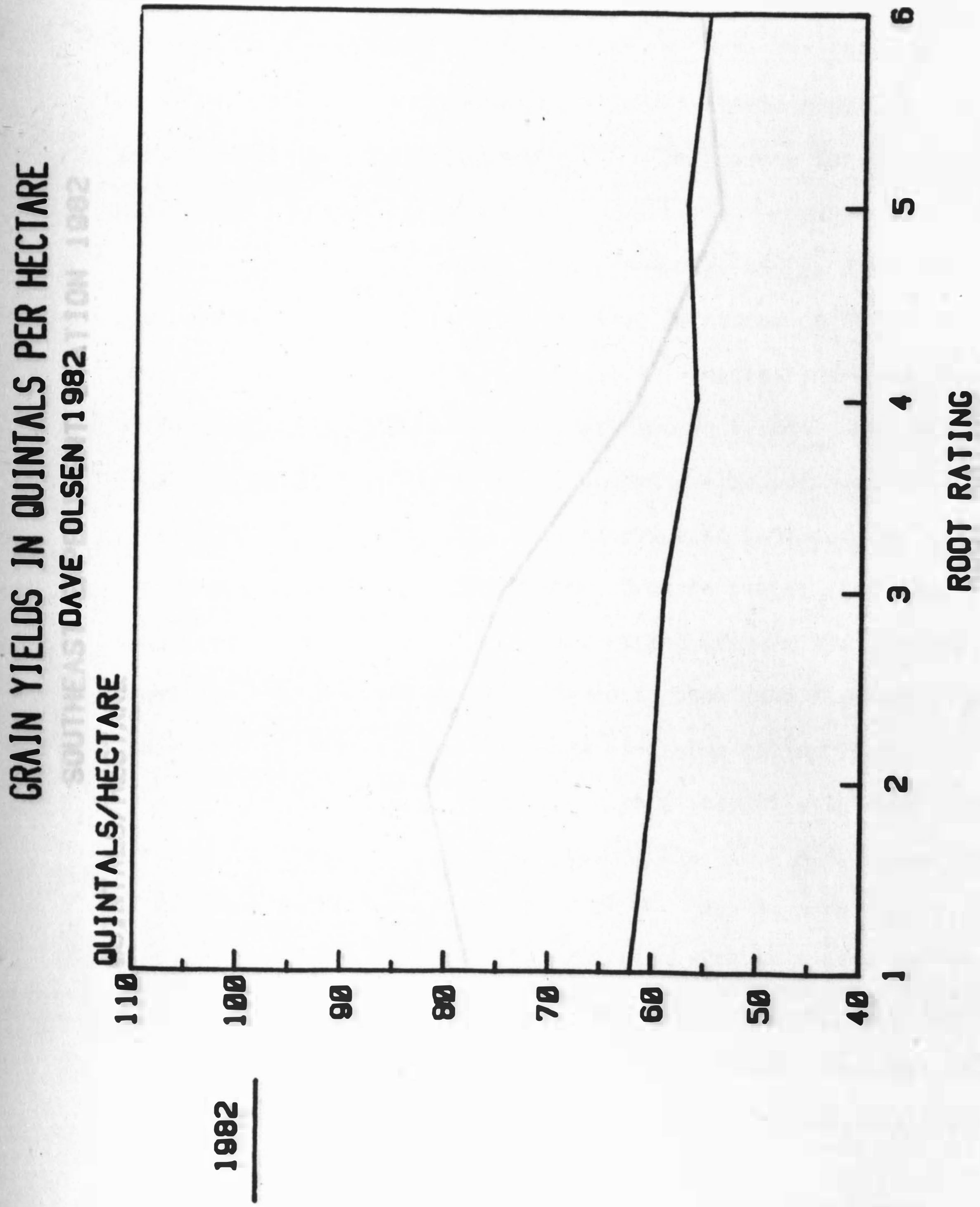

Figure 5. Grain yields in quintals per hectare - Dave Olsen 1982

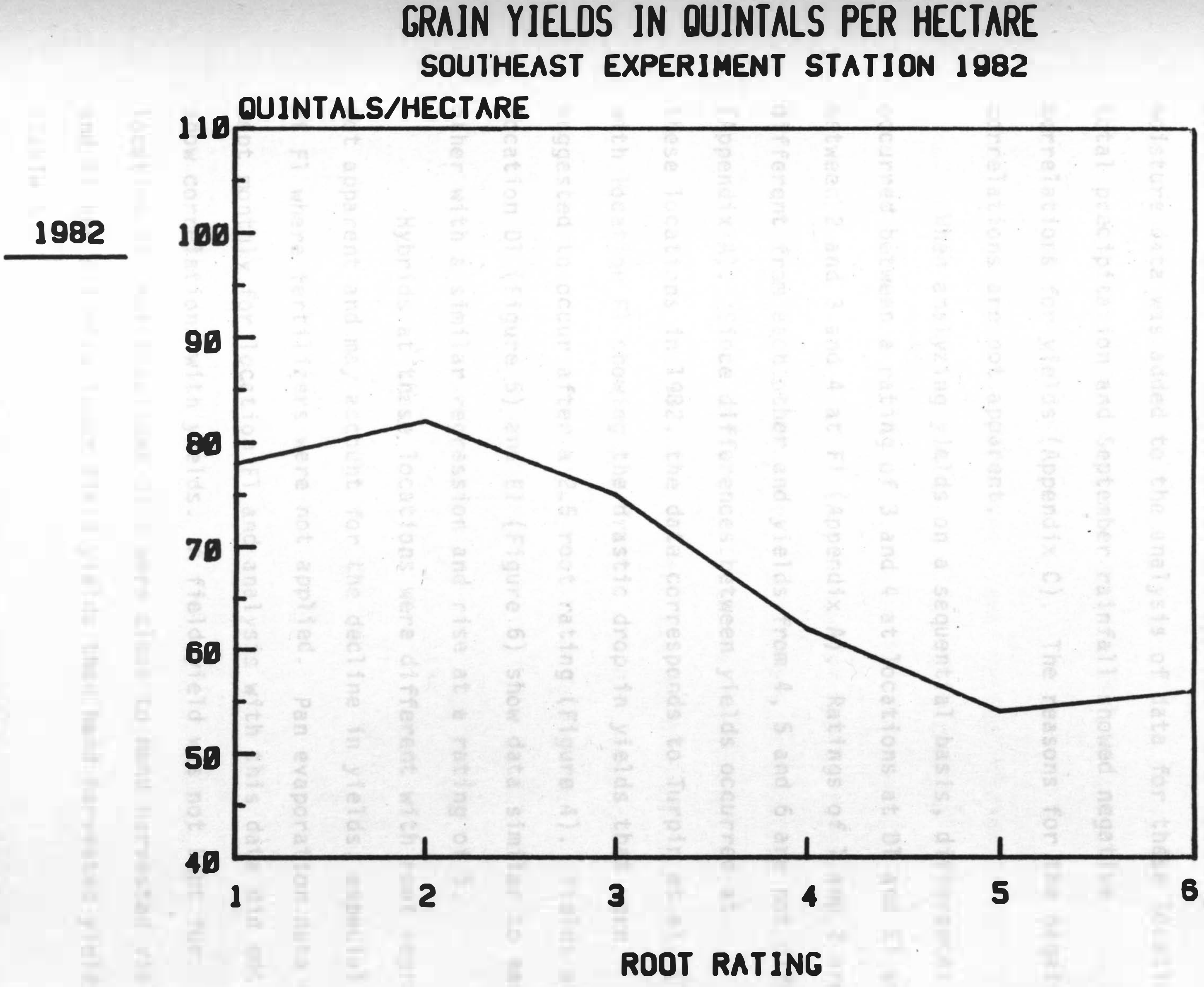

Figure 6. Grain yields in quintals per hectare - Southeast Experiment Station 1982

even at F1 where no fertilizers were applied. When monthly moisture data was added to the analysis of data for these locations, total precipitation and September rainfall showed negative correlations for yields (Appendix C). The reasons for the negative correlations are not apparent.

When analyzing yields on a sequential basis, differences occurred between a rating of 3 and 4 at locations at D1 and E1 and between 2 and 3 and 4 at F1 (Appendix A). Ratings of 1 and 2 are not different from each other and yields from 4, 5 and 6 are not different (Appendix A). Since differences between yields occurred at these locations in 1982, the data corresponds to Turpin et al. (1972) with location F1 showing the drastic drop in yields that were suggested to occur after a 2.5 root rating (Figure 4). Yields at location D1 (Figure 5) and E1 (Figure 6) show data similar to each other with a similar regression and rise at a rating of 5.

Hybrids at these locations were different with root regrowth not apparent and may account for the decline in yields, especially at F1 where fertilizers were not applied. Pan evaporation data was kept monthly for location F1 and analysis with this data did not show correlations with yields. A field yield was not kept for location F1, but locations D1's were close to hand harvested yields and E1 had slightly lower field yields than hand harvested yields (Table 9).

Using those locations that showed differences between yields, root ratings were grouped into three different combinations to determine if positive correlations exist between root ratings and yield. Rating groups of 1-2, 3-4, 5-6; of (1,2,3)(4,5,6) and (1,2,3,4)(5,6) were attempted for segregation of differences in the rating scheme.

When utilizing the three tiered system, fields D1 and F1 showed differences between 1-2 and 3-4 and 5-6 while differences occurred between 1-2 and 5-6 at field E1. The 3-4 rating is different than both 1-2 and 5-6 at location F1 and different than 1-2 at D1, but not different than either 1-2 or 5-6 at location E1 (Appendix A). When utilizing the (1,2,3)(4,5,6) rating scheme, all three locations showed differences between yields, but when using the (1,2,3,4)(5,6) ratings, locations E1 and F1 showed differences whereas D1 did not (Appendix A).

Table 10

Yields by Grouped Root Ratings in Fields D1, E1, F1
Yield in quintals/hectare

Root Rating	Field D1	Field E1	Field F1
1-2	86	60	80
3-4	81	58	71
5-6	82	56	55
1-3	84	60	77
4-6	80	56	58
1-4	83	59	74
5-6	82	56	55

1983 Results

John West, Onida, SD(Field D2): Southeast Experiment Station, Beresford, SD (Field F2)

These two locations were grouped due to lack of plants found in the 5 and 6 root rating categories. Both locations were

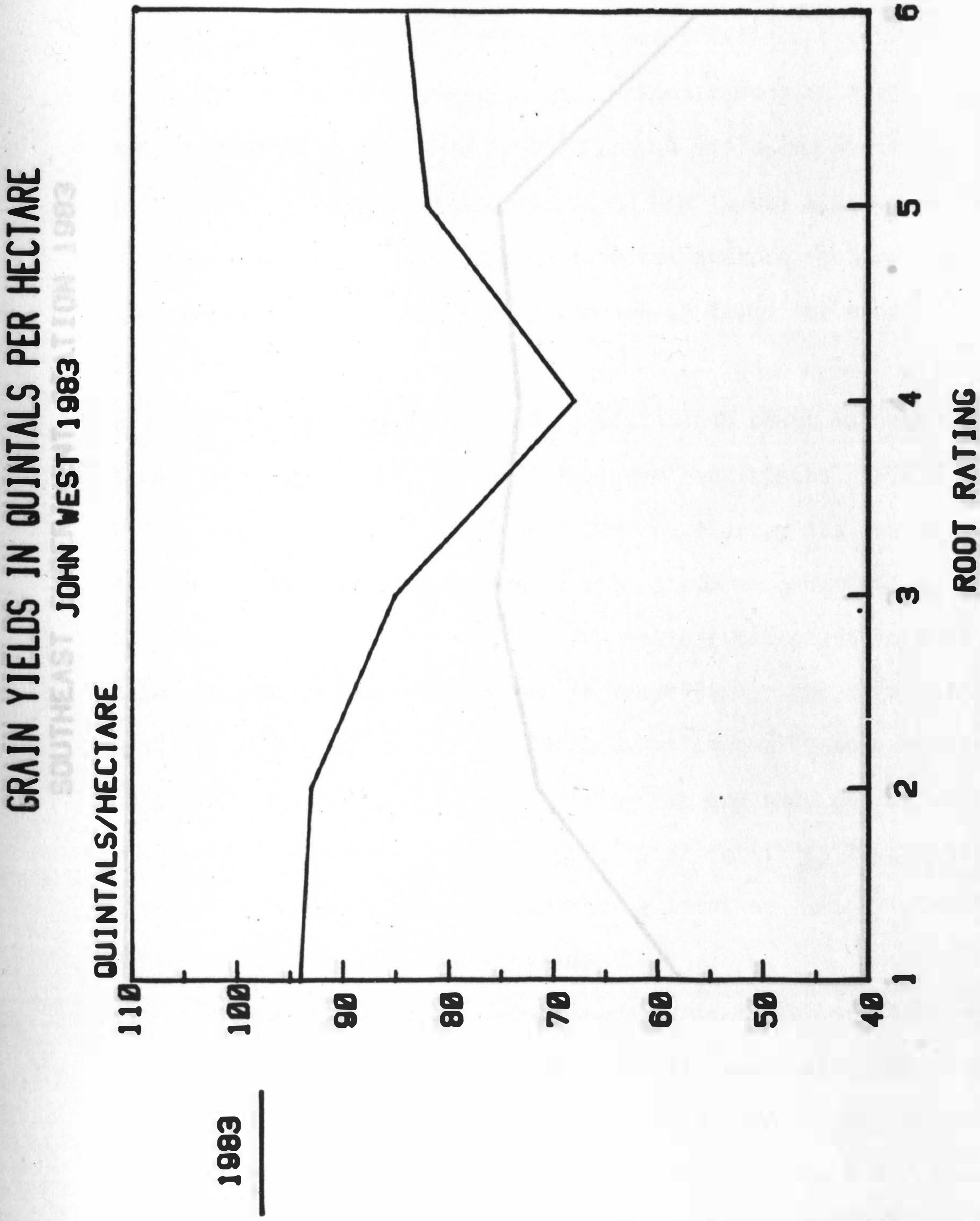

Figure 7. Grain yields in quintals per hectare - John West 1983

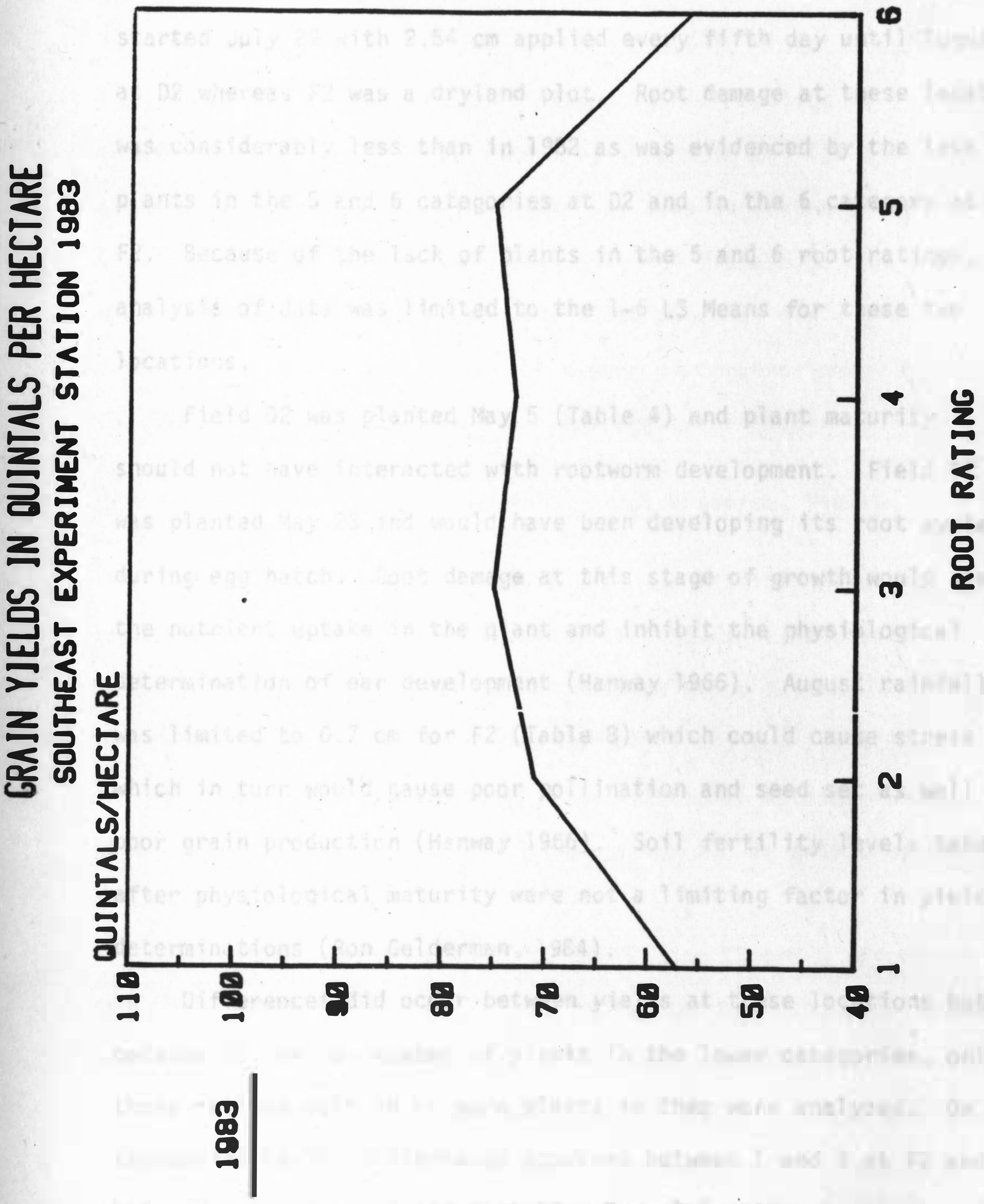

Figure 8. Grain yields in quintals per hectare - Southeast Experiment Station 1983

insecticide evaluation plots in 1983. Center pivot irrigation started July 29 with 2.54 cm applied every fifth day until August 12 at D2 whereas F2 was a dryland plot. Root damage at these locations was considerably less than in 1982 as was evidenced by the lack of plants in the 5 and 6 categories at D2 and in the 6 category at F2. Because of the lack of plants in the 5 and 6 root ratings, analysis of data was limited to the 1-6 LS Means for these two locations.

Field D2 was planted May 5 (Table 4) and plant maturity should not have interacted with rootworm development. Field F2 was planted May 23 and would have been developing its root system during egg hatch. Root damage at this stage of growth would limit the nutrient uptake in the plant and inhibit the physiological determination of ear development (Hanway 1966). August rainfall was limited to 0.7 cm for F2 (Table 8) which could cause stress which in turn would cause poor pollination and seed set as well as poor grain production (Hanway 1966). Soil fertility levels taken after physiological maturity were not a limiting factor in yield determinations (Ron Gelderman, 1984).

Differences did occur between yields at these locations but because of the low number of plants in the lower categories, only those ratings with 20 or more plants in them were analyzed. On a sequential basis, differences occurred between 1 and 2 at F2 and between 2 and 3 and 3 and 4 at D2. On a 1-6 rating basis, 1 and 2 were different at field F2, but were not different at D2. At D2, when comparing combinations other than 1 and 2, all yields were different. At F2, no differences were observed except when comparing the yield of 1 to 2, 3, 4 and 5 (Appendix A). Ratings of 1-4 at D2 showed a regression line as stated by Turpin et al. (1972) occurring after a rating of 2.5 but is unlike the data suggested by Sutter et al. (1981) for no difference in yields (Figures 7 and 8). Hand harvested yields for D2 were higher than rough estimates of field yield determined by the farmer from the number of combine loads taken from the field whereas F2 had no field average taken (Table 9).

Dave Olsen, Fairview, SD (Field E2) Paul Bonhorst, Pierre, SD (Field G)

Two locations were grouped based on significant differences between yields and having more than 20 plants in each category. Both locations were insecticide evaluation plots in 1983. Field G was center pivot irrigated beginning July 1 and run every sixth day until August 29 supplying 25.4 cm additional moisture whereas E2 was a dryland field. Overall damage was not as severe at E2 as in 1982.

Planting dates were May 17 and 10 for E2 and G respectively and plant maturity should not have interacted with rootworm development. May rainfall was over 7 cm and gave sufficient moisture for germination and July rainfall was over 5.8 cm to initiate pollination. Location E2 had 0.03 cm of rainfall in August (Table 8) and may have caused stress which would result in poor pollination and seed set (Hanway 1966) whereas G had 6.5 cm of rainfall in August. Soil

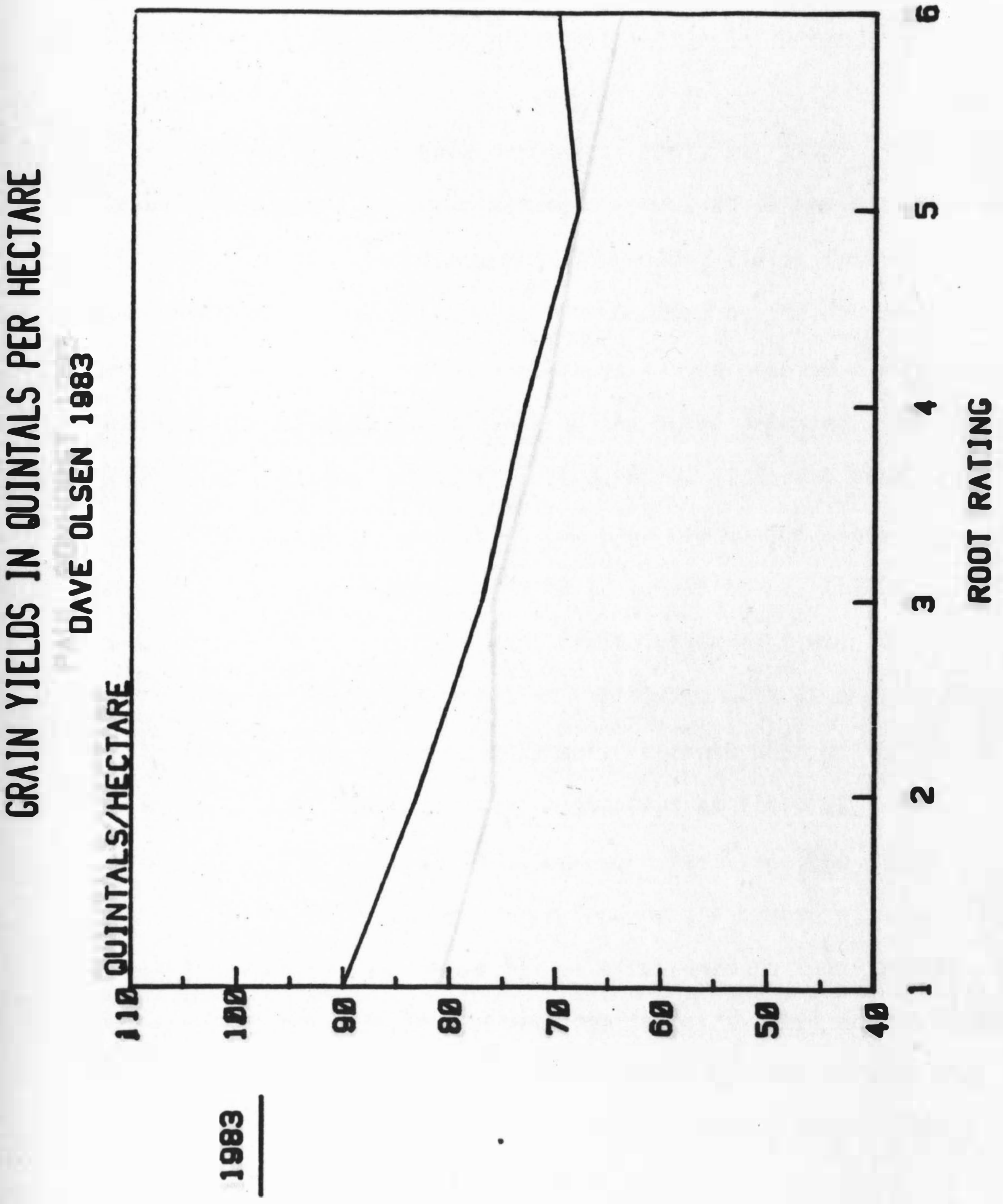

Figure 9. Grain yields in quintals per hectare - Dave Olsen 1983

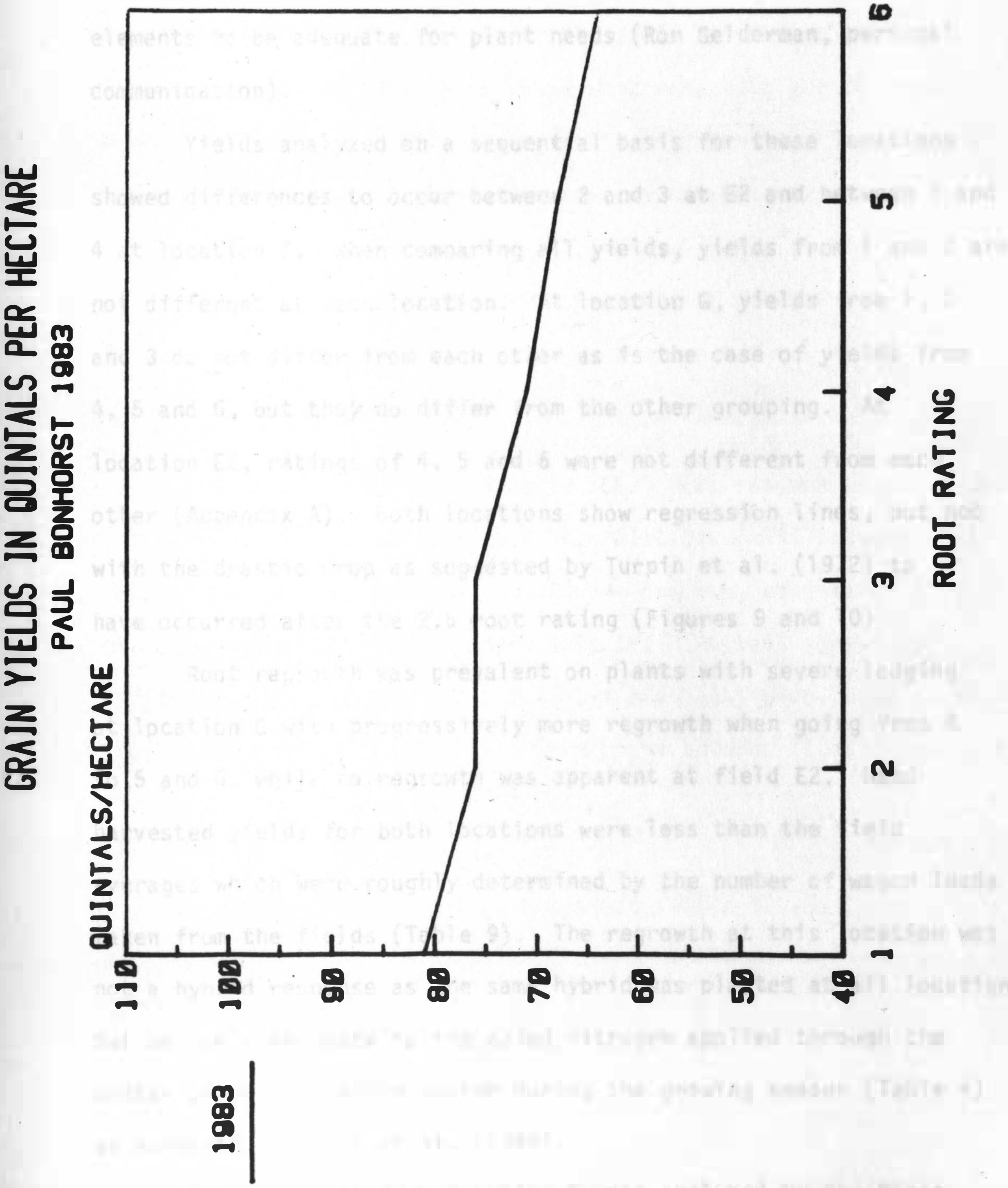

Figure 10. Grain yields in quintals per hectare - Paul Bonhorst 1983

testing results obtained after physiological maturity showed major elements to be adequate for plant needs (Ron Gelderman, personal communication).

Yields analyzed on a sequential basis for these locations showed differences to occur between 2 and 3 at E2 and between 3 and 4 at location G. When comparing all yields, yields from 1 and 2 are not different at each location. At location G, yields from 1, 2 and 3 do not differ from each other as is the case of yields from 4, 5 and 6, but they do differ from the other grouping. At location E2, ratings of 4, 5 and 6 were not different from each other (Appendix A). Both locations show regression lines, but not with the drastic drop as suggested by Turpin et al. (1972) to have occurred after the 2.5 root rating (Figures 9 and 10).

Root regrowth was prevalent on plants with severe lodging at location G with progressively more regrowth when going from 4 to 5 and 6, while no regrowth was apparent at field E2. Hand harvested yields for both locations were less than the field averages which were roughly determined by the number of wagon loads taken from the fields (Table 9). The regrowth at this location was not a hybrid response as the same hybrid was planted at all locations, but may be a response to the added nitrogen applied through the center pivot irrigation system during the growing season (Table 4) as suggested by Hill et al. (1948).

Grain samples from location G were analyzed by the Plant Testing Laboratory at South Dakota State University for percent protein, N, P and K in the grain. Kjeldahl tests were used to determine nutrient differences in the grain for damage ratings 1, 3 and 6. No differences were shown when analyzing for percent protein, N, P and K. This indicated that in field G there was no major response of root damage on nutrient uptake.

Table 11

% Protein, N, P, K in Grain Samples from Field G

Root Rating	% Protein	% N	% P	% K
1	10.5	1.7	0.31	0.38
3	10.3	1.7	0.29	0.38
6	10.7	1.7	0.32	0.38

Using locations E2 and G in 1983, root ratings were grouped into three groups to determine if correlations exist between root ratings and yields, ratings of 1-2, 3-4 and 5-6; ratings of (1,2,3) (4,5,6); and (1,2,3,4)(5,6) were selected. At both locations, differences were shown betwen 1-2, 3-4 and 5-6. When grouping into broader categories, differences were shown between (1,2,3) and (4,5,6) as well as (1,2,3,4)(5,6) (Appendix A).

Table 12

Yields by Grouped Root Rating in Fields D2, G

Root Rating	Field D2	Field G
1-2	84	77
3-4	75	74
5-6	69	67
1-3	80	76
4-6	71	69
1-4	79	75
5-6	69	67

Combined Years 1982 and 1983

Data for D1, D2; E1, E2; and F1, F2 were combined and analyzed similar to data for single years. These locations were used because of differences between ratings, having all ratings both years and having 20 or more plants in each category when combined. Data was first analyzed on a 1-6 basis with D1, D2 and E1, E2 showing ratings 1 and 2 as not different while F1, F2 showed differences between 1 and 2. No differences were noticed between ratings of 4, 5 and 6 for E1, E2; between 5 and 6 at D1, D2; and between 4 and 5 and 1 and 2 at F1, F2 (Appendix A).

Combined data for D1, D2 showed the regression line occurring at a rating of 2.5 as stated by Turpin et al. (1972) until a rating of 5 increases yields (Figure 11). E1, E2 (Figure 12) shows a regression line occurring although not as severe as suggested by Turpin et al. (1972) and F1, F2 shows a line unlike both Turpin et al. (1972) data and Sutter et al. (1981) data for no differences (Figure 13).

The three tiered system showed differences among all ratings and yields at E1, E2. D1, D2 yields for 5-6 were not different than 3-4 yields while all others showed differences in yields whereas F1, F2 yields for 1-2 were not different than 3-4 but all other comparisons were different. Differences were shown at each location when using the (1,2,3)(4,5,6) rating system whereas D1, D2 did not show differences using the (1,2,3,4)(5,6) system and E1, E2 and

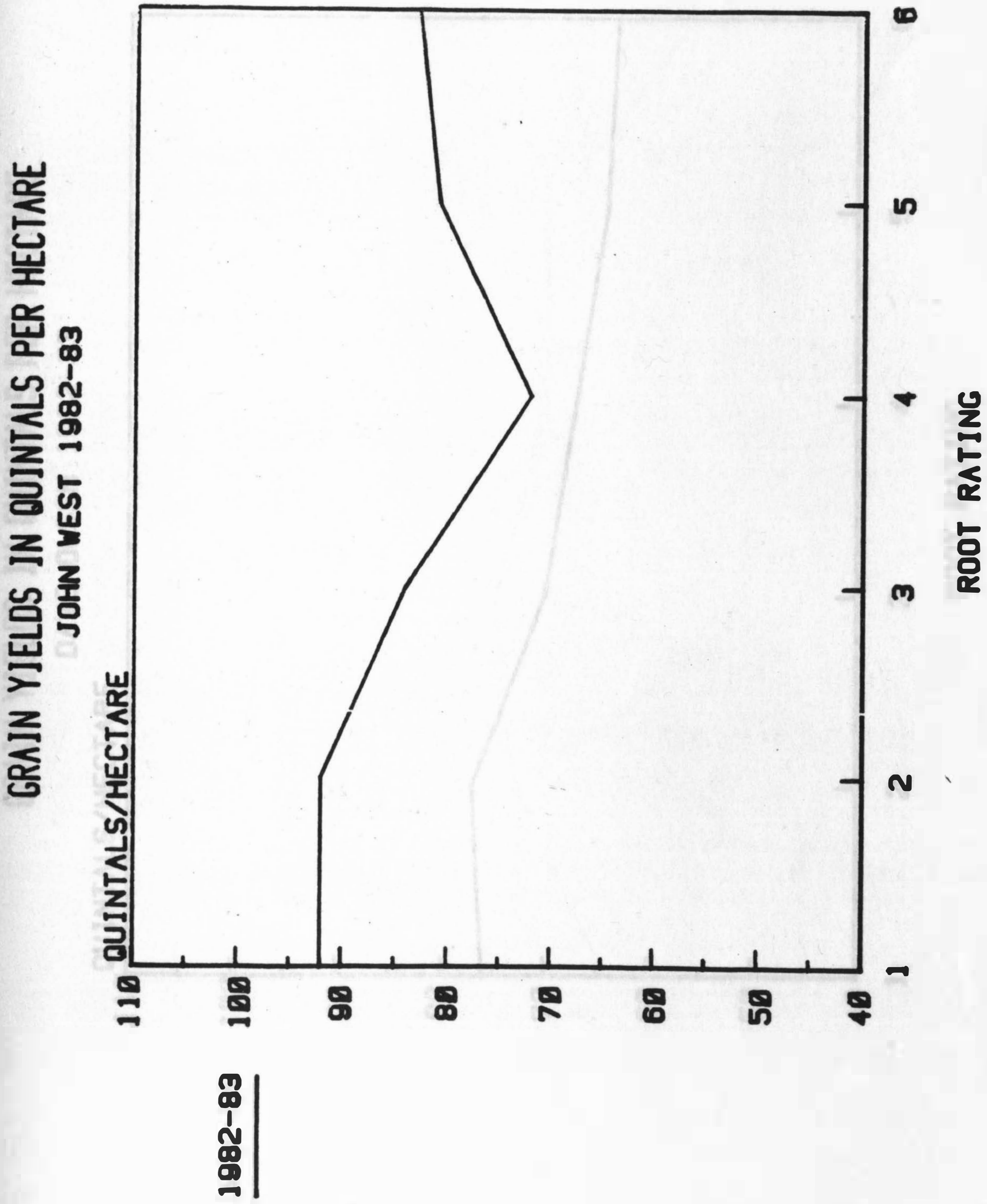

Figure 11. Grain yields in quintals per hectare - John West 1982-83

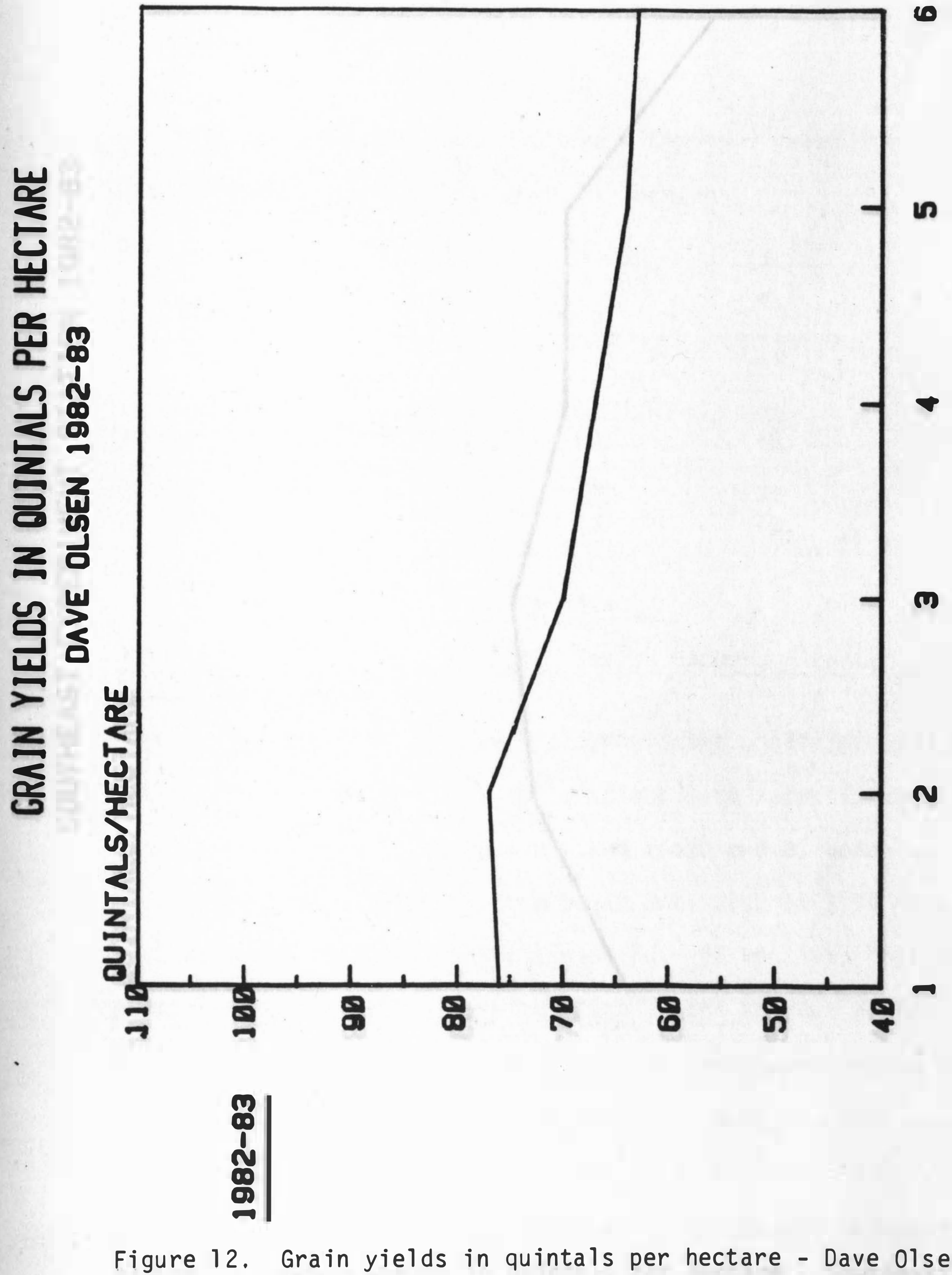

Figure 12. Grain yields in quintals per hectare - Dave Olsen 1982-83

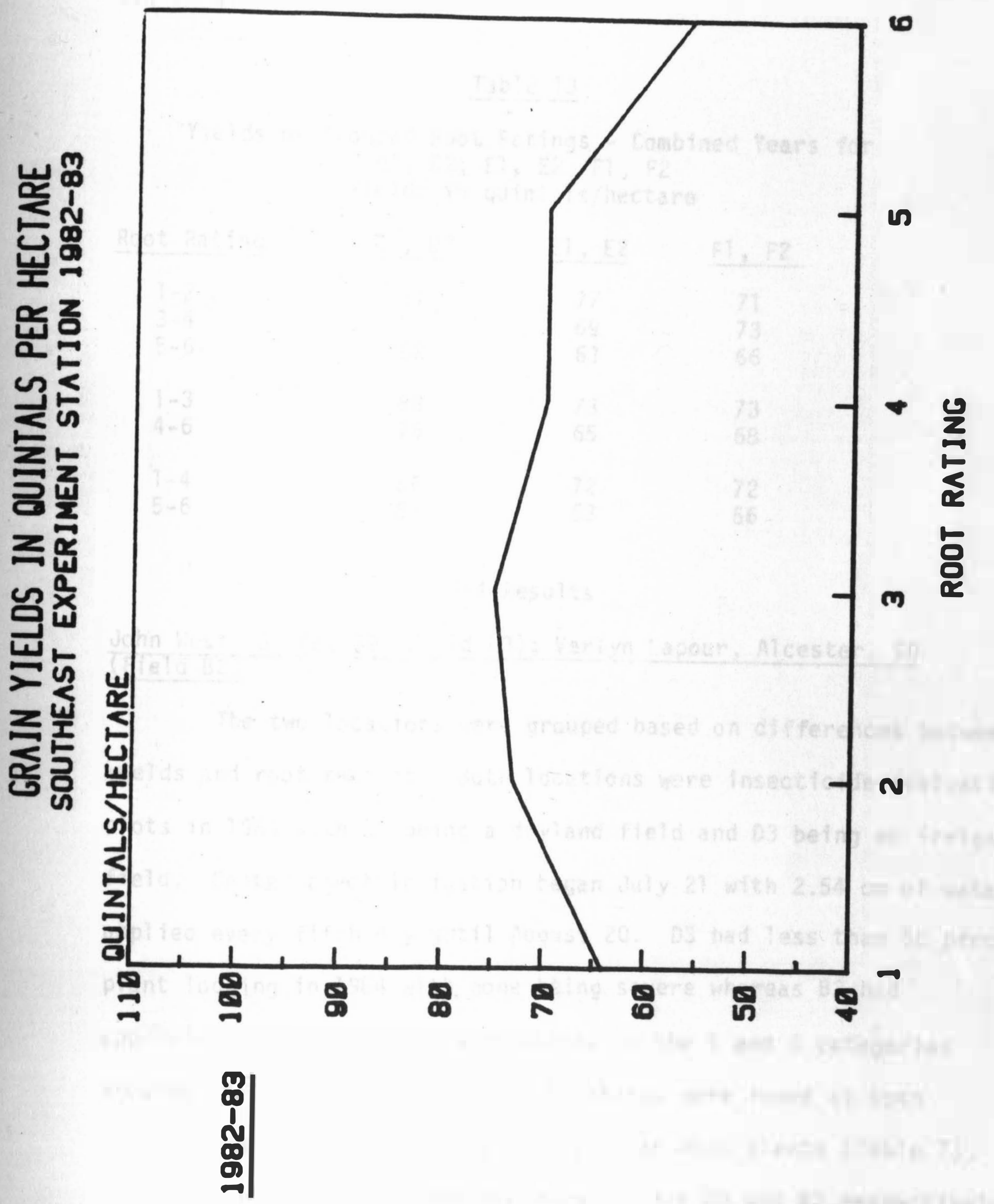

Figure 13. Grain yields in quintals per hectare - Southeast Experiment Station 1982-83

F1, F2 did (Appendix A).

Table 13

Yields by Grouped Root Ratings - Combined Years for
D1, D2; E1, E2; F1, F2
Yields in quintals/hectare

Root Rating	D1, D2	E1, E2	F1, F2
1-2	91	77	71
3-4	81	69	73
5-6	82	63	66
1-3	88	73	73
4-6	76	65	68
1-4	86	72	72
5-6	82	63	66

1984 Results

John West, Onida, SD (Field D3); Verlyn Lapour, Alcester, SD (Field B2)

The two locations were grouped based on differences between yields and root ratings. Both locations were insecticide evaluation plots in 1984 with B2 being a dryland field and D3 being an irrigated field. Center pivot irrigation began July 21 with 2.54 cm of water applied every fifth day until August 20. D3 had less than 50 percent plant lodging in 1984 with none being severe whereas B2 had approximately 50% lodging with plants in the 5 and 6 categories showing the greatest lodging. All ratings were found at both locations with all categories having 20 or more plants (Table 7).

Planting dates were May 9 and 21 for D3 and B2 respectively (Table 6). Plant maturity at D3 should not have interacted with

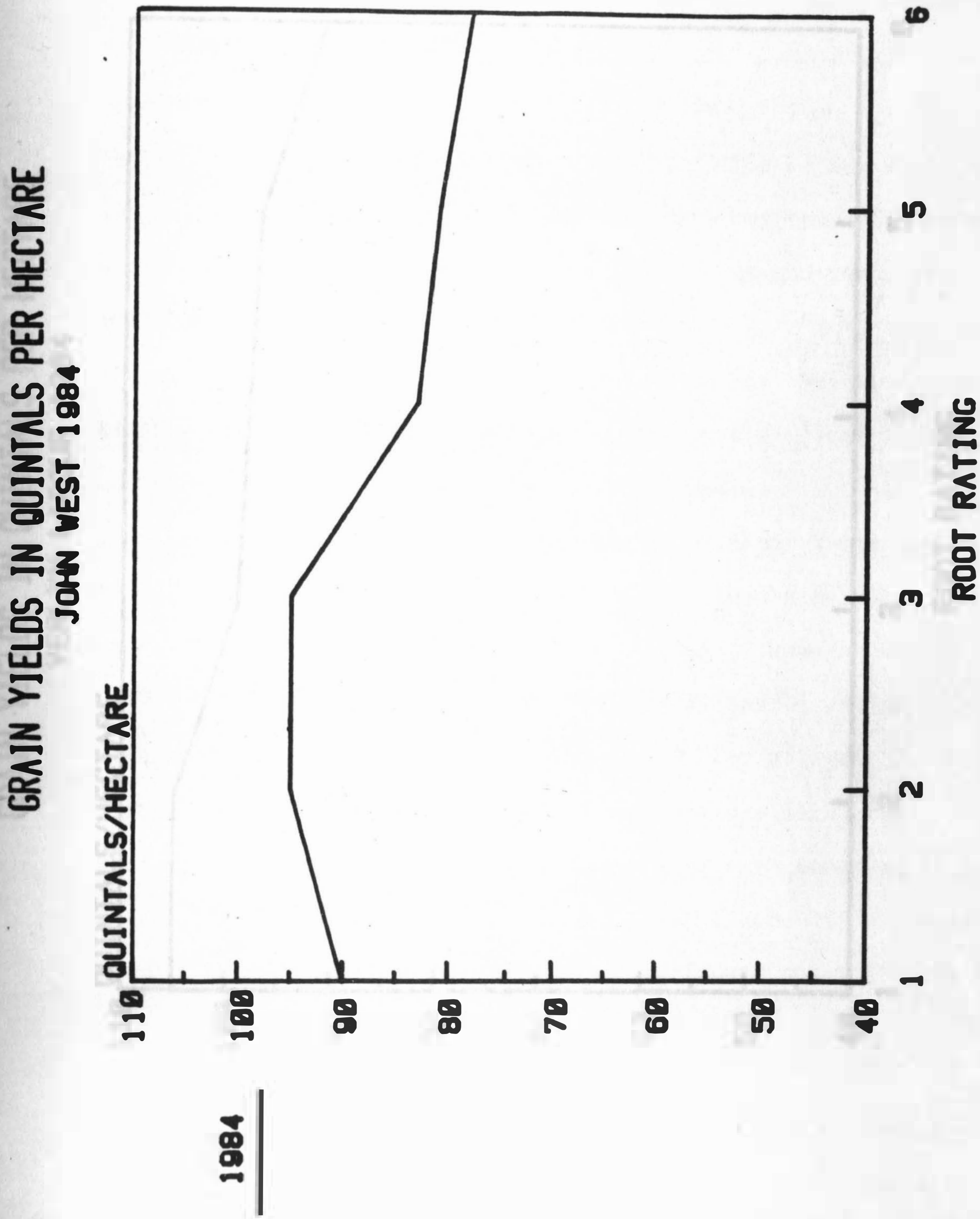

Figure 14. Grain yields in quintals per hectare - John West 1984

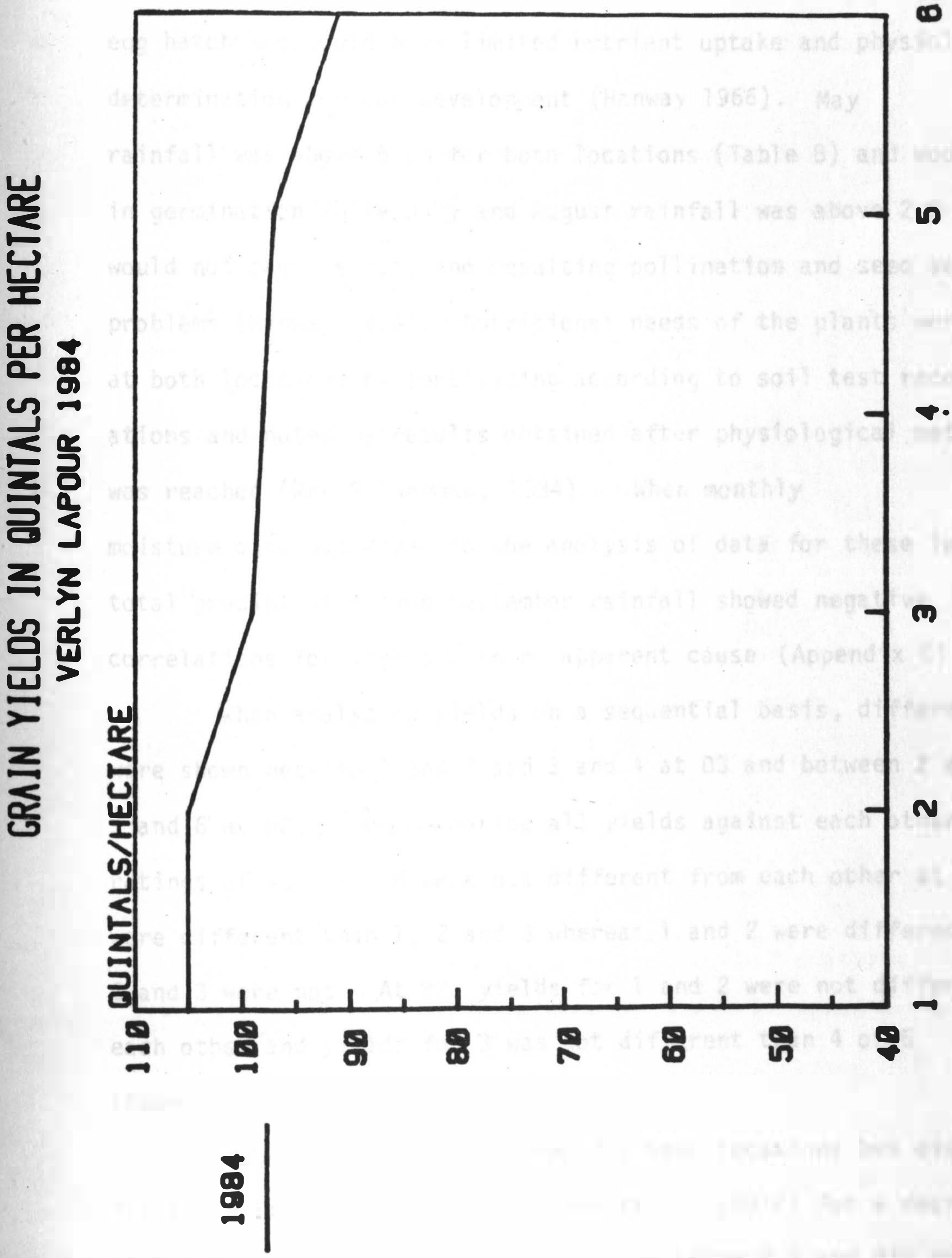

Figure 15. Grain yields in quintals per hectare - Verlyn Lapour 1984

rootworm development whereas B2 was developing its root system at egg hatch and could have limited nutrient uptake and physiological determination for ear development (Hanway 1966). May rainfall was above 6 cm for both locations (Table 8) and would aid in germination while July and August rainfall was above 2.9 cm and would not cause stress and resulting pollination and seed set problems (Hanway 1966). Nutritional needs of the plants were met at both locations by fertilizing according to soil test recommendations and noted by results obtained after physiological maturity was reached (Ron Gelderman, 1984). When monthly moisture data was added to the analysis of data for these locations, total precipitation and September rainfall showed negative correlations for yields with no apparent cause (Appendix C).

When analyzing yields on a sequential basis, differences were shown between 1 and 2 and 3 and 4 at D3 and between 2 and 3 and 5 and 6 at B2. When comparing all yields against each other, ratings of 4, 5 and 6 were not different from each other at D3 but were different than 1, 2 and 3 whereas 1 and 2 were different although 2 and 3 were not. At B2, yields for 1 and 2 were not different from each other and yields for 3 was not different than 4 or 5 (Appendix A).

Regressions were apparent for both locations but did not fit the data as suggested by Turpin et al. (1972) for a decrease of 6.3 quintals/hectare for each rating below 2.5 and did not coincide with Sutter et al. (1981) data (Figures 14 and 15). Hand harvested yields for both locations were approximately the same as rough estimates of yields made by the farmers from combine loads taken from the fields (Table 9).

When analyzing yields by the 1-2, 3-4, 5-6 groupings or the (1,2,3)(4,5,6) and (1,2,3,4)(5,6) groupings, B2 showed differences for all three groupings whereas D2 had no differences between 1-2 and 3-4 with all other groupings being different (Appendix A).

Table 14

Yields by Grouped Root Ratings in Fields B2, D3
Yield in quintals/hectare

Root Rating	B2	D3
1-2	105	94
3-4	99	92
5-6	95	80
1-3	102	94
4-6	96	82
1-4	101	93
5-6	95	80

Combined Years 1982-84

Data was combined for D1, D2 and D3 and analyzed the same as single year data. On a sequential basis, differences were observed between 2 and 3 and 3 and 4. When comparing all yields, no differences occurred between 4, 5 and 6 although they were different than 1, 2 and 3. When analyzing yields from 1, 2 and 3, only 2 and 3 were different from each other (Appendix A).

A regression line occurred for the combination of data that coincides with data from Turpin et al. (1972) for a decrease in

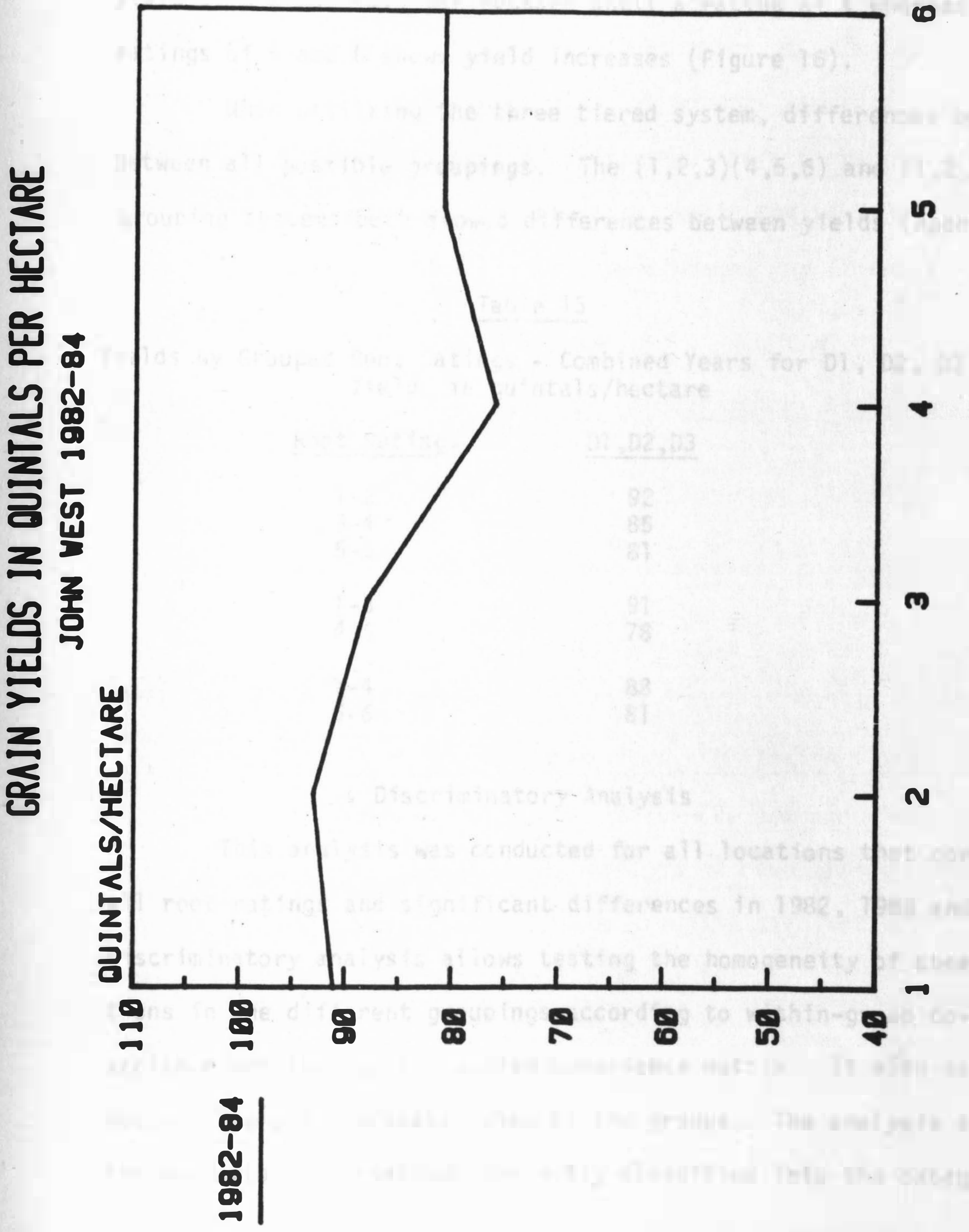

Figure 16. Grain yields in quintals per hectare - John West 1982-84

yield of 6.3 quintals per hectare until a rating of 4 whereas ratings of 5 and 6 shows yield increases (Figure 16).

When utilizing the three tiered system, differences occurred between all possible groupings. The (1,2,3)(4,5,6) and (1,2,3,4)(5,6) grouping systems both showed differences between yields (Appendix A).

Table 15

Yields by Grouped Root Ratings - Combined Years for D1, D2, D3
Yields in quintals/hectare

Root Rating	D1,D2,D3
1-2	92
3-4	85
5-6	81
1-3	91
4-6	78
1-4	88
5-6	81

Discriminatory Analysis

This analysis was conducted for all locations that contained all root ratings and significant differences in 1982, 1983 and 1984. Discriminatory analysis allows testing the homogeneity of observations in the different groupings according to within-group covariance matrices or the pooled covariance matrix. It also takes into account the prior probabilities of the groups. The analysis shows the number of observations correctly classified into the categories.

Dave Olsen, Fairview, SD (Fields E1, E2 and E1-E2)

When utilizing all six root ratings separately, very low percentages of plants fell into the correct categories on a yield basis. The amount of correct responses improves when grouping the ratings into three tiers and still better when grouping into two tiers. E1 gave the highest percentage of correct response when using the (1,2,3)(4,5,6) rating scale, while the (1,2,3,4)(5,6) grouping system provided the best percentages for E2 and E1-E2 (Appendix B).

Table 16

Summary of Correct Responses from Discriminatory Analysis for E1, E2, E1-E2

	E1		E2		E1-E2	
Ratings	# correct	% correct	# correct	% correct	# correct	% correct
1-6	36	14.4	74	15.4	156	21.4
1-2,3-4,5-6	83	33.2	189	39.4	239	32.7
1-3,4-6	148	59.2	282	58.7	388	53.2
1-4,5-6	144	57.6	293	61.0	354	48.4

Southeast Experiment Station, Beresford, SD (Fields F1,F2; F1-F2)

As in the data for E1, E2 and E1-E2, grouping into new tiered systems gave the best percentages of responses on the basis of yield. Using the (1,2,3,4)(5,6) grouping gave the best responses for F1, F2 and F1-F2 (Appendix B).

Table 17

Summary of Correct Responses from Discriminatory Analysis for F1, F2, F1-F2

	F1		F2		F1-F2	
Ratings	# correct	% correct	# correct	% correct	# correct	% correct
1-6	40	20.1	85	17.1	108	14.7
1-2,3-4,5-6	82	34.3	230	46.4	280	38.1
1-3,4-6	162	67.8	235	47.4	365	49.7
1-4,5-6	169	70.7	242	48.8	423	57.6

Paul Bonhorst, Pierre, SD (Field G); Verlyn Lapour, Alcester, SD (Field B2)

As in other locations, using a 1-6 rating scale does not give high percentages of correct responses on a yield basis. At both locations the (1,2,3,4)(5,6) groupings gave the best response though only by 0.7 and 0.4 percent respectively over the (1,2,3)(4,5,6) groupings (Appendix B).

Table 18

Summary of Correct Responses from Discriminatory Analysis for G, B2

	G		B2	
Ratings	# correct	% correct	# correct	% correct
1-6	58	11.9	62	12.5
1-2,3-4,5-6	172	35.4	179	36.0
1-3,4-6	301	61.9	296	59.6
1-4,5-6	304	62.6	298	60.0

John West, Onida, SD (Field D1, D2, D3, D1-D2, D1-D3)

As in other locations when using the two grouping systems higher percentages of correct responses occur when using the (1,2,3)(4,5,6) or (1,2,3,4)(5,6) grouping systems than when using the

1-6 groupings or the 1-2, 3-4, 5-6 grouping (Appendix B).

Table 19

Summary of Correct Responses from Discriminatory Analysis for D1, D2, D3, D1-D2, D1-D3

Ratings	D1 # correct	D1 % correct	D2 # correct	D2 % correct	D3 # correct	D3 % correct
1-6	41	18.8	82	17.4	121	24.2
1-2,3-4,5-6	81	37.2	255	54.0	199	39.8
1-3,4-6	126	57.8	281	59.5	340	68.0
1-4,5-6	114	52.3	240	50.8	335	67.0

Ratings	D1-D2 # correct	D1-D2 % correct	D1-D3 # correct	D1-D3 % correct
1-6	105	15.2	210	17.7
1-2,3-4,5-6	216	31.3	373	31.3
1-3,4-6	362	52.5	685	57.6
1-4,5-6	278	40.3	542	45.5

On the basis of discriminatory analysis, data showed that when estimating yields on a root rating basis, the percentages of correct responses were not high but a three tiered or a two tiered system gave a higher percentage of correct responses. Using the 1-6 rating system the lowest percentage of correct responses was 11.9 for location G whereas the highest percentage was 24.2 for location D3. When using the two tiered systems, the (1,2,3)(4,5,6) groupings gave the best percentage of correct responses seven times whereas the (1,2,3,4)(5,6) groupings gave the best percentage of correct responses six times. The highest overall percentage for correct responses occurred for F1 with 70.7 percent when using the

(1,2,3,4)(5,6) grouping while the lowest percentage using the two tiered systems occurred with the E1, E2 combination with 40.3 percent using the (1,2,3,4)(5,6) grouping.

When analyzing the data by LS Means, differences between each rating and its corresponding yield did not occur on a sequential basis. In nine of eleven locations, no difference was shown between yields from 1 and 2 and at eight locations no differences were noted between yields from 4, 5 and 6. When utilizing groupings of 1-2, 3-4, 5-6; of (1,2,3)(4,5,6); and (1,2,3,4)(5,6), differences between yields became apparent. The three tiered system showed differences between all groups at five locations whereas the (1,2,3,4)(5,6) system showed differences at nine locations and the (1,2,3)(4,5,6) system showed differences at eleven locations.

Differences between yields were shown for all locations except A, B1 and C, contrary to data obtained by Sutter et al. (1981) which stated no difference in yields would be noticed when insecticide treated and having varying amounts of infestation by rootworm. Turpin et al. (1972) stated that after a 2.5 root rating, yields decreased by 6.3 quintals per hectare. However, three years data from these locations did not show this reduction through all root ratings, with eight locations showing increases in yields at the 5 and 6 ratings.

The Iowa State root rating scale developed by Hills and Peters (1971) is not correct when segregating for expected yields, and does not fairly assess damage between ratings. On a yield basis, the (1,2,3)(4,5,6) root rating system gave correct responses for 64 percent of the locations when classifying plants into the correct categories and showed differences in yields for 100 percent of the locations.

CONCLUSIONS

The ISU (1-6) root rating scale does not segregate between ratings on a yield basis. At no location in the three year study did differences between yields for each root rating occur whether analyzed sequentially or between all possible combinations.

Regressions as suggested by Turpin et al. (1972) did not exist on an individual plant basis in South Dakota during the period of this study. Their data was an accumulation of the average root ratings and yields for 526 fields without investigating nutrient levels in the fields, weed control or farming practices for each field. The data at three locations was similar to Sutter et al. (1981) showing no difference between root ratings and yields. They used several levels of artificial egg infestations to vary damage and did not report root ratings by yields.

The yield-root rating relationship showed two tiered grouping (1,2,3) (4,5,6) or (1,2,3,4) (5,6) systems with the best correlations between yields and root ratings. The highest percentage of correct responses on the basis of yields came from the (1,2,3,4) (5,6) grouping system and was 46 percent higher than the best percentage using the 6 rating system. More research needs to be conducted on where to divide the two tiered groupings on a root damage and yield basis. On the basis of yield, 11 locations showed differences between the (1,2,3) (4,5,6) grouping and 9 locations showed differences between the (1,2,3,4) (5,6) grouping.

More locations and combined years data would help to segregate the groups on a yield basis.

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Appendix A

Glen Langum - 1982
Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
73	1	*	0.6474	0.9786	0.5499	0.3547	0.9013
71	2	0.6474	*	0.6043	0.8831	0.1478	0.7407
73	3	0.9786	0.6043	*	0.4914	0.2641	0.9057
71	4	0.5499	0.8831	0.4914	*	0.1103	0.6368
77	5	0.3547	0.1478	0.2641	0.1103	*	0.2887
72	6	0.9013	0.7407	0.9057	0.6368	0.2887	*

Verlyn Lapour - 1982
Probability Table for Yields by Root Rating

Yield LS Means	Ratings	4	5	6
81	4	*	0.9918	0.8861
80	5	0.9918	*	0.9113
81	6	0.8861	0.9113	*

Arlyn Olsen - 1982
Probability Table for Yields by Root Rating

Yield LS Means	Ratings	4	5	6
75	4	*	0.9045	0.9151
75	5	0.9045	*	0.9951
75	6	0.9151	0.9951	*

Appendix A

John West - 1982

Probability Table for Yields by Root Rating

Yield LS Means qu/ha	Ratings	1	2	3	4	5	6
88	1	*	0.2192	0.0296	0.0011	0.0204	0.0974
85	2	0.2192	*	0.3636	0.0214	0.1902	0.5830
82	3	0.0296	0.3636	*	0.0640	0.4748	0.8500
78	4	0.0011	0.0214	0.0640	*	0.4460	0.1113
80	5	0.0204	0.1902	0.4748	0.4460	*	0.4629
75	6	0.0974	0.5830	0.8500	0.1113	0.4629	*

Probability Table for Yields by Root Rating

Yield LS Means qu/ha	Ratings	1-2	3-4	5-6
86	1-2	*	0.0085	0.0556
81	3-4	0.0085	*	0.7445
82	5-6	0.0556	0.7445	*

Probability Table for Yield by Root Rating

Yield LS Means qu/ha	Ratings	1-3	4-6
84	1-3	*	0.0224
80	4-6	0.0224	*

Probability Table for Yield by Root Rating

Yield LS Means qu/ha	Ratings	1-4	5-6
83	1-4	*	0.6252
82	5-6	0.6252	*

Appendix A

Dave Olsen - 1982

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
62	1	*	0.4605	0.3242	0.0255	0.0816	0.0204
60	2	0.4605	*	0.8108	0.0605	0.1971	0.0483
59	3	0.3242	0.8101	*	0.0554	0.2184	0.0484
56	4	0.0255	0.0605	0.0554	*	0.7377	0.6688
57	5	0.0816	0.1971	0.2184	0.7377	*	0.4980
55	6	0.0204	0.0483	0.0484	0.6688	0.4980	*

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1-2	3-4	5-6
60	1-2	*	0.1563	0.0140
58	3-4	0.1563	*	0.1281
56	5-6	0.0140	0.1281	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-3	4-6
60	1-3	*	0.0022
56	4-6	0.0022	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-4	5-6
59	1-4	*	0.0435
56	5-6	0.0435	*

Appendix A

Southeast Experiment Station - 1982

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
78	1	*	0.5062	0.4856	0.0058	0.0002	0.0007
82	2	0.5062	*	0.0603	0.0001	0.0001	0.0001
75	3	0.4856	0.0603	*	0.0030	0.0001	0.0003
62	4	0.0058	0.0001	0.0030	*	0.1548	0.2882
54	5	0.0002	0.0001	0.0001	0.1548	*	0.7342
56	6	0.0007	0.0001	0.0003	0.2882	0.7342	*

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1-2	3-4	5-6
80	1-2	*	0.0044	0.0001
71	3-4	0.0044	*	0.0001
55	5-6	0.0001	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-3	4-6
77	1-3	*	0.0001
58	4-6	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-4	5-6
74	1-4	*	0.0001
55	5-6	0.0001	*

Appendix A

John West - 1983
Probability Table for Yields by Root Rating

Yield LS Means qu/ha	Ratings	1	2	3	4	5	6
94	1	*	0.7998	0.0388	0.0001	0.3012	0.5760
93	2	0.7998	*	0.0019	0.0001	0.3236	0.6117
85	3	0.0388	0.0019	*	0.0001	0.7914	0.9622
68	4	0.0001	0.0001	0.0001	*	0.2461	0.3836
82	5	0.3012	0.3236	0.7914	0.2461	*	0.9178
84	6	0.5760	0.6117	0.9622	0.3836	0.9178	*

Southeast Experiment Station - 1983
Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
57	1	*	0.0005	0.0001	0.0002	0.0001	0.9943
71	2	0.0005	*	0.1494	0.4909	0.2027	0.0894
75	3	0.0001	0.1494	*	0.6186	0.7951	0.0313
73	4	0.0002	0.4909	0.6186	*	0.5397	0.0548
75	5	0.0001	0.2027	0.7951	0.5397	*	0.0306
57	6	0.9943	0.0894	0.0313	0.0548	0.0306	*

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Dave Olsen - 1983

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
90	1	*	0.1361	0.0045	0.0008	0.0001	0.0001
83	2	0.1361	*	0.0074	0.0007	0.0001	0.0081
77	3	0.0045	0.0074	*	0.2191	0.0160	0.1805
73	4	0.0008	0.0007	0.2191	*	0.1825	0.5646
68	5	0.0001	0.0001	0.0160	0.1825	*	0.6583
70	6	0.0001	0.0081	0.1805	0.5646	0.6583	*

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1-2	3-4	5-6
84	1-2	*	0.0001	0.0001
75	3-4	0.0001	*	0.0213
69	5-6	0.0001	0.0213	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-3	4-6
80	1-3	*	0.0001
71	4-6	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-4	5-6
79	1-4	*	0.0004
66	5-6	0.0004	*

Appendix A

Paul Bonhorst - 1983

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
81	1	*	0.1908	0.1925	0.0110	0.0025	0.0010
76	2	0.1908	*	0.9650	0.0439	0.0086	0.0040
76	3	0.1925	0.9650	*	0.0612	0.0122	0.0051
71	4	0.0110	0.0439	0.0612	*	0.3280	0.1043
68	5	0.0025	0.0086	0.0122	0.3280	*	0.4281
64	6	0.0010	0.0040	0.0051	0.1043	0.4281	*

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1-2	3-4	5-6
77	1-2	*	0.0982	0.0001
74	3-4	0.0982	*	0.0056
67	5-6	0.0001	0.0056	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-3	4-6
76	1-3	*	0.0001
69	4-6	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-4	5-6
75	1-4	*	0.0004
67	5-6	0.0004	*

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John West - 1982 & 1983

Probability Table for Yields by Root Rating

Yield LS Means qu/ha	Ratings	1	2	3	4	5	6
92	1	*	0.9120	0.0101	0.0001	0.0227	0.0723
91	2	0.9120	*	0.0001	0.0001	0.0114	0.0485
84	3	0.0101	0.0001	*	0.0001	0.4498	0.8245
72	4	0.0001	0.0001	0.0001	*	0.0599	0.0193
81	5	0.0227	0.0114	0.4498	0.0599	*	0.6951
83	6	0.0723	0.0485	0.8245	0.0193	0.6951	*

Probability Table for Yields by Root Rating

Yield LS Means qu/ha	Ratings	1-2	3-4	5-6
91	1-2	*	0.0001	0.0022
81	3-4	0.0001	*	0.6995
82	5-6	0.0022	0.6995	*

Probability Table for Yield by Root Rating

Yield LS Means qu/ha	Ratings	1-3	4-6
88	1-3	*	0.0001
76	4-6	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means qu/ha	Ratings	1-4	5-6
86	1-4	*	0.2247
82	5-6	0.2247	*

Appendix A

Dave Olsen - 1982 & 1983

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
76	1	*	0.6740	0.0936	0.0170	0.0017	0.0021
77	2	0.6740	*	0.0003	0.0001	0.0001	0.0001
70	3	0.0936	0.0003	*	0.1787	0.0134	0.0180
67	4	0.0170	0.0001	0.1787	*	0.2049	0.1720
64	5	0.0017	0.0001	0.0134	0.2049	*	0.8042
63	6	0.0021	0.0001	0.0180	0.1720	0.8042	*

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1-2	3-4	5-6
77	1-2	*	0.0001	0.0001
69	3-4	0.0001	*	0.0039
63	5-6	0.0001	0.0039	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-3	4-6
73	1-3	*	0.0001
65	4-6	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-4	5-6
72	1-4	*	0.0001
63	5-6	0.0001	*

Appendix A

Southeast Experiment Station - 1982 & 1983

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
64	1	*	0.0045	0.0009	0.1045	0.1419	0.1319
73	2	0.0045	*	0.5625	0.1835	0.2513	0.0002
75	3	0.0009	0.5625	*	0.0585	0.1085	0.0001
70	4	0.1045	0.1835	0.0585	*	0.9933	0.0049
70	5	0.1419	0.2513	0.1085	0.9933	*	0.0078
56	6	0.1319	0.0002	0.0001	0.0049	0.0078	*

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1-2	3-4	5-6
71	1-2	*	0.2598	0.0625
73	3-4	0.2598	*	0.0058
66	5-6	0.0625	0.0058	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-3	4-6
73	1-3	*	0.0100
68	4-6	0.0100	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-4	5-6
72	1-4	*	0.0110
66	5-6	0.0110	*

Appendix A

John West - 1984

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
90	1	*	0.0392	0.0445	0.0144	0.0051	0.0024
95	2	0.0392	*	0.9004	0.0001	0.0001	0.0001
95	3	0.0445	0.9004	*	0.0001	0.0001	0.0001
83	4	0.0144	0.0001	0.0001	*	0.5443	0.2700
81	5	0.0051	0.0001	0.0001	0.5443	*	0.5970
79	6	0.0024	0.0001	0.0001	0.2700	0.5970	*

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1-2	3-4	5-6
94	1-2	*	0.2180	0.0001
92	3-4	0.2180	*	0.0001
80	5-6	0.0001	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-3	4-6
94	1-3	*	0.0001
82	4-6	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-4	5-6
93	1-4	*	0.0001
81	5-6	0.0001	*

Appendix A

Verlyn Lapour - 1984

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
105	1	*	0.8938	0.0406	0.0168	0.0039	0.0009
105	2	0.8938	*	0.0111	0.0035	0.0003	0.0001
99	3	0.0406	0.0111	*	0.5733	0.2251	0.0094
98	4	0.0168	0.0035	0.5733	*	0.5537	0.0301
97	5	0.0039	0.0003	0.2251	0.5537	*	0.0712
90	6	0.0009	0.0001	0.0094	0.0301	0.0712	*

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1-2	3-4	5-6
105	1-2	*	0.0004	0.0001
99	3-4	0.0004	*	0.0589
95	5-6	0.0001	0.0589	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-3	4-6
102	1-3	*	0.0001
96	4-6	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-4	5-6
101	1-4	*	0.0004
95	5-6	0.0004	*

Appendix A

John West - 1982-1984

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1	2	3	4	5	6
91	1	*	0.3383	0.1758	0.0001	0.0006	0.0014
93	2	0.3383	*	0.0011	0.0001	0.0001	0.0001
88	3	0.1758	0.0011	*	0.0001	0.0041	0.0087
76	4	0.0001	0.0001	0.0001	*	0.1148	0.1541
81	5	0.0006	0.0001	0.0041	0.1148	*	0.9826
81	6	0.0014	0.0001	0.0087	0.1541	0.9826	*

Probability Table for Yields by Root Rating

Yield LS Means	Ratings	1-2	3-4	5-6
92	1-2	*	0.0001	0.0001
85	3-4	0.0001	*	0.0430
81	5-6	0.0001	0.0430	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-3	4-6
91	1-3	*	0.0001
78	4-6	0.0001	*

Probability Table for Yield by Root Rating

Yield LS Means	Ratings	1-4	5-6
88	1-4	*	0.0001
81	5-6	0.0001	*

Appendix B

Discriminatory Analysis Tables - Dave Olsen 1982

Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	20	2	5	4	0	16	47
	42.6%	4.2%	10.6%	8.5%	0.0%	34.0%	100%
4	13	0	2	3	2	20	40
	32.5%	0.0%	5.0%	7.5%	5.0%	50.0%	100%
1	11	1	4	0	1	5	22
	50.0%	4.6%	18.2%	0.0%	4.6%	22.7%	100%
3	43	1	8	3	12	28	95
	45.3%	1.1%	8.4%	3.2%	12.6%	29.5%	100%
6	6	1	1	2	0	11	21
	28.6%	4.8%	4.7%	9.5%	0.0%	52.4%	100%
5	9	2	0	1	1	12	25
	36.0%	8.0%	0.0%	4.0%	4.0%	48.0%	100%
Total	102	7	20	13	16	92	250
	40.8%	2.8%	8.0%	5.2%	6.4%	36.8%	100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	38	6	25	69
	55.1%	8.7%	36.2%	100%
3-4	58	19	58	135
	43.0%	14.1%	43.0%	100%
5-6	18	2	26	46
	39.1%	4.4%	56.5%	100%
Total	114	27	109	250
	45.6%	10.8%	43.6%	100%

Discriminatory Analysis Table - Dave Olsen 1982 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	35	51	86
	40.7%	59.3%	100%
1-3	97	67	164
	59.2%	40.9%	100%
Total	132	118	250
	52.8%	47.2%	100%

From Rating	1-4	5-6	Total
1-4	117	87	204
	57.4%	42.7%	100%
5-6	19	27	46
	41.3%	58.7%	100%
Total	136	114	250
	54.4%	45.6%	100%

Appendix B

Discriminatory Analysis Table - Dave Olsen 1983
Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	67 46.5%	3 2.1%	0 0.0%	53 36.8%	18 12.5%	3 2.1%	144 100%
4	15 18.3%	0 0.0%	0 0.0%	41 50.0%	26 31.7%	0 0.0%	82 100%
1	12 54.6%	0 0.0%	0 0.0%	7 31.8%	3 13.6%	0 0.0%	22 100%
3	61 36.1%	1 0.6%	0 0.0%	66 39.1%	36 21.3%	5 3.0%	169 100%
6	4 18.2%	0 0.0%	0 0.0%	12 54.6%	5 22.7%	1 4.6%	22 100%
5	4 9.8%	0 0.0%	0 0.0%	19 46.3%	17 41.5%	1 2.4%	41 100%
Total	163 34.0%	4 0.8%	0 0.0%	198 41.3%	105 21.9%	10 2.1%	480 100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	72 43.4%	50 30.1%	44 26.5%	166 100%
3-4	59 23.5%	78 31.1%	114 45.4%	251 100%
5-6	7 11.1%	17 27.0%	39 61.9%	63 100%
Total	138 28.8%	145 30.2%	197 41.0%	480 100%

Discriminatory Analysis Table - Dave Olsen 1983 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	31 21.4%	114 78.6%	145 100%
1-3	168 50.2%	167 49.9%	335 100%
Total	199 41.5%	281 58.5%	480 100%

From Rating	1-4	5-6	Total
1-4	255 61.2%	162 38.9%	417 100%
5-6	25 39.7%	38 60.3%	63 100%
Total	280 58.3%	200 41.7%	480 100%

Appendix B

Discriminatory Analysis Tables - Dave Olsen 1982-83
Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	21 1.1%	59 30.9%	6 3.1%	57 29.8%	28 14.7%	20 10.5%	191 100%
4	14 11.5%	9 7.4%	6 4.9%	49 40.2%	25 20.5%	19 15.6%	122 100%
1	5 11.4%	10 22.7%	0 0.0%	14 31.8%	6 13.6%	9 20.5%	44 100%
3	28 10.6%	47 17.8%	14 5.3%	80 30.3%	49 18.6%	46 17.4%	264 100%
6	1 2.3%	9 9.3%	0 0.0%	18 41.9%	14 32.6%	6 14.0%	43 100%
5	7 10.6%	3 4.6%	2 3.0%	24 36.4%	23 34.9%	7 10.6%	66 100%
Total	76 10.4%	132 18.7%	28 3.8%	242 33.2%	145 19.9%	107 14.7%	730 100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	94 40.0%	50 21.3%	91 38.7%	235 100%
3-4	93 24.1%	71 18.4%	222 57.5%	386 100%
5-6	14 12.9%	21 19.3%	74 67.9%	109 100%
Total	201 27.5%	142 19.5%	387 53.0%	730 100%

Discriminatory Analysis Table - Dave Olsen 1982-83 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	56 24.2%	175 75.8%	231 100%
1-3	213 42.7%	286 57.3%	499 100%
Total	269 36.9%	461 63.2%	730 100%

From Rating	1-4	5-6	Total
1-4	270 43.5%	351 56.5%	621 100%
5-6	25 22.9%	84 77.1%	109 100%
Total	295 40.4%	435 59.6%	730 100%

Appendix B

Discriminatory Analysis Tables - S.E. Experiment Station 1982
Number of Observations & Percent Classified into Ratings

From Rating	1	2	3	4	5	6	Total
1	2	11	3	2	4	0	22
	9.1%	50.0%	13.6%	9.1%	18.2%	0.0%	100%
2	3	25	7	5	3	3	46
	6.5%	54.4%	15.2%	10.9%	6.5%	6.5%	100%
3	5	47	9	13	21	3	98
	5.1%	48.0%	9.2%	13.3%	21.4%	3.1%	100%
4	3	6	7	4	11	3	34
	8.8%	17.7%	20.6%	11.8%	32.4%	8.8%	100%
5	1	1	1	4	6	6	19
	5.3%	5.3%	5.3%	21.5%	31.6%	31.6%	100%
6	1	2	2	4	9	2	20
	5.0%	10.0%	10.0%	20.0%	45.0%	10.0%	100%
Total	15	92	29	32	54	17	239
	6.3%	38.5%	12.1%	13.4%	22.6%	7.1%	100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	52	0	16	68
	76.5%	0.0%	23.5%	100%
3-4	80	0	52	132
	60.6%	0.0%	39.4%	100%
5-6	9	0	30	39
	23.1%	0.0%	76.9%	100%
Total	141	0	98	239
	59.0%	0.0%	41.0%	100%

Discriminatory Analysis Table - S.E. Exper. Sta, 1982 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
1-3	115 63.9%	15 30.7%	166 100%
4-6	26 35.6%	47 64.4%	73 100%
Total	141 59.0%	98 41.0%	239 100%

From Rating	1-4	5-6	Total
1-4	141 70.%	59 29.5%	200 100%
5-6	11 28.2%	28 71.8%	39 100%
Total	152 63.6%	87 36.4%	239 100%

Appendix B

Discriminatory Analysis Table - S.E. Experiment Station 1983
Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	39 26.5%	12 8.2%	7 4.8%	31 21.1%	44 29,9%	14 9.5%	147 100%
4	16 20,0%	4 5.0%	2 2.5%	23 28,8%	33 41,3%	2 2.5%	80 100%
1	16 38.2%	1 2,4%	0 0,0%	7 16.7%	10 23,8%	8 19,1%	42 100%
3	35 21,1%	8 4.8%	11 6.6%	39 23.5%	66 39,8%	7 4,2%	166 100%
6	4 50,0%	0 0,0%	0 0,0%	0 0.0%	3 37.5%	1 12.5%	8 100%
5	5 9,4%	4 7,6%	2 3.8%	18 34,0%	22 41.5%	2 3.8%	53 100%
Total	115 23,2%	29 5,9%	22 4,4%	118 23,8%	178 35,9%	34 6,9%	496 100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	78 41.5%	81 43,1%	29 15.4%	188 100%
3-4	44 17.8%	138 55.9%	65 26.3%	247 100%
5-6	14 23.0%	33 54,1%	14 23.0%	61 100%
Total	136 27,4%	252 50,8%	108 21,8%	496 100%

Discriminatory Analysis Table - S.E. Exper. Sta. 1983 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	35 24.8%	106 75.2%	141 100%
1-3	129 36.3%	226 63.7%	355 100%
Total	164 33.1%	332 66.9%	496 100%

From Rating	1-4	5-6	Total
1-4	207 47.6%	228 52.4%	435 100%
5-6	26 42.6%	35 57.4%	61 100%
Total	233 47.0%	263 53.0%	496 100%

Appendix B

Discriminatory Analysis Table - S.E, Experiment Station 1982-83
Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
1	1 0,5%	21 10.9%	69 35,9%	35 18,2%	0 0,0%	66 34.4%	192 100%
2	0 0.0%	6 5.3%	40 35.1%	29 25,4%	0 0,0%	39 34.2%	114 100%
3	0 0,0%	4 6.3%	19 29,7%	10 15,6%	0 0,0%	31 48.4%	64 100%
4	0 0,0%	22 8.3%	106 40,0%	57 21,5%	0 0.0%	80 30,2%	265 100%
5	0 0,0%	0 0,0%	6 21,4%	4 14,3%	0 0,0%	18 64,3%	28 100%
6	0 0.0%	5 6,9%	24 33.3%	18 25,0%	0 0.0%	25 34.7%	72 100%
Total	1 0,1%	58 7,9%	264 35,9%	153 20.8%	0 0.0%	259 35.2%	735 100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	36 14,1%	121 42,3%	99 38,7%	256 100%
3-4	40 10.6%	200 52.8%	139 36,7%	379 100%
5-6	15 15.0%	41 41,0%	44 44,0%	100 100%
Total	91 12,4%	362 49,3%	282 38,4%	735 100%

Discriminatory Analysis Table - S.E. Exp. Sta. 1982-83 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	63 29.4%	151 70.6%	214 100%
1-3	214 41.1%	307 58.9%	521 100%
Total	277 37.7%	458 62.3%	735 100%

From Rating	1-4	5-6	Total
1-4	368 58.0%	267 42.1%	635 100%
5-6	45 45.0%	55 55.0%	100 100%
Total	413 56.2%	322 43.8%	735 100%

Appendix B

Discriminatory Analysis Table - Bonhorst 1983
Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	82 53.2%	9 5.8%	8 5.1%	9 5.8%	10 6.4%	37 23.7%	156 100%
4	37 37.0%	2 2.0%	5 5.0%	10 10.0%	7 7.0%	39 39.0%	100 100%
1	21 61.8%	0 0.0%	2 5.9%	2 5.9%	2 5.9%	7 20.6%	34 100%
3	65 53.7%	5 4.1%	4 3.3%	7 5.8%	1 0.8%	39 32.2%	121 100%
6	4 16.0%	2 8.0%	2 8.0%	3 12.0%	1 4.0%	13 52.0%	25 100%
5	18 36.0%	1 2.0%	1 2.0%	7 14.0%	1 2.0%	22 44.0%	50 100%
Total	228 46.91%	19 3.91%	22 4.5%	38 7.8%	22 4.5%	157 32.3%	486 100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	115 60.5%	18 9.5%	57 30.0%	190 100%
3-4	115 52.0%	17 7.7%	89 40.3%	221 100%
5-6	28 37.3%	7 9.3%	40 53.3%	75 100%
Total	258 53.1%	42 8.6%	186 38.3%	486 100%

Discriminatory Analysis Table - Bonhorst 1983 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	75 42.9%	100 57.1%	175 100%
1-3	201 64.6%	110 35.4%	311 100%
Total	276 56.8%	210 43.2%	486 100%

From Rating	1-4	5-6	Total
1-4	261 63.5%	150 36.5%	411 100%
5-6	32 42.7%	43 57.3%	75 100%
Total	293 60.3%	193 39.7%	486 100%

Appendix B

Discriminatory Analysis Table - Lapour 1984
Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	58 57.4%	4 4.0%	6 5.9%	0 0.0%	10 9.9%	23 22.8%	101 100%
4	35 36.8%	7 7.4%	8 8.4%	0 0.0%	8 8.4%	37 39.0%	95 100%
1	26 61.9%	3 7.1%	2 4.8%	0 0.0%	2 4.8%	9 21.4%	42 100%
3	49 40.2%	13 10.7%	8 6.6%	4 3.3%	7 5.7%	41 33.6%	122 100%
6	6 20.7%	2 6.9%	2 6.9%	1 3.5%	4 13.8%	14 48.3%	29 100%
5	34 31.5%	7 6.5%	7 6.5%	7 6.5%	10 9.3%	43 39.8%	108 100%
Total	208 41.9%	36 7.2%	33 6.6%	12 2.4%	41 8.3%	167 33.6%	497 100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	91 63.6%	10 7.0%	42 29.4%	143 100%
3-4	104 47.9%	21 9.7%	92 42.4%	217 100%
5-6	49 35.8%	21 15.3%	67 48.9%	137 100%
Total	244 49.1%	52 10.5%	201 40.4%	497 100%

Discriminatory Analysis Table - Lapour 1984 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	101 43.5%	131 56.5%	232 100%
1-3	165 62.3%	100 37.7%	265 100%
Total	266 53.5%	231 46.5%	497 100%

From Rating	1-4	5-6	Total
1-4	220 61.1%	140 38.9%	360 100%
5-6	59 43.1%	78 56.9%	137 100%
Total	279 56.1%	218 43.9%	497 100%

Appendix B

Discriminatory Analysis Table - John West 1982
Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	10 31,3%	5 15,6%	1 3,1%	8 25.0%	5 15,6%	3 9.4%	32 100%
4	8 22,2%	3 8,3%	2 5,6%	20 55,6%	2 5.2%	1 2,8%	36 100%
1	10 47,6%	2 9.5%	0 0,0%	5 23.8%	4 19.6%	0 0.0%	21 100%
3	33 40.7%	10 12.4%	4 4.9%	26 32,1%	5 6,1%	3 3.7%	81 100%
6	11 44.0%	1 4,0%	0 0,0%	11 44.0%	1 4,0%	1 4.0%	25 100%
5	7 30.4%	3 13.0%	0 0.0%	12 52,6%	1 4.4%	0 0,0%	23 100%
Total	79 36,2%	24 11.0%	7 3.2%	82 37.6%	18 8.3%	8 3.7%	218 100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	27 50,9%	22 41,5%	4 7.6%	53 100%
3-4	52 44,4%	53 45.3%	12 10.3%	117 100%
5-6	22 45.8%	25 52.1%	1 2.1%	48 100%
Total	101 46,3%	100 45.9%	17 7,8%	218 100%

Discriminatory Analysis Table - John West 1982 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	36 42.9%	48 57.1%	84 100%
1-3	78 58.2%	56 41.8%	134 100%
Total	114 52.3%	104 47.7%	218 100%

From Rating	1-4	5-6	Total
1-4	89 52.4%	81 47.7%	170 100%
5-6	23 47.9%	25 52.1%	48 100%
Total	112 51.4%	106 48.6%	218 100%

Appendix B

Discriminatory Analysis Table - John West 1983

Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	98 49.5%	11 5.6%	14 7.1%	41 20.7%	30 15.2%	4 2.0%	198 100%
4	5 8.2%	1 1.6%	4 6.6%	41 67.2%	7 11.5%	3 4.9%	61 100%
1	20 52.6%	2 5.3%	3 7.9%	8 21.1%	2 5.3%	3 7.9%	38 100%
3	53 31.6%	17 10.1%	9 5.4%	50 29.8%	34 20.2%	5 3.0%	168 100%
6	1 50.0%	0 0.0%	0 0.0%	1 50.0%	0 0.0%	0 0.0%	2 100%
5	2 40.0%	0 0.0%	0 0.0%	2 40.0%	1 20.0%	0 0.0%	5 100%
Total	179 37.9%	31 6.6%	30 6.4%	143 30.3%	74 15.7%	15 3.2%	472 100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	133 56.4%	73 30.9%	30 12.7%	236 100%
3-4	79 34.5%	122 53.3%	28 12.2%	229 100%
5-6	3 42.9%	4 57.1%	0 0.0%	7 100%
Total	215 45.5%	199 42.2%	58 12.3%	472 100%

Discriminatory Analysis Table - John West 1983 (cont.)
Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	13 19.1%	55 80.9%	68 100%
1-3	226 55.9%	178 44.1%	404 100%
Total	239 50.6%	233 49.4%	472 100%

From Rating	1-4	5-6	Total
1-4	236 50.8%	229 49.3%	465 100%
5-6	3 42.9%	4 57.1%	7 100%
Total	239 50.6%	233 49.4%	472 100%

Appendix B

Discriminatory Analysis Table - John West 1984
Number of Observations and Percent Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	12	78	6	6	4	30	136
	8.8%	57.4%	4.4%	4.4%	2.9%	22.1%	100%
4	9	16	2	7	0	31	65
	13.9%	24.6%	3.1%	10.8%	0.0%	47.7%	100%
1	11	25	5	5	2	20	68
	16.2%	36.8%	7.4%	7.4%	2.9%	29.4%	100%
3	29	86	9	5	2	26	157
	18.5%	54.8%	5.7%	3.2%	1.3%	16.6%	100%
6	2	7	1	4	1	15	30
	6.7%	23.3%	3.3%	13.3%	3.3%	50.0%	100%
5	4	12	1	2	1	24	44
	9.1%	27.3%	2.3%	4.6%	2.3%	54.6%	100%
Total	67	224	24	29	10	146	500
	13.4%	44.8%	4.8%	5.8%	2.0%	29.2%	100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	115	23	66	204
	56.4%	11.3%	32.4%	100%
3-4	114	37	71	222
	51.4%	16.7%	32.0%	100%
5-6	21	6	47	74
	28.4%	8.1%	63.5%	100%
Total	250	66	184	500
	50.0%	13.2%	36.8%	100%

Discriminatory Analysis Table - John West 1984 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	51	88	139
	36.7%	63.3%	100%
1-3	252	109	361
	69.8%	30.2%	100%
Total	303	197	500
	60.6%	39.4%	100%

From Rating	1-4	5-6	Total
1-4	288	138	426
	67.6%	32.4%	100%
5-6	27	47	74
	36.5%	63.5%	100%
Total	315	185	500
	63.0%	37.0%	100%

Appendix B

Discriminatory Analysis Tables - John West 1982-83
Number of Observations and Percent Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	66	30	0	36	28	70	230
	28.7%	13.0%	0.0%	15.7%	12.2%	30.4%	100%
4	4	1	0	42	21	29	97
	4.1%	1.0%	0.0%	43.3%	21.7%	29.9%	100%
1	15	8	0	5	11	20	59
	25.4%	13.6%	0.0%	8.5%	18.6%	33.9%	100%
3	39	16	1	48	46	99	249
	15.7%	6.4%	0.4%	19.3%	18.5%	39.8%	100%
6	6	0	0	6	6	9	27
	22.2%	0.0%	0.0%	22.2%	22.2%	33.3%	100%
5	4	0	0	7	8	9	28
	14.3%	0.0%	0.0%	25.0%	28.6%	32.1%	100%
Total	134	55	1	144	120	236	690
	19.4%	8.0%	0.1%	20.9%	17.4%	34.2%	100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	110	31	148	289
	38.1%	10.7%	51.2%	100%
3-4	53	69	224	346
	15.3%	19.9%	64.7%	100%
5-6	10	8	37	55
	18.2%	14.6%	67.3%	100%
Total	173	108	409	690
	25.1%	15.7%	59.3%	100%

Discriminatory Analysis Table - John West 1982-83 (cont.)

Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	35 23.0%	117 77.0%	152 100%
1-3	245 45.5%	293 54.5%	538 100%
Total	280 40.6%	410 59.4%	690 100%

From Rating	1-4	5-6	Total
1-4	236 37.2%	399 62.8%	635 100%
5-6	13 23.6%	42 76.4%	55 100%
Total	249 36.1%	441 63.9%	690 100%

Appendix B

Discriminatory Analysis Table - John West 1982-84
Number of Observations and Percents Classified into Ratings

From Rating	1	2	3	4	5	6	Total
2	129 35.3%	82 22.4%	0 0.0%	58 15.5%	97 26.5%	0 0.0%	366 100%
4	31 19.1%	7 4.3%	0 0.0%	66 40.7%	58 35.8%	0 0.0%	162 100%
1	43 33.9%	26 20.5%	0 0.0%	19 19.0%	39 30.7%	0 0.0%	127 100%
3	149 36.7%	61 15.0%	0 0.0%	79 19.5%	117 28.8%	0 0.0%	406 100%
6	19 33.3%	2 3.5%	0 0.0%	16 28.1%	20 35.1%	0 0.0%	57 100%
5	22 30.6%	3 4.2%	0 0.0%	28 38.9%	19 26.4%	0 0.0%	72 100%
Total	393 33.0%	181 15.2%	0 0.0%	266 22.4%	350 29.4%	0 0.0%	1190 100%

Number of Observations and Percents Classified into Ratings

From Rating	1-2	3-4	5-6	Total
1-2	252 51.1%	13 2.6%	228 46.3%	493 100%
3-4	188 33.1%	32 5.6%	348 61.3%	568 100%
5-6	35 27.1%	5 3.9%	89 69.0%	129 100%
Total	475 40.0%	50 4.2%	665 55.9%	1190 100%

Discriminatory Analysis Table - John West 1982-84 (cont.)
Number of Observations and Percents Classified into Ratings

From Rating	1-3	4-6	Total
4-6	82	209	291
	28.2%	71.8%	100%
1-3	476	423	899
	53.0%	47.1%	100%
Total	558	632	1190
	46.9%	53.1%	100%

From Rating	1-4	5-6	Total
1-4	449	612	1061
	42.3%	57.7%	100%
5-6	36	93	129
	27.9%	72.1%	100%
Total	485	705	1190
	40.8%	59.2%	100%

Appendix C

Regression Coefficients with 5 Predictors for Locations and Years

Best Model

Predictor	Coefficient	F-Ratio
2 Root Rating	0.1766D+02	79.96
3 Root Rating	0.1142D+02	36.48
Total Rainfall	-0.2795D+01	182.55
June Rainfall	0.1382D+01	31.35
September Rainfall	-0.1365D+02	86.42

R square = .20431

Intercept - .2467D+03