AGRONOMIC CHARACTERISTICS OF MONO- AND DOUBLE-CROPPED SOYBEANS GROWN UNDER IRRIGATED AND RAINFED CONDITIONS

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CHAPTER I

INTRODUCTION

Both the irrigation of soybeans (*Glycine max* (L.) Merr.) and the double-cropping of soybeans with winter wheat (*Triticum aestivum* (L.) Thell) have been fairly extensively studied, but only recently has interest been expressed in combining the two management systems into one. This is being studied in eastern Oklahoma as a means of decreasing some of the risk involved in the double-cropping system, risk which develops as a result of erratic precipitation patterns and of the late planting of soybeans into water depleted soil. When the two management systems are combined, one would hope that the yield reductions typically found with double-cropping might be diminished.

When such management constraints are applied to a soybean crop, both crop and individual plant responses vary. Crop yields respond to changes in both stand density and water supply while individual plants respond to changes in water supply and interplant competition. The purpose of the research herein reported was to study the responses of individual agronomic characteristics to the cropping and water management contrasts and to study the interactions between individual plant responses and total crop responses to the contrasts.

CHAPTER II

LITERATURE REVIEW

Water Stress

Irrigation of soybeans has been studied in sufficient detail to conclude that under water deficient conditions irrigation will significantly increase yields (35, 38, 48, 49) and that the most critical period during which to avoid stress or apply irrigation water is during the pod filling reproductive stages (8, 14, 30, 45). In contrast, however, Doss and Thurlow (15) concluded that yield increases due to irrigation would probably not be sufficient to make the practice economical in Alabama; Ashley and Ethridge (2) found best yields to come from season long irrigation and from bloom stage irrigation, with irrigation at only pod filling stage causing occasional decreases in yield; and Thompson (55), after reviewing 38 years of records in the corn belt, concluded that rainfall during July was more critical than rainfall in August. The discrepancy between the majority opinion on the one hand and the latter three parties on the other hand may be resolved by a less rigid position acknowledging the need for water during vegetative growth, too, if available soil water is depleted 50 to 60% by volume during vegetative and flowering stages (8, 16). Perhaps contributing to the lack of increased yield under early irrigation as compared to late are the facts of (i) increased lodging when plants are irrigated during vegetative growth (8, 15, 49), (ii) increased sensitivity of photosynthesis to water stress during podfill (21), and (iii) ability of soybeans to recover from fairly extensive stand and pod reductions (9, 47).

Although the fact of decreased yield under water stress has been well established, the actual mechanics of this stress are much less well understood. In general terms, a reduction in soil water potential causes reductions in leaf water potential (7, 28, 46) and stomatal conductivity (6, 46), which in turn cause reduced rates of leaf area enlargement (4, 11, 46) and photosynthesis (5, 20, 21, 29), and all these reductions, mutually compounding one another, then reduce nitrogen fixation (28, 29) and respiration (4). However, other factors such as cultivar, nutrient levels, stage of growth, atmospheric conditions, location of leaf water potential measurements within the canopy, etc., all obviously complicate the picture, and none of these latter contributions has been adequately quantified.

Teare et al. (53) found soybean water use efficiency to be only one-third that of grain sorghum (Sorghum bicolor (L.) Moench), primarily because soybean stomata respond so sluggishly to decreases in leaf water potential. Leaf water potential must drop down to -11 to -13 bars before soybean photosynthetic rates drop off significantly (4, 5, 21), before leaf conductance markedly decreases (11), and before wilting commences (28). Yet, leaf area enlargment decreases rapidly at leaf water potentials of -2 to -3 bars (4), indicating a 9 to 10 bar window between initiation of stress and stomatal closure in response to that stress. Between leaf water potentials of -11 and -16 bars Boyer (4, 5) and Ghorashy et al. (20) found photosynthesis to decrease to 50% of fully turgid rates, probably due to stomatal resistance, and below

-16 bars Boyer surmised that the further reductions in photosynthesis were caused by disruption of biochemical pathways, although carbon fixation still occurred at, and plants were able to recover from leaf water potentials as low as -41 bars. Ghorashy et al. (21) found photosynthesis to be more sensitive to water stress at podfill than at flowering. Irrigation has been found to reduce stomatal resistance (35, 51) and to increase plant water use (15, 39, 49), as well as to reduce canopy temperatures (35, 59), the last enough to perhaps prevent disruption of photosynthesis due to excessive heat.

Smaller seeds have given acceptable germination at lower soil moisture contents than have larger seeds of the same cultivar (17), but reports of the critical soil moisture tension vary from -6.6 bars for acceptable germination (31) to -0.6 bars for emergence (24). Once roots emerge, they penetrate the soil more deeply without than with irrigation (39, 40). Although 50% (40) to 90% (42) of the root mass is located within the uppermost 15 cm of the soil, water depletion efficiency increases with depth (52, 60) due to suberization and senescence of older, shallower roots; the roots at 1.75 to 2.00 meters extract water up to four times as efficiently as do those at 1.25 to 1.50 meters (60), which points out the importance of maintaining soil profile moisture as well as soil surface moisture.

Agronomic Characteristics

Soybeans compensate for reductions in stand by increasing yield of individual plants (19, 43, 54, 58) as well as compensate for reductions in number of seeds per plant by increasing individual seed weight (25, 41, 54). The mechanisms of these compensations are probably inter- and intra-plant competition (1, 22, 44) for nutrients (1, 12, 36), water (10, 16, 43), light (34, 58), and photosynthate (19, 23, 36, 58). Inter-plant competition is often evidenced by negative correlations between planting density on the one hand and seeds per plant (3, 26, 37, 44), branches per plant (3, 27, 37, 44), and nodes per plant (3, 44) on the other hand; intra-plant competition is exhibited by a negative correlation between seeds per plant and weight per seed (1, 19, 25, 41). Because soybeans have the capability to shed between 43 and 81% of their flowers and/or pods (56), they have great latitude of adjustment to establish as many reproductive sinks as the environment can support (12). If the environmental conditions should change after establishment of pods, then seed set or seed size will compensate (12, 16, 19, 43), although it has been noted that seed weight (12, 58) and particularly seeds per pod (36, 41, 43, cf 10, 18) are relatively more invariable under differing conditions than is the number of seeds per plant.

Although relatively few studies of the effects of water stress on agronomic characteristics of soybeans have been conducted, the results of those few indicate that yield components reduced by stress are those components that are developing at the time of the stress (16, 43). Hence, stress at podset reduces yield by reducing seed size and seed number rather than pod number (43). Water stress at flowering will in turn reduce pod number but not seed size because at flowering it is the pods that are at the first stage of development (16, 43). Similarly, plant height and number of nodes are reduced by stress at the vegetative stages more than at the reproductive stages (43), but the ratio of yield on branches to yield on stem has not been reported as a function of water stress. Burnside and Colville (10) found irrigation to increase seed weight and hence yield.

The proportion of yield borne by branches depends on the degree of branching (37), and therefore more widely spaced plants carry a larger portion of the yield on branches than do narrowly spaced plants. Seeds per pod and seed weight have been found to be slightly smaller on branches than on the stem (37). Interestingly, branches do not seem to recover from removal of floral buds as well as do stems (25).

Soybean plants planted close together tend to be taller, suffer more lodging, and lose fewer seeds at harvest due to combine clearance than do soybeans planted further apart (3, 10, 26, 32). Irrigation also increases plant height and lodging and causes more seeds to be located below combine harvest height (10). Weber and Fehr (57) noted a 1.9% loss in yield for each inch of plant the combine fails to harvest.

Because of soybeans' "buffered yield system" (1), it has been difficult to select secondary yield characteristics to couple with yield in breeding programs (1, 27, 44, 47). Although selection for long fruiting period and heavy seed weight has been suggested (33), others have found seed size to be significantly correlated to yield within but not across genotypes (48). Seeds per pod and pods per area have both shown high correlations with yield, but because they are usually negatively correlated with each other, even these characteristics are not entirely satisfactory as yield predictors (44). When growing different genotypes in the same row, interspecific competition causes branches per plant and average seed weight to be biased yield predictors (27), and varying row spacing causes practically all secondary yield components to be biased, with the exception of nodes per plant (27).

CHAPTER III

MATERIALS AND METHODS

A field study analyzing agronomic characteristics of 'Forrest' soybeans mono- and double-cropped after winter wheat under irrigated and rainfed conditions was conducted at the Oklahoma Vegetable Research Station, Bixby, Oklahoma, in 1980 and 1981 on a Wynona silty clay loam (Cumulic Haplaquolls) with a 0 to 1% slope. The experimental design consisted of a 2 X 2 factorial arranged in randomized complete blocks with four replications.

'TAM W-101' winter wheat was planted on the double-cropped plots on 24 November 1979 and harvested on 2 July 1980. Mono-cropped and double-cropped soybeans were planted on 22 May 1980 and 3 July 1980, respectively, using 51-cm rows in 18.3 X 18.3-m plots at a seeding rate of 370,000 viable seeds per hectare using a no-tillage planter equipped with 5-cm fluted coulters, double-disk openers, 4-cm depth bands, and press wheels. An area of 6.1 X 15.2 m was harvested from each mono-cropped plot on 30 October 1980 and from each double-cropped plot on 7 November 1980 using a Gleaner Model "A" combine. Wheat was planted directly into soybean stubble on 25 November 1980 and was harvested on 22 June 1981. Mono- and double-cropped plots were again planted with soybeans on 9 June 1981 and 22 June 1981, respectively, using the same seeding rate, row width, planter, and plot size as the previous year, and were both harvested on 14 November 1981, using the same harvest procedure as in 1980.

Because the Oklahoma State University soil testing laboratory procedures and recommendations showed available phosphorus (P) and potassium (K) to be 100% sufficient each year, no P or K fertilizer was added during the study. Ammonium nitrate (NH_4NO_3) was applied to the double-cropped plots as a top dressing to wheat on 28 February 1980 and 26 February 1981 at a rate of 101 kg N/ha.

Double-cropped plots received no tillage during the experiment, and mono-cropped plots were mold-board plowed once each year and tandem-disced twice each year following application of herbicide. Chemical weed control was effected on double-cropped plots each year with 0.84 kg active ingredient (AI)/ha glyphosate [N-(phosphonomethyl)glycine], 1.1 kg AI/ha oryzalin (3,5-dinitro-N^4,N^4-dipropylsulfanilamide), and 0.37 kg AI/ha metribuzin [4-amino-6-tert-butyl-3-(methylthio)-as-triazin-5(4H)-one], and on mono-cropped plots with 1.1 kg AI/ha trifluralin (a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) incorporated with two tandem discings. In addition, mono-cropped plots received one mechanical cultivation each year.

Irrigated plots received water using a solid-set sprinkler system, with water applied frequently enough to prevent protracted water stress and at rates that did not exceed run-off. Rates and dates of addition of water as irrigation and precipitation are sumarized in Table 1 and Figure 1.

Ten soybean plants were selected from the harvest area of each plot each year by use of a computerized random number program. The program randomly selected rows from within the harvest area of each plot and then randomly selected distances of 90-cm increments into each of the

Table 1. Precipitation and irrigation data at Bixby, Oklahoma, for 1980 and 1981.

Date	Precipitation	Irrigation†
	——— cm ———	
1 Jan - 30 April, 1980	22.7	
May	12.0	
16-20 June	22.9	
11-14 July		3.2 M,D
17-18 July		10.2 M
22 July	0.2	6.3 D
24-25 July		10.2 M
26 July	0.3	
31 July - 1 Aug.		10.2 D
7-8 Aug.		15.2 M
18 Aug.	4.8	
19-22 Aug.		10.2 M,D
21 Aug.	0.6	
28-30 Aug.		10.2 M,D
3 Sept.	7.7	
13 Sept.	0.3	
17 Sept.	1.1	
23 Sept.		5.1 D
25 Sept.	3.7	
28 Sept.	2.7	
Oct.	6.5	
1 Nov. 1980 - 30 Apr. 1981	27.7	
May 1981	14.1	
2 June	0.2	
6 June	0.4	
15 June	2.8	
16 June	5.8	
27 June	0.1	
30 June	0.4	
1 July	0.1	
4 July	0.8	
7 July	1.8	
8 July		4.1 D,M
17 July		7.6 D,M
20 July		7.6 D,M
22 July	0.4	
28 July	2.4	
29 July	1.6	
30 July	0.5	
3 Aug.	0.4	
7 Aug.	0.4	
11 Aug.	0.1	5.2 D,M
16 Aug.	2.7	
26 Aug.	0.5	7.6 D,M
27 Aug.	6.2	
1 Sept.	1.5	
7 Sept.	0.2	
14 Sept.	5.8	
27 Sept.	2.6	
Oct.	16.6	
Nov.	8.1	

†"D" and "M" applied to mono- and double-crop plots, respectively.

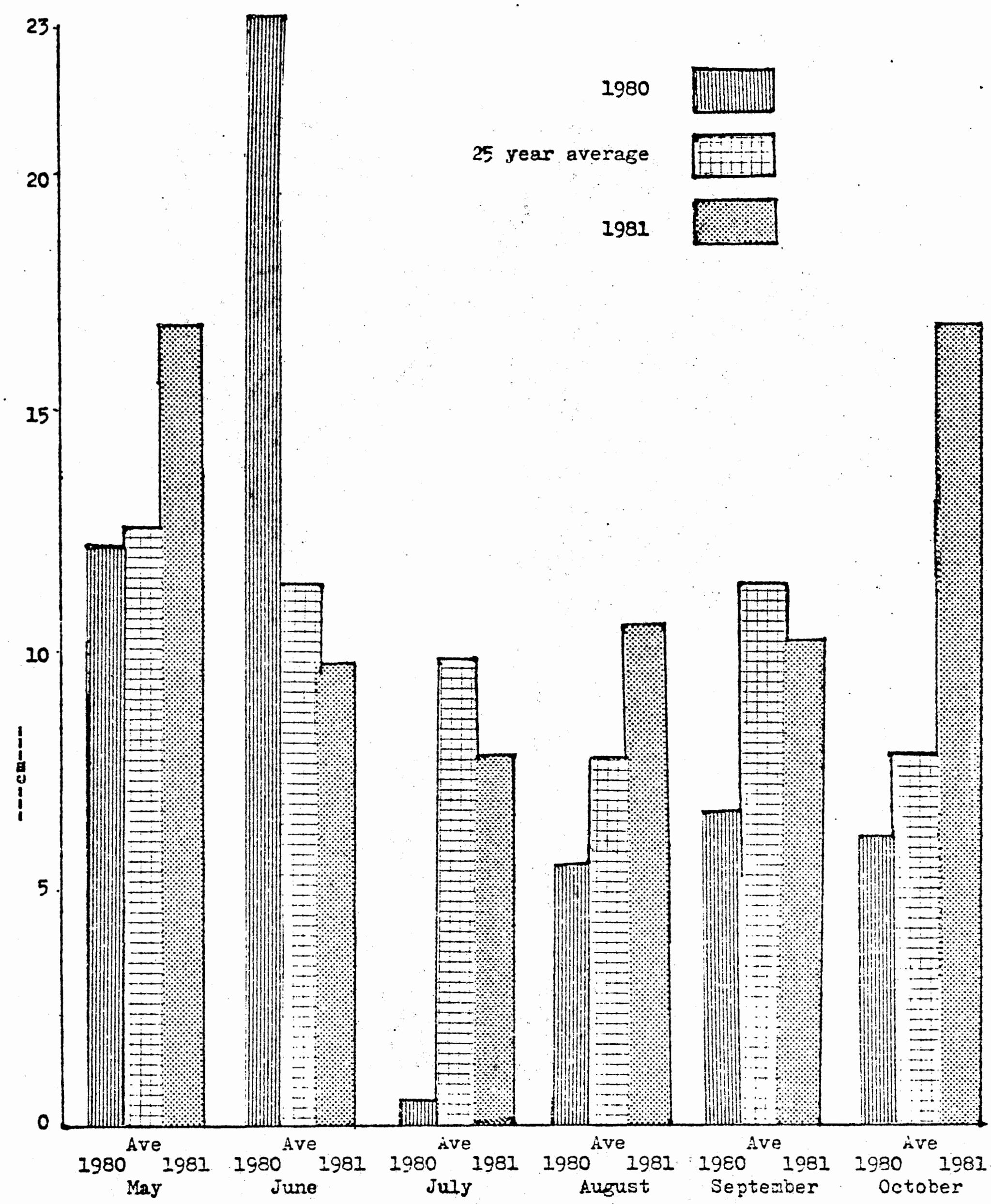

Figure 1. Monthly summer rainfall for 1980 and 1981 as compared to 25 year averages (1950 to 1975), at Bixby, Oklahoma.

selected rows. The closest plant in the direction of the front of the plot was harvested by hand at the random distance into each selected row unless the closest plant at that distance was isolated from other plants, in which case the closest non-isolated plant in the row in the direction of the front of the plot was chosen. Plants were evaluated for agronomic characteristics of: plant height to the terminal node, nodes per plant, pod-bearing branches per plant, mature and immature pods above 10 cm height on the stem and on branches, number and weight of undamaged seeds above 10 cm height on the stem and on branches, weight of undamaged seeds on the bottom 10 cm of the plant, and weight of loose seeds in the bottom of bags in which plants were transported. Plot yields were determined by weighing seed harvested by combine.

In 1981 stand density was measured by counting numbers of plants per linear meter of row. Ten one-meter lengths of row from each plot were selected in the same manner as were plants, but with a different randomization schedule and without adjustment for isolated plants. This method of selecting rows for stand counts may have been biased because of a possible non-uniform planting pattern in which one disc on one double-disc opener froze up and possibly planted fewer seeds per row than did the other three planting units, but no evidence of such a difference was found after emergence or at harvest.

CHAPTER IV

RESULTS AND DISCUSSION

Method of Statistical Analysis

The data collected were organized in a design of randomized complete blocks with two treatment levels in each of the two factors. These levels consisted of irrigated plots (I) versus rainfed plots (R) within the water management factor (W), and double-cropped plots (D) versus mono-cropped plots (M) within the cropping management factor (C), resulting in treatments DI, DR, MI, and MR. Experimental units were plots; plants (or plant data) were considered to be subsamples within experimental units. With four treatments (plots, experimental units) per replication, four replications, and ten subsamples per plot, the analysis of variance table (ANOVA) for each agronomic characteristic conformed to that presented in Table 2.

In calculations of the "F" value, the C x W x Rep mean square was used as an error term because it contained both between-plant variation and between-experimental-unit variation. The computer package on which the data were analyzed was that of the Statistical Analysis System (SAS) as used at the Oklahoma State University Computer Center (50).

When total plot yields and stand density were analyzed, the subsamples (individual plants) within each plot were all assigned the same value, so the subsampling variance was null, forcing the ANOVA into the

Table 2. ANOVA model for agronomic characteristics with one year's data.

Source of Variation	Degrees of Freedom	SS	MS	F
Total	159			
Model	15			
Replications (Rep)	3			
Water management system (W)	1			
Cropping management system (C)	1			
C x W interaction	1			
C x W x Rep interaction	9			
Subsampling	144			

above design.

Not all agronomic characteristics had the same number of total degrees of freedom because some plants failed to produce certain reproductive traits. In particular, branch yield components were often missing. Nineteen plants in 1980 and 12 plants in 1981 failed to produce seeds on branches and in 1980 two plants failed to produce any seeds on the entire plant. Because certain traits were defined by ratios for which a yield component was the denominator, those ratios would be undefined for each subsample missing that particular denominator. When data points were undefined, the ANOVA was run without them rather than supplying "missing values." Hence, the discrepancy in degrees of freedom between particular traits and years.

When the biased trait was positively correlated with individual plant yield or seed number, under-representing low yielding plants would cause a positive bias on the trait mean; that is, the mean for a trait would probably be calculated as larger than it really was if low data points were neglected. This bias would be particularly prominent on mono-cropped and rainfed treatments, those which were more heavily stressed and therefore more likely to have plants with particularly low valued yield components. Such traits included harvest loss; seeds per pod on branches, stem, and plant; and the four ratios of seed number and weight on branches to seed number and weight on stem and plant.

Traits which were negatively correlated with individual plant vigor--that is, traits which were smaller in size on heavily yielding plants--would be biased downward by under-representing stressed plants. Such traits were individual seed weight and percent immature pods.

In all, there were 14 traits with fewer than 160 data points in

1980, but only three of those had fewer than 157 data points. These latter were the branch components of individual seed weight, seeds per pod, and percent immature pods. Only these latter three traits were missing data points in 1981.

Correlation coefficients and regression equations were also calculated and were subject to the same biases as were the analyses of variance.

Generalized Responses

The patterns in which 'Forrest' soybeans responded to the cropping and irrigation treatments of the experiment can be explained in general terms by availability of water and density of population. Under irrigated conditions more water was available for plant growth, and consequently both individual yield components and total plot yields increased. Under double-cropped conditions less water was available at germination because of delayed planting and because of soil water depletion by the preceding wheat crop. Consequently, under double-cropping fewer plants emerged, population density decreased, inter-plant competition for nutrients, water, light and space decreased, individual yield components tended to increase, but plot yields decreased.

In both 1980 and 1981 hot, dry weather preceding and immediately following planting of double-cropped plots reduced surface soil moisture and germination. This suppression of emergence was more pronounced in 1981 than in 1980 despite more rainfall later in the 1981 season. Crabtree and Rupp (13) also studied double-cropping of soybeans and wheat on this soil and found soil moisture levels to be lower under double-cropping than under mono-cropping because of water depletion by the preceding wheat crop.

With the exceptions of individual seed weight responses and certain interactions which will be discussed below, almost all of the results of the experiment can be explained in terms of these two overriding principles of planting density and moisture. Treatment means for the individual traits measured are presented in tables in the Appendix.

Plot Yield

Total plot yields (Table 7, Appendix; Figure 2, p. 17) harvested by combine responded to the treatments as would be predicted by weather (Table 1, p. 9) and stand density information (Table 8, Appendix). In the dry summer of 1980 yields significantly increased 27% with irrigation and insignificantly descreased 18% with double-cropping. In 1981 yields insignificantly increased 7.8% with irrigation because of more precipitation and significantly decreased 20% with double-cropping because of a 42% decrease in stand density. Although density measurements were not taken in 1980, it can be stated with fair certainty from visual observations that stand density was more reduced on double-cropped plots in 1981 than in 1980. This year to year difference is attributed to soil moisture differences at time of planting, germination, and stand establishment.

In 1981 stand density measurements were taken by randomly selecting one meter lengths of row from each of ten randomly selected rows of the center 20 rows of each plot. With this random selection of rows it is possible that there was a bias on certain plots due to the suspected irregular planting pattern mentioned in the Materials and Methods

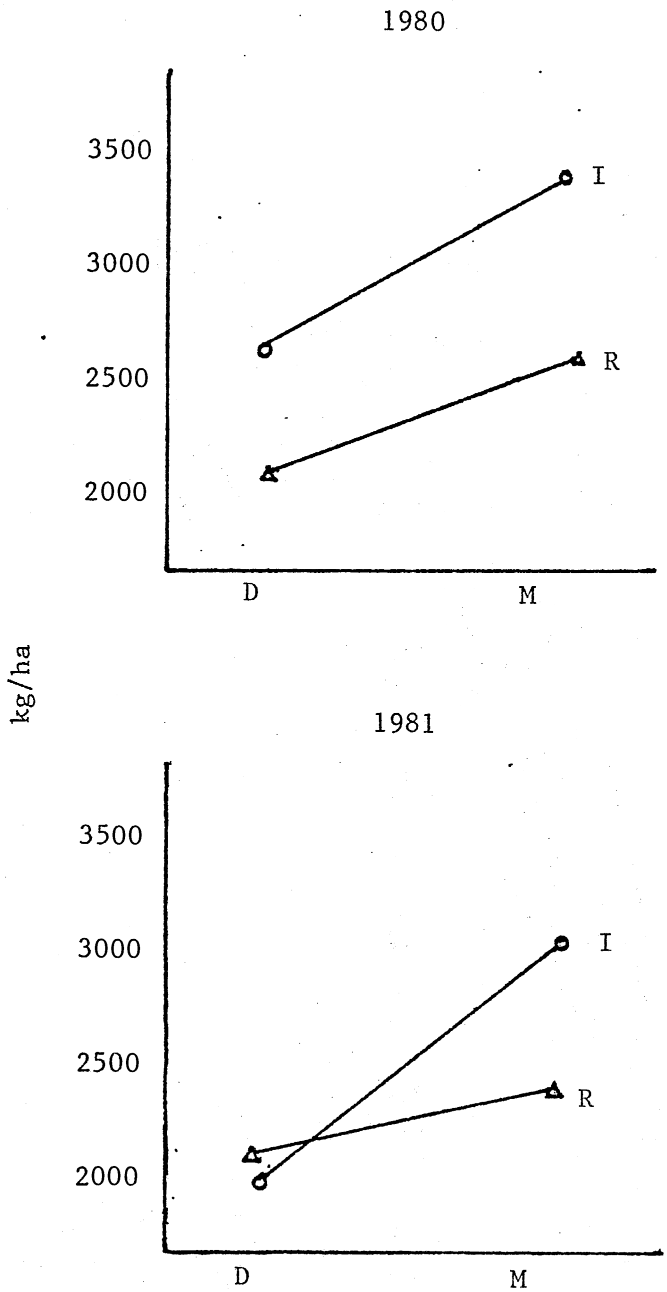

Figure 2. Plot yields for 1980 and 1981.

chapter of this thesis. However, such a pattern (one row in four with possible skips) was observed neither upon emergence nor at harvest.

The significant treatment differences in 1980 and 1981 caused the two years' composite data to show significant differences within both water and cropping management contrasts.

An unexpected anomaly was found in year to year yield comparisons. Yields in 1980 significantly surpassed those in 1981 by 14%. The pattern should have been exactly reversed because of the weather conditions of the two years. It is suspected that the wet weather in October and November of 1981 may have caused some lodging. The frequent rains kept the harvest crew off the field at least two weeks after the soybeans were ready to harvest, and some lodging was noted. The difference is hardly a physiological effect because there were 15% greater yields per plant in 1981 than in 1980 [observed significance level (OSL) = 0.19].

Vegetative Traits

Plant height (Table 9, Appendix) and number of nodes (Table 10, Appendix) were both affected by stand density. Both in 1981 and when the two years' data were combined (1980/81) the more sparsely populated, double-cropped plots had significantly shorter plants with significantly fewer nodes than did the mono-cropped plots where competition for light was higher. In 1980 the pattern was present but not significant. Irrigation significantly increased neither plant height nor node number either year although there was a significant increase in height due to irrigation when both years' data were combined, and there were 8% more nodes in 1980 than in 1981.

Number of branches increased significantly due to double-cropping in both years (Table 11, Appendix), which was an anticipated consequence of reduced competition. Branch number also increased with irrigation in 1980, the drier year. The decreased stand density of double-cropping should decrease height and node number by reducing competition for nutrients, water, light, and space. Irrigation should increase height, node number, and branch number simply via increased vigor.

Harvest loss as estimated by seed weight below 10 cm of plant height was insignificantly affected by any treatment (Table 12, Appendix). Overall, it was less than 1% of the total yield harvested. These responses of 'Forrest' cultivar differ markedly from responses of several other cultivars, in which both irrigation (10) and row width, (3, 10) significantly altered harvest losses due to low lying pods and in which such harvest losses amounted to up to 7.5% of the total crop yield (57).

Primary Yield Characteristics

Pod Number

Increased branching resulted in increased pod set on branches (Table 13, Appendix). Consequently, there were significant 96 and 67% increases in pods on branches due to double-cropping in 1980 and 1981, respectively, and a significant 45% increase in pods on branches due to irrigation in 1981. In 1980 the 49% increase due to irrigation was significant at only the 0.09 level, but when the two years' data were combined, the 47% increase in pods on branches due to irrigation was significant at the 0.008 level. It seems fairly certain that pod load on branches tends to increase under irrigation as well as with double-cropping. In neither year were there any significant interactions.

The number of pods on stem varied relatively little in response to the treatments applied (Table 14, Appendix); the only significant treatment response either year or with both years combined was a 30% increase due to irrigation in 1980, the drier year.

These results suggest the possibility that stem pod load may be relatively more fixed than branch pod load, which would imply that stem pod load may be less influenced by stress than would be branch pod load. Whether or not this implies a priority given to stems cannot be tested with this experimental design but would probably necessitate the use of radio-active tracers used in controlled environments. Some evidence in support of such a hypothesis is the finding of Hicks and Pendleton (25) that stems recover from floral bud removal more than do branches.

The branch and stem responses to the treatments combined to cause significantly more pods on the entire plant with double-cropping in 1980, 1981, and 1980/81 and more pods on the plant with irrigation in 1980 and 1980/81 (Table 15, Appendix).

Seeds per Pod

In 1980 seeds per pod on branches significantly increased 12% due to double-cropping, increased insignificantly due to irrigation, and showed a significant crop management by water management system interaction (Table 16, Appendix; Figure 3, p. 21). In 1981 there were no significant treatment responses. The increase due to double-cropping in 1980 coincided with an increase in pod number due to double-cropping that year, though the correlation between pod number and seeds per pod

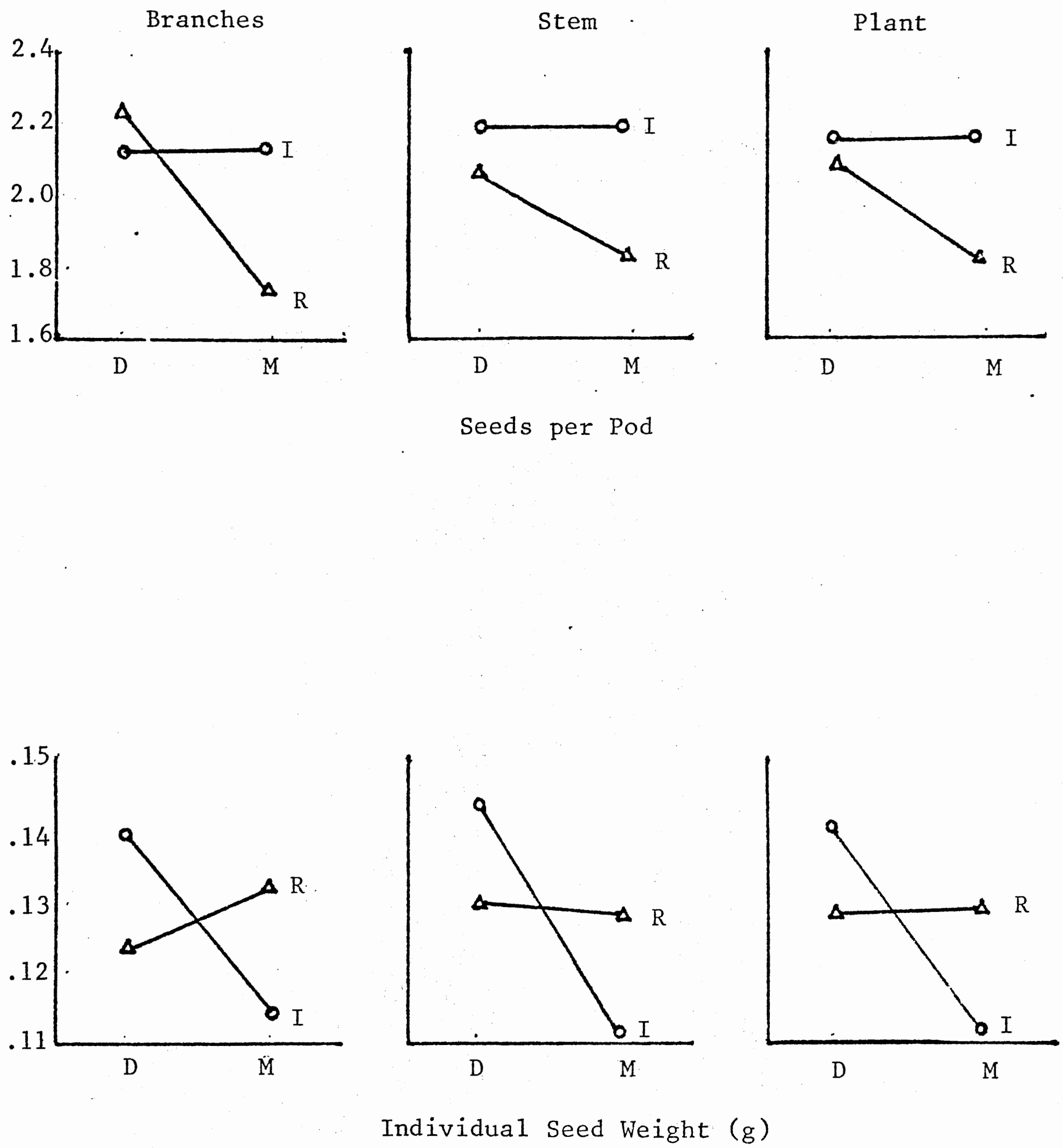

Figure 3. Water management x crop management interactions: means for mono- and double-cropped, irrigated and rainfed treatments for seeds per pod and individual seed weight on branches, stem, and plant for 1980.

(r = 0.12) was insignificant. The crop management by water management system interaction in 1980 was characterized by a greater response to cropping on rainfed plots than on irrigated plots. MR plots averaged only 1.7 seeds per pod on branches while DR plots averaged 2.2 seeds per pod on branches. Since this interaction was present for seeds per pod but was not present for number of pods on branches, it is suggested that stress set in on MR plots in early August after pods set but before seeds were established, whereas in DR plots stress was relatively less pronounced in mid-September during DR seed establishment.

During the wetter summer of 1981 water status was more uniform from treatment to treatment and consequently seeds per pod on branches varied less from treatment to treatment. This response conforms to results of other investigations that seeds per pod is a relatively invariable trait (36, 43).

Seeds per pod on stem showed no significant treatment responses either year except to irrigation in 1980 when there was a 12% increase with supplemental irrigation (Table 17, Appendix). In 1980 there was also a significant increase in pod number on stems due to irrigation.

These responses raise the question of why seeds per pod on branches responded more to double-cropping and seeds per pod on stem responded more to irrigation. The same trend was noticed with pod number, but there the increase in branch number would supply sufficient explanation. All that can be suggested is that the mechanism which establishes pods was perhaps operative in establishing seeds per pod too. This would imply no intra-plant competition between seeds per pod and pod number, and indeed correlations between seeds per pod and pod number were positive on all plant parts each year and with both years combined and were significant on all plant parts when both years' data were combined (Table 3, p. 24).

In 1981 there were 5.8% and 5.9% more seeds per pod on stem and entire plant, respectively, than in 1980 (Tables 17 and 18, Appendix). It may be that the precipitation and temperature differences for the two years caused this. In both cases there were significant (OSL = 0.01) year by water management system interactions in which rainfed plots had more seeds per pod in 1981 than they did in 1980.

Individual Seed Weight

Individual seed weight showed no significant main effects to either water management or cropping management factors either year, with the exception of a significant increase in individual seed weight on stem with double-cropping in 1980 (Table 20, Appendix). While main effects on individual seed weight were generally insignificant, there were significant crop management by water management system interactions on branches, stem, and entire plant in 1980 (Tables 19, 20, 21, Appendix). In this interaction DI plots had much heavier seeds than did MI plots, while rainfed plots were essentially unchanged by cropping (Figure 3, p. 21). It is difficult to explain the response in terms of water stress because it is the irrigated plots that fluctuated, not the rainfed.

One explanation would be the possibility that DI, MI and DR plots all set seeds per pod close to the genetic maximum, that DI treatments allowed more water to the DI plants on a per plant basis, and that consequently those seeds which did set filled out more fully than expected. The temperature difference between mid-September 1980 when MI seeds were

Table 3. Correlation coefficients for seeds per pod x pod number, seeds per pod x individual seed weight, and individual seed weight x pod number.

Year and Plant Part	Seeds/Pod x Pod Number†	Seeds/Pod x Ind. Seed Wt.†	Ind. Seed Wt. x Pod Number†
1980 Branches	0.12 (0.15)	-0.31 (0.0002)	0.02 (0.77)
1980 Stems	0.38 (0.0001)	-0.20 (0.01)	-0.10 (0.22)
1980 Plant	0.38 (0.0001)	-0.34 (0.0001)	-0.01 (0.91)
1981 Branches	0.19 (0.02)	-0.05 (0.53)	0.04 (0.63)
1981 Stems	0.05 (0.57)	-0.58 (0.0001)	0.03 (0.70)
1981 Plant	0.04 (0.65)	-0.19 (0.02)	-0.06 (0.46)
1980/81 Branches	0.13 (0.03)	-0.27 (0.0001)	0.03 (0.67)
1980/81 Stems	0.22 (0.0001)	-0.39 (0.0001)	0.01 (0.94)
1980/81 Plant	0.24 (0.0001)	-0.28 (0.0001)	-0.03 (0.61)

†Observed significance levels in parentheses.

filling and early October 1980 when DI seeds were filling may have further magnified the difference.

Intra-plant competition for water and metabolites was probably exhibited between ripening seeds within pods, as there were significant negative correlations between individual seed weight and seeds per pod on stems, branches, and entire plant both years and with both years combined, the only exception being a nonsignificant negative correlation on branches in 1981 (Table 3, p. 24).

Secondary Yield Characteristics

The primary reproductive traits of pod number, seeds per pod, and individual seed weight combine together to produce secondary traits such as total seed number and total seed weight on branches, stem, and total plant, as well as seed number and total seed weight per node. One would expect that as pod number changed either significantly or insignificantly, so too would total seed number and total seed weight change. This pattern did obtain on branches, stem, and plant both years, with the exception of on the stem in 1980 (Tables 22 through 27, Appendix). In that year seed weight per stem significantly increased 42% due to double-cropping while pod number and seed number on stems insignificantly increased only 19%. The increase in seed weight on stem under double-cropping was probably due to the 15% increase in individual seed weight on stem with double-cropping that year. With this one exception the primary yield characteristic which seemed to control the plant yield most was that trait which had the most latitude for change: pod number. Total seed weight was also more highly correlated with pod number than with seeds per pod or individual seed weight in all year and plant part combinations (Table 4, p. 27).

Because of this dependency of total seed weight on number of pods, double-cropping increased yield per plant in 1980, 1981, and 1980/81, and irrigation increased yield per plant in the dry year, 1980, and in 1980/81. In 1981 plants carried more yield per plant than they did in 1980, but not significantly so.

The above discussion of "total seed weight" per plant is based on a measurement of seeds above 10 cm. Seeds below 10 cm--approximating harvest loss--was not included and neither were loose seeds lost to shattering during storage and handling in collection bags. When those components were added to the "total seed weight" the resultant ANOVAs were practically indistinguishable from each other (of Tables 27 and 28, Appendix). Loose seeds gathered from the bottoms of the collecting bags accounted for 0.8% of the "total seed weight" for the two years (Table 29, Appendix). Seeds below 10 cm accounted for 0.9% of the total for the two years (Table 12, Appendix). Because adding them to the total did not change the analyses of variance and because their contributions to yield were so small in relative terms, they were simply left out of the calculations.

Seed number and total seed weight per node (Tables 30 and 31, respectively, Appendix) increased as an inverse function of node number. In double-cropping total seed weight per plant increased but node number tended to decrease, so total seed number and total seed weight per node decreased too. Similarly, in 1981 there were more seeds per node and greater yield per node than in 1980 because there were significantly fewer nodes in 1981.

Table 4. Correlation coefficients for seed weight per plant part with pod number, seeds per pod, and individual seed weight.

Year and Plant Part	Pod Number†	Total Seed Weight x Seeds/Pod†	Individual Seed Weight†
1980 Branches	0.98 (0.0001)	0.14 (0.10)	0.12 (0.14)
1980 Stems	0.91 (0.0001)	0.45 (0.0001)	0.18 (0.02)
1980 Plant	0.97 (0.0001)	0.40 (0.0001)	0.17 (0.03)
1981 Branches	0.98 (0.0001)	0.23 (0.004)	0.16 (0.05)
1981 Stems	0.96 (0.001)	0.14 (0.08)	0.07 (0.37)
1981 Plant	0.98 (0.0001)	0.10 (0.20)	0.08 (0.32)
1980/81 Branches	0.98 (0.0001)	0.15 (0.01)	0.13 (0.03)
1980/81 Stems	0.94 (0.0001)	0.31 (0.0001)	0.09 (0.12)
1980/81 Plant	0.97 (0.0001)	0.28 (0.0001)	0.13 (0.02)

†Observed significance levels in parentheses.

Immature Pods

Average numbers of immature pods ranged from 2 to 21% of the average numbers of mature pods over the years and plant parts (Tables 32, 33, and 34, Appendix). In general there seemed to be more immature pods on stem than on branches (9.0% and 7.6%, respectively), though this conclusion cannot be statistically tested with this experimental design.

Two kinds of immature pods were noted but not differentiated in the data collection. They were (i) small, dark, very hairy, tightly curled pods that did not develop to a fleshed out stage, and (ii) at the other extreme, pods that were flat, full sized, light colored, but simply lacking seeds. These latter in some cases may have even had undeveloped seed embryos in them. The two extremes would be produced by termination of development at different stages of reproductive growth, with intermediate degrees of development terminated by stress at intermediate stages of growth.

Main effect responses of percentage immature pods to the contrasts were usually nonsignificant at the 0.05 level. The only pattern of response that seemed to occur over the years and plant parts was an often significant interaction in which DI and DR plots had very similar immature pod percentages but MI plots had higher immature pod percentages than did MR plots. It is conceivable that irrigated plants might initiate pods more luxuriantly than would rainfed plants and would then be unable to fill all those initiated pods once irrigation was terminated in late August or early September. This water management difference would be much more likely found on mono-cropped plots than on double-cropped plots because of the differences in planting date and consequently in time of reproductive development. Mono-cropped plots initiated reproductive growth in late July to early August during the period of most intense stress and irrigation whereas double-cropped plots initiated reproductive development a month later as irrigation treatments were being phased out.

Yield Distribution on Stems and Branches

The relative distribution of yield on branches and stem may be calculated by dividing branch yield by either stem yield or total plant yield (seeds-on-branches/seeds-on-stem, seeds-on-branches/seeds-on-plant, yield-on-branches/yield-on-stem, and yield-on-branches/yield-on-plant). See Tables 35, 36, 37 and 38, Appendix. When one calculates these ratios on a per plant basis and averages all plant ratios together, seemingly contradictory results are obtained. Ratios of branch-yield/stem-yield averaged by treatment are generally greater than 1.2 (Tables 35 and 37, Appendix), but the ratios of branch-yield/plant-yield when averaged by treatments are generally less than 0.45 (Tables 36 and 38, Appendix). One would expect something more closely approximating the following:

$$\text{if } \frac{\text{branch yield}}{\text{stem yield}} = 1.2, \text{ then } \frac{\text{branch yield}}{\text{plant yield}} \cong \frac{1.2}{1 + 1.2} = 0.55.$$

Rather than 0.55, the ratio of branch-yield/plant-yield was found to be closer to 0.45. Although the ratios of averages are not necessarily the same as the averages of ratios, one would expect them to be closer to one another when 160 to 320 plants are used. However, because the standard deviations of these traits were often greater than the means, the seeming discrepancy is seen to be purely an artifact of the mathematics.

One way to avoid the problem of averages is not to average at all, but simply to count the number of plants which had more yield on branches than on stem. When this was done, it was found that branches carried more seeds and more yield than did stem on the DI plots in both years, but that stem out-yielded or equalled branches on the other three treatments both years (Table 5, p. 31). Because the stems and branches compared were from the same plants rather than from different ones, one cannot statistically test the null hypothesis that there was no difference in yield on stem and branches. It can only be suggested that there is an indication that stems may out-yield branches within the contrasts imposed, and that branches may carry relatively larger portions of the yield under irrigation or double-cropping because of more favorable growing conditions for the individual plants.

Yield Prediction

With an eye to gaining insight into the contributions of plant yield components to both plant and plot yields, simple correlations, linear regression equations, and analyses of covariance were calculated. When plot yields were correlated with plot means of individual yield components over the two years, the most significant correlation was pods-on-stem x plot-yield ($r = 0.28$, OSL = 0.13) (Table 6, p. 31). In contrast, the 1981 correlation of stand density with plot yield was $r = 0.65$ (OSL = 0.006).

An "optimum regression procedure" was run in which regression equations were calculated for "n" number of variables, and those "n" variables were so selected as to maximize the equation's "r" squared

Table 5. Number of plants per treatment carrying greater branch yield than stem yield.

Treatment n = 40	Seeds-on-branches exceeds seeds-on-stem 1980	1981	Branch-yield exceeds stem-yield 1980	1981
DI	23	28	22	27
DR	18	18	17	18
MI	12	20	13	20
MR	12	9	11	8

Table 6. Correlation coefficients for plot yield with plot means of seeds per pod, pod number, and individual seed weight.

Year and Plant Part	Pod Number	Seeds Per Pod	Individual Seed Weight
	correlation with plot yield†		
1980 Branches	0.03 (0.91)	0.15 (0.57)	-0.58 (0.02)
1980 Stem	0.50 (0.05)	0.47 (0.07)	-0.43 (0.10)
1981 Branches	-0.28 (0.30)	-0.22 (0.41)	0.48 (0.06)
1981 Stem	0.13 (0.64)	-0.15 (0.59)	-0.08 (0.77)
1980/81 Branches	-0.14 (0.43)	-0.11 (0.56)	0.01 (0.97)
1980/81 Stem	0.28 (0.13)	0.18 (0.32)	-0.13 (0.47)

†Observed significance levels in parentheses.

value. When "n" was varied from one to "x" where "x" was the number of variables under consideration, it was possible to select the "optimum" equation by choosing the equation with the minimum variance, i.e., minimum error mean square. Using this procedure for the variables pods on branches and stem, seeds per pod on branches and stem, and individual seed weight on branches and stem, the optimum equation was found to be $Y = 2640 + 38.7\ PoS - 13.4\ PoB - 65.2\ ISWS$ ($r^2 = 0.25$, OSL = 0.04), where Y is plot yield, PoS is pods on stem, PoB is pods on branches, and ISWS is individual seed weight on stem. The yield components contributing most significantly to the above equation were pods on stem and branches (OSL = 0.02 and 0.06, respectively). This equation accounted for 25% of the variation in plot yield. Obviously some factors other than plant yield components were contributing very significantly to plot yields, and it is suspected that the dominant one was stand density.

In order to minimize the dominating influence of stand density in the data and thereby allow the contributions of primary yield components to stand out in sharper relief, three strategies were employed. First, the optimum regression procedure was run on 1981 data with and without stand density included as a yield component. Second, the optimum regression procedure was run when the two years' data were sorted by treatment, on the assumption that individual treatments would have more uniform stands than did the entire experiment. And third, analyses of covariance were run on all data, in which the treatment parameters of crop system, water management system and the interaction between the two were all treated as classification variables, yield characteristics were treated as covariates, and plot yield was the predicted dependent variable.

When these procedures were completed, the outstanding characteristic held in common was again the lack of significant contribution to yield on the parts of individual traits, even with treatment differences in varying degrees compensated for. The trait most commonly occurring as a significant contribution to yield was pods on stem. In 1981 when the optimum regression equation was calculated with and without stand density included, the equation with stand density had a much higher "r" squared value than did that without (r^2 = 0.69 and 0.34, respectively). Without compensation for the influence of stand density in 1981 the yield traits contributing to the optimum regression equation were individual seed weight on branches (OSL = 0.04) and pods on branches (OSL = 0.16). When stand density was included in the equation, contributing yield components were seeds per pod on branches (OSL = 0.22) and stem (OSL = 0.10), pods on branches (OSL = 0.06), and individual seed weight on stem (OSL = 0.02) as well as stand density (OSL = 0.002).

When the two years' data were sorted by treatment and then fitted to regression equations, pods on stem was the only significantly contributing yield component, and that only on DR plots.

When covariance was analyzed, pods on stem was much the most significantly contributing covariant factor (OSL = 0.06). Covariance was also analyzed using combinations of yield components sorted by plant part (stem and branches) and sorted by trait (pod number, seeds per pod, and individual seed weight), and in these combinations pods on stem was again the only significantly contributing factor.

Correlations of plot means of yield components with total yield were also calculated (Table 6, p. 31). With the two years combined none of these correlations were significant at the 0.10 level and pods on stem (r = 0.28, OSL = 0.13) was the only component significant at greater than the 0.30 level. During 1980 plot means of pods on stem and individual seed weight on branches correlated significantly (OSL = 0.05) with plot yield, and during 1981 plot means of no traits did, although individual seed weight on branches was almost significant (OSL = 0.06).

The results of calculating the optimum regression equation predicting the dependent variable of plant yield included all six components significantly contributing at the 0.0001 level. Pods on branches had the highest "F" value, followed by pods on stem (F = 3920 and 761, respectively).

The results of these various correlations, regression equations, and analyses of covariance seem to indicate that stand density has a more important contribution to plot yield than does any combination of primary yield components. The results also indicate that of the primary yield components those most significantly contributing to either plot or plant yield are those with the greatest latitude for variation, pods on stem and branches. Pods on stem seemed to predict plot yields better than did pods on branches because of the negative correlation of branch number with plot yield (r = -0.34, OSL = 0.06); pods on branches seemed to predict plant yield because of the high correlation of branch number with plant yield (r = 0.73, OSL = 0.0001). Although other characteristics contributed significantly when data were analyzed within rather than across years and/or treatments, the lack of common patterns indicates that these contributions were probably the consequence of stress patterns unique to those years and/or treatments.

If stand density is the dominant trait predicting plot yield, management decisions should be made to increase it. Such decisions will most likely attempt to increase soil surface moisture at and immediately following soybean planting. Manipulable variables include timeliness of wheat harvest, soybean planting date, and early season irrigation.

CHAPTER V

CONCLUSIONS

Irrigation tends to increase both soybean crop yields and individual plant yields, while double-cropping tends to decrease plot yields through reductions in stand density and tends to increase individual plant yields through reduced inter-plant competition.

Individual plants responded more markedly on branches than on stems to changes in water management or cropping management systems; however, the yield characteristic which most significantly predicted total plot yield was number of pods on stem.

Of the primary yield components (i.e., number of pods, number of seeds per pod, and weight of individual seeds), number of pods varied most and also most significantly reflected both plant and plot yields.

Intra-plant competition was exhibited by negative correlations between individual seed weight and pod number; inter-plant competition was exhibited by increased height and node numbers with mono-cropping and by increased branching and branch yields with double-cropping.

Harvest loss as estimated by seed yield below 10 cm of height on the plant did not vary significantly with the applied treatments on 'Forrest' soybeans.

The primary source of reduction in crop yield with double-cropping was reduced stand density, and it should therefore be a higher priority to increase plant populations than to increase individual plant yields within the present double-cropping management system.

LITERATURE CITED

1. Adams, M. W. 1967. Basis of yield component compensation in crop plants with special reference to the field bean, Phaseolus vulgaris. Crop Sci. 7:505-510.

2. Ashley, D. A., and W. J. Ethridge. 1978. Irrigation effects on vegetative and reproductive development of three soybean cultivars. Agron. J. 70:467-471.

3. Basnet, B., E. L. Mader, and C. D. Nickell. 1974. Influence of between and within-row spacing on agronomic characteristics of irrigated soybeans. Agron. J. 66:657-659.

4. Boyer, J. S. 1970. Leaf enlargement and metabolic rates in corn, soybean, and sunflower at various leaf water potentials. Plant Physiol. 46:233-235.

5. ______. 1970. Differing sensitivity of photosynthesis to low leaf water potentials in corn and soybean. Plant Physiol. 46: 236-239.

6. Brady, R. A., S. M. Goltz, W. L. Powers, and E. T. Kanemasu. 1975. Relation of soil water potential to stomatal resistance of soybean. Agron. J. 67:97-99.

7. ______, W. L. Powers, L. R. Stone, and S. M. Goltz. 1974. Relation of soybean leaf water potential to soil water potential. Agron. J. 66:795-798.

8. ______, L. R. Stone, C. D. Nickell, and W. L. Powers. 1974. Water conservation through proper timing of soybean irrigation. J. Soil Water Conserv. 29:266-268.

9. Burmwood, D. T., and W. R. Fehr. 1973. Variety and row spacing effects on recoverability of soybeans from simulated hail injury. Agron. J. 65:301-303.

10. Burnside, O. C., and W. L. Colville. 1964. Yield components and composition of soybeans as affected by mechanical, cultural, and chemical weed control practices. Agron. J. 56:348-351.

11. Carlson, R. E., N. N. Momen, O. Arjmand, and R. H. Shaw. 1979. Leaf conductance and leaf-water potential relationships for two soybean cultivars grown under controlled irrigation. Agron. J. 71:321-325.

12. Cartter, J. L., and T. H. Hopper. 1942. Influence of variety, environment, and fertility level on the chemical composition of soybean seed. USDA Technical Bulletin 787. U.S. Government Printing Office, Washington, D.C.

13. Crabtree, R. J., and R. N. Rupp. 1980. Double and mono-cropped wheat and soybeans under different tillage and row spacings. Agron. J. 72:445-448.

14. Doss, B. D., R. W. Pearson, and Howard T. Rogers. 1974. Effect of soil water stress at various growth stages on soybean yield. Agron. J. 66:297-299.

15. ______, and D. L. Thurlow. 1974. Irrigation, row width, and plant population in relation to growth characteristics of two soybean varieties. Agron. J. 66:620-623.

16. Dusek, D. A., J. T. Musick, and K. B. Porter. 1971. Irrigation of soybeans in the Texas high plains. Texas Agric. Expt. Sta. Misc. Publ. 973.

17. Edwards, Calton J., Jr., and Edgar E. Hartwig. 1971. Effect of seed size upon rate of germination in soybeans. Agron. J. 63:429-430.

18. Egli, D. B. 1975. Rate of accumulation of dry weight in seed of soybeans and its relationship to yield. Can. J. Plant Sci. 55:215-219.

19. ______, and J. E. Leggett. 1976. Rate of dry matter accumulation in soybean seeds with varying source-sink ratios. Agron. J. 68:371-374.

20. Ghorashy, S. R., R. L. Monroe, and J. W. Pendleton. 1971. The thirsty soybean. Illinois Expt. Sta., Illinois Res. 13(3): 5-6.

21. ______, J. W. Pendleton, D. B. Peters, J. S. Boyer, and J. E. Beuerlein. 1971. Internal water stress and apparent photosynthesis with soybeans differing in pubescense. Agron. J. 63:674-676.

22. Hanson, W. D., C. A. Brim, and Kuell Hinson. 1961. Design and analysis of competition studies with an application to field plot competition in the soybean. Crop Sci. 1:255-258.

23. Hardman, L. L., and W. A. Brun. 1971. Effect of atmospheric carbon dioxide enrichment at different developmental stages on growth and yield components of soybeans. Crop Sci. 11: 886-888.

24. Heatherly, L. G., and W. J. Russell. 1979. Effect of soil water potential of two soils on soybean emergence. Agron. J. 71: 980-982.

25. Hicks, D. R., and J. W. Pendleton. 1969. Effect of floral bud removal on performance of soybeans. Crop Sci. 9:435-437.

26. ______, ______, R. L. Bernard, and T. J. Johnston. 1969. Response of soybean plant types to planting patterns. Agron. J. 61:290-293.

27. Hinson, Kuell, and W. D. Hanson. 1962. Competition studies in soybeans. Crop Sci. 2:117-123.

28. Huang, Chi-Ying, John S. Boyer, and Larry N. Vanderhoef. 1975. Acetylene reduction (nitrogen fixation) and metabolic activities of soybean having various leaf and nodule water potentials. Plant Physiol. 56:222-227.

29. ______, ______, and ______. 1975. Limitation of acetylene reduction (nitrogen fixation) by photosynthesis in soybean having low water potentials. Plant Physiol. 56:228-232.

30. Huck, M. G., and J. H. Davis. 1976. Water requirements and root growth. p. 16-27. In L. D. Hill (ed.) World soybean research. The Interstate Printers and Publishers, Inc., Danville, Ill.

31. Hunter, J. R., and A. E. Erickson. 1952. Relation of seed germination to soil moisture tension. Agron. J. 44:107-109.

32. Johnson, B. J., and H. B. Harris. 1967. Influence of plant population on yield and other characteristics of soybeans. Agron. J. 59:447-449.

33. Johnson, Herbert W., H. F. Robinson, and R. E. Comstock. 1955. Genotypic and phenotypic correlations in soybeans and their implications in selection. Agron. J. 47:477-483.

34. Johnston, T. J., J. W. Pendleton, D. B. Peters, and D. R. Hicks. 1969. Influence of supplemental light on apparent photosynthesis, yield, and yield components of soybeans (*Glycine max* L.). Crop Sci. 9:577-581.

35. Jung, P. K., and H. D. Scott. 1980. Leaf water potential, stomatal resistance, and temperature relations in field-grown soybeans. Agron. J. 72:986-990.

36. Kollman, G. E., J. G. Streeter. D. L. Jeffers, and R. B. Curry. 1974. Accumulation and distribution of mineral nutrients, carbohydrates, and dry matter in soybean plants as influenced by reproductive sink size. Agron. J. 66:549-554.

37. Lehman, W. F., and J. W. Lambert. 1960. Effects of spacing of soybean plants between and within rows on yield and its components. Agron. J. 52:84-86.

38. Matson, Arnold L. 1964. Some factors affecting the yield response of soybeans to irrigation. Agron. J. 56:552-555.

39. Mayaki, W. C., L. R. Stone, and I. D. Teare. 1976. Irrigated and nonirrigated soybean, corn, and grain sorghum root systems. Agron. J. 68:532-534.

40. ______, I. D. Teare, and L. R. Stone. 1976. Top and root growth of irrigated and nonirrigated soybeans. Crop Sci. 16:92-94.

41. McAlister, Dean F., and Orland A. Krober. 1958. Response of soybeans to leaf and pod removal. Agron. J. 50:674-677.

42. Mitchell, R. L., and W. R. Russell. 1971. Root development and rooting patterns of soybean (*Glycine max* (L.) Merr) evaluated under field conditions. Agron. J. 63:313-316.

43. Momen, N. N., R. E. Carlson, R. H. Shaw, and O. Arjmand. 1979. Moisture-stress effects on the yield components of two soybean cultivars. Agron. J. 71:86-90.

44. Pandey, J. P., and J. H. Torrie. 1973. Path coefficient analysis of seed yield components in soybeans (*Glycine max* (L.) Merr.) Crop Sci. 13:505-507.

45. Runge, E. C. A., and R. T. Odell. 1960. The relation between precipitation, temperature, and the yield of soybeans on the Agronomy South Farm, Urbana, Illinois. Agron. J. 52:245-247.

46. Sivakumar, M. V. K., and R. H. Shaw. 1978. Relative evaluation of water stress indicators for soybeans. Agron. J. 70:619-623.

47. Smith, T. J., and H. M. Camper, Jr. 1975. Effects of seed size on soybean performance. Agron. J. 67:681-684.

48. Sojka, R. A., H. D. Scott, J. A. Ferguson, and E. M. Rutledge. 1977. Relation of plant water status to soybean growth. Soil Sci. 123:182-187.

49. Somerhalder, B. R., and P. E. Schleusener. 1960. Irrigation can increase soybean production. Neb. Expt. Sta. Qrtly. 7(1): 16-17.

50. Statistical Analysis System, SAS Institute, Inc., Box 8000, Cary, North Carolina 27511.

51. Stevenson, K. R., and R. H. Shaw. 1971. Diurnal changes in leaf resistance to water vapor diffusion at different heights in a soybean canopy. Agron. J. 63:17-19.

52. Stone, L. R., I. D. Teare, C. D. Nickell, and W. C. Mayaki. 1976. Soybean root development and soil water depletion. Agron. J. 68:677-680.

53. Teare, I. D., E. T. Kanemasu, W. L. Powers, and H. S. Jacobs. 1973. Water-use efficiency and its relation to crop canopy area, stomatal regulation, and root distribution. Agron. J. 65:207-211.

54. Teigen, James B., and James J. Forst. 1975. Soybean response to stand reduction and defoliation. Agron. J. 67:813-816.

55. Thompson, Louis M. 1970. Weather and technology in the production of soybeans in the central United States. Agron. J. 62:232-236.

56. Van Schaik, P. H., and A. H. Probst. 1958. Effects of some environmental factors on flower production and reproductive efficiency in soybeans. Agron. J. 50:287-289.

57. Weber, C. R., and W. R. Fehr. 1966. Seed yield losses from lodging and combine harvesting in soybeans. Agron. J. 58:287-289.

58. Weil, R. R., and A. J. Ohlrogge. 1976. Components of soybean seed yield as influenced by canopy level and interplant competition. Agron. J. 68:583-587.

59. Wien, H. C., E. J. Littleton, and A. Ayanaba. 1979. Drought stress of cowpea and soybean under tropical conditions. p. 283-301. <u>In</u> Harry Mussell and Richard C. Staples (eds.) Stress physiology in crop plants. John Wiley and Sons, Inc., New York.

60. Willatt, S. T., and H. M. Taylor. 1978. Water uptake by soyabean roots as affected by their depth and by soil water content. J. Agric. Sci., Camb. 90:205-213.

APPENDIX

Table 7. Treatments: Plot yields.[##]

Yearly Factor Levels[†]	N	Mean[††] (kg/ha)		OSL	Treatment	Mean[#]
1980	16	2730 ($\bar{s}$ = 650)				
D	8	2450	-----	.0664	DI	2710 ab
M	8	3000			DR	2200 b
I	8	3050	-----	.0363	MI	3390 a
R	8	2410			MR	2610 ab
C x W			-----	.6183		
1981	16	2390 ($\bar{s}$ = 440)				
D	8	2130	-----	.0175	DI	2110 b
M	8	2660			DR	2140 b
I	8	2480	-----	.3449	MI	2860 a
R	8	2300			MR	2460 ab
C x W			-----	.2620		
1980/81	32	2560 ($\bar{s}$ = 540)				
D	16	2290	-----	.0027	DI	2410 b
M	16	2830			DR	2170 b
I	16	2770	-----	.0165	MI	3120 a
R	16	2350			MR	2530 b
C x W			-----	.2775		
1980 x 1981			-----	.0471		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Yield gathered by combine harvest.

Table 8. Treatment means: Stand density.[##]

Yearly Factor Levels[†]	N	Mean[†] (plants/m)		OSL	Treatment	Mean[#]
1981	16	11.8 ($\underline{s}$ = 4.3)				
D	8	8.7	-----	.0028	DI	10.4 ab
M	8	14.9			DR	7.0 b
I	8	12.7	-----	.2428	MI	15.1 a
R	8	10.8			MR	14.7 a
C x W	-------------------------------			.3571		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Plot average of 10 counts per plot of plants per linear one meter of row.

Table 9. Treatment means: Height.[##]

Yearly Factor Levels[†]	N	Mean[††] (cm)	OSL	Treatment	Mean[#]
1980	160	68.2 (s = 12.8)			
D	80	67.7	.8037	DI	68.5 a
M	80	68.7		DR	67.0 a
I	80	70.5	.2717	MI	72.5 a
R	80	65.9		MR	64.9 a
C x W			.4586		
1981	160	66.6 (s = 9.9)			
D	80	57.4	.0051	DI	62.9 bc
M	80	75.7		DR	51.8 c
I	80	72.0	.0563	MI	81.1 a
R	80	61.1		MR	70.4 ab
C x W			.9747		
1980/81	320	67.4 (s = 11.5)			
D	160	62.6	.0120	DI	65.7 ab
M	160	72.2		DR	59.4 b
I	160	71.3	.0389	MI	76.8 a
R	160	63.5		MR	67.6 ab
C x W			.6881		
1980 x 1981			.6399		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Measured to terminal node.

Table 10. Treatment means: Nodes per plant.

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	160	15.4 ($\underline{s}$ = 2.1)				
D	80	15.0	-----	.0653	DI	15.1 a
M	80	15.9			DR	14.9 a
I	80	15.5	-----	.8256	MI	15.9 a
R	80	15.4			MR	15.9 a
C x W			-----	.8687		
1981	160	14.2 ($\underline{s}$ = 1.8)				
D	80	13.1	-----	.0066	DI	13.3 ab
M	80	15.3			DR	12.9 b
I	80	14.2	-----	.8300	MI	15.2 a
R	80	14.1			MR	15.4 a
C x W			-----	.6550		
1980/81	320	14.8 (s = 2.0)				
D	160	14.0	-----	.0006	DI	14.2 b
M	160	15.6			DR	13.9 b
I	160	14.9	-----	.7624	MI	15.6 a
R	160	14.8			MR	15.6 a
C x W			-----	.6450		
1980 x 1981			-----	.0037		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

Table 11. Treatment means: Pod bearing branches per plant.

Yearly Factor Levels[†]	N	Mean[††]	OSL	Treatment	Mean[#]
1980	160	2.8 (s = 1.8)			
D	80	3.6	.0001	DI	4.0 a
M	80	2.0		DR	3.2 a
I	80	3.1	.0223	MI	2.3 b
R	80	2.5		MR	1.8 b
C x W			.6817		
1981	160	3.3 (s = 1.8)			
D	80	3.7	.0285	DI	3.9 a
M	80	2.8		DR	3.5 ab
I	80	3.5	.1330	MI	3.2 ab
R	80	3.0		MR	2.4 b
C x W			.6446		
1980/81	320	3.0 (s = 1.8)			
D	160	3,6	.0001	DI	3.9 a
M	160	2.4		DR	3.4 ab
I	160	3.3	.0126	MI	2.8 bc
R	160	2.7		MR	2.1 c
C x W			.8895		
1980 x 1981			.0659		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

Table 12. Treatment means: Harvest loss.[##]

Yearly Factor Levels[†]	N	Mean[††] (%)	OSL	Treatment	Mean[#]
1980	158	0.23 (s = 1.13)			
D	80	0.35	.3924	DI	0.61 a
M	78	0.10		DR	0.10 a
I	80	0.39	.2774	MI	0.17 a
R	78	0.07		MR	0.04 a
C x W			.4972		
1981	160	1.62 (s = 14.23)			
D	80	3.28	.3440	DI	0.01 a
M	80	0.07		DR	6.35 a
I	80	0.03	.3330	MI	0.05 a
R	80	3.22		MR	0.09 a
C x W			.3383		
1980/81	318	0.93 (s = 10.13)			
D	160	1.77	.2986	DI	0.31 a
M	158	0.08		DR	3.22 a
I	160	0.21	.3675	MI	0.11 a
R	158	1.66		MR	0.06 a
C x W			.3623		
1980 x 1981			.3868		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Seed weight below 10 cm divided by sum of seed weight on branches and stem, multiplied by 100.

Table 13. Treatment means: Pods on branches.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	160	31.5 (s = 28.2)				
D	80	41.7				
M	80	21.3	-----	.0129	DI	47.2 a
					DR	36.2 ab
I	80	37.7	-----		MI	28.2 ab
R	80	25.3		.0927	MR	14.4 b
C x W			-----	.8410		
1981	160	37.6 (s = 32.8)				
D	80	47.0				
M	80	28.2	-----	.0062	DI	53.4 a
					DR	40.7 a
I	80	44.6	-----		MI	35.8 ab
R	80	30.7		.0276	MR	20.6 b
C x W			-----	.8171		
1980/81	320	34.6 (s = 30.6)				
D	160	44.4				
M	160	24.8	-----	.0003	DI	50.3 a
					DR	38.5 ab
I	160	41.2	-----	.0085	MI	32.0 bc
R	160	28.0			MR	17.5 c
C x W			-----	.7750		
1980 x 1981			-----	.1920		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Mature pods above 10 cm.

Table 14. Treatment means: Pods on stem.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	160	31.1 (s = 15.7)				
D	80	33.8	-----	.1074	DI	37.8 a
M	80	28.4			DR	29.8 ab
I	80	35.1	-----	.0253	MI	32.4 ab
R	80	27.1			MR	24.4 b
C x W			-------------------------------	.9935		
1981	160	33.1 (s = 16.1)				
D	80	33.9	-----	.7369	DI	33.8 a
M	80	32.3			DR	34.0 a
I	80	33.2	-----	.9672	MI	32.6 a
R	80	33.0			MR	32.1 a
C x W			-------------------------------	.9410		
1980/81	320	32.1 (s = 15.9)				
D	160	33.8	-----	.2027	DI	35.8 a
M	160	30.4			DR	31.8 ab
I	160	34.1	-----	.1327	MI	32.5 ab
R	160	30.1			MR	28.3 b
C x W			-------------------------------	.9528		
1980 x 1981			-------------------------	.4478		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Mature pods above 10 cm.

Table 15. Treatment means: Pods on plant.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	160	62.6 (s = 37.4)				
D	80	75.5	-----	.0168	DI	85.0 a
M	80	49.7			DR	66.0 ab
I	80	72.8	-----	.0454	MI	60.6 ab
R	80	52.4			MR	38.9 b
C x W	------------	------------	------------	.8824		
1981	160	70.7 (s = 43.4)				
D	80	80.9	-----	.0356	DI	87.2 a
M	80	60.6			DR	74.7 ab
I	80	77.8	-----	.1217	MI	68.4 ab
R	80	63.7			MR	52.7 b
C x W	------------	------------	------------	.8506		
1980/81	320	66.7 (s = 40.4)				
D	160	78.2	-----	.0012	DI	86.1 a
M	160	55.1			DR	70.3 ab
I	160	75.3	-----	.0104	MI	64.5 b
R	160	58.0			MR	45.8 c
C x W	------------	------------	------------	.8130		
1980 x 1981	------------	------------	------------	.1990		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Sum of mature pods above 10 cm on stem and branches.

Table 16. Treatment means: Seeds per pod on branches.##

Yearly Factor Levels†	N	Mean††	OSL	Treatment	Mean#
1980	141	2.06 (s = .59)			
D	75	2.17	.0267	DI	2.11 a
M	66	1.93		DR	2.24 a
I	74	2.11	.2138	MI	2.12 a
R	67	1.99		MR	1.73 b
C x W			.0198		
1981	148	2.12 (s = .21)			
D	75	2.16	.1245	DI	2.15 a
M	73	2.08		DR	2.17 a
I	77	2.12	.9808	MI	2.09 a
R	71	2.12		MR	2.07 a
C x W			.6569		
1980/81	289	2.09 (s = .44)			
D	150	2.16	.0044	DI	2.13 a
M	139	2.01		DR	2.20 a
I	151	2.12	.2395	MI	2.10 a
R	138	2.06		MR	1.90 b
C x W			.0108		
1980 x 1981			.2136		

†C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

††Yearly means followed by standard deviation in parentheses.

#Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

##Mature pods on branches above 10 cm divided by undamaged seeds on branches above 10 cm.

Table 17. Treatment means: Seeds per pod on stem.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	158	2.07 ($\bar{s}$ = .31)				
D	79	2.12	-----	.2513	DI	2.18 a
M	79	2.01			DR	2.07 ab
I	80	2.18	-----	.0300	MI	2.19 a
R	78	1.95			MR	1.84 b
C x W			-------------------------------	.2360		
1981	160	2.19 ($\bar{s}$ = .26)				
D	80	2.21	-----	.5170	DI	2.19 a
M	80	2.16			DR	2.23 a
I	80	2.16	-----	.4193	MI	2.13 a
R	80	2.22			MR	2.20 a
C x W			-------------------------------	.8234		
1980/81	318	2.13 ($\bar{s}$ = .29)				
D	159	2.17	-----	.1652	DI	2.19 a
M	159	2.09			DR	2.15 a
I	160	2.17	-----	.1322	MI	2.16 a
R	158	2.09			MR	2.02 a
C x W			-------------------------------	.3806		
1980 x 1981			-------------------------	.0439		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Mature pods on stem above 10 cm divided by undamaged seeds on stem above 10 cm.

Table 18. Treatment means: Seeds per pod on plant.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	159	2.05 ($\underline{s}$ = .29)				
D	80	2.12	-----	.1404	DI	2.15 a
M	79	1.98			DR	2.09 a
I	80	2.15	-----	.0385	MI	2.15 a
R	79	1.95			MR	1.81 b
C x W				.1220		
1981	160	2.17 ($\underline{s}$ = .17)				
D	80	2.19	-----	.3584	DI	2.17 a
M	80	2.14			DR	2.21 a
I	80	2.14	-----	.3026	MI	2.11 a
R	80	2.20			MR	2.18 a
C x W				.7539		
1980/81	319	2.11 ($\underline{s}$ = .24)				
D	160	2.15	-----	.0631	DI	2.16 a
M	159	2.06			DR	2.15 a
I	160	2.14	-----	.1409	MI	2.13 a
R	159	2.07			MR	2.00 a
C x W				.2053		
1980 x 1981				.0170		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Mature pods on plant above 10 cm divided by undamaged seeds on plant above 10 cm.

Table 19. Treatment means: Individual seed weight on branches.[##]

Yearly Factor Levels[†]	N	Mean[††] (g)		OSL	Treatment	Mean[#]
1980	141	.128 (s = .035)				
D	75	.132	-----	.0836	DI	.140 ab
M	66	.123			DR	.124 ab
I	74	.128	-----	.9199	MI	.115 b
R	67	.128			MR	.132 ab
C x W			-----	.0102		
1981	148	.126 (s = .016)				
D	75	.124	-----	.2708	DI	.128 a
M	73	.128			DR	.120 a
I	77	.127	-----	.4534	MI	.127 a
R	71	.125			MR	.130 a
C x W			-----	.1159		
1980/81	289	.127 (s = .027)				
D	150	.128	-----	.4233	DI	.134 a
M	139	.126			DR	.122 b
I	151	.128	-----	.6048	MI	.121 b
R	138	.126			MR	.131 a
C x W			-----	.0024		
1980 x 1981			-----	.5474		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Weight of seeds on branches divided by number of seeds on branches.

Table 20. Treatment means: Individual seed weight on stem.[##]

Yearly Factor Levels[†]	N	Mean[††] (g)	OSL	Treatment	Mean[#]
1980	157	.128 (s = .024)			
D	79	.137	.0001	DI	.143 a
M	78	.119		DR	.131 b
I	80	.127	.3396	MI	.111 c
R	77	.130		MR	.128 b
C x W			.0003		
1981	160	.136 (s = .088)			
D	80	.139	.6228	DI	.129 a
M	80	.132		DR	.149 a
I	80	.129	.3748	MI	.129 a
R	80	.142		MR	.135 a
C x W			.6178		
1980/81	317	.132 (s = .065)			
D	159	.138	.0945	DI	.136 a
M	158	.126		DR	.140 a
I	160	.128	.2667	MI	.120 a
R	157	.136		MR	.132 a
C x W			.6071		
1980 x 1981			.2782		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Weight of seeds on stem divided by number of seeds on stem.

Table 21. Treatment means: Individual seed weight on plant.##

Yearly Factor Levels†	N	Mean†† (g)		OSL	Treatment	Mean#
1980	158	.128 (s = .023)				
D	80	.135	-----	.0013	DI	.141 a
M	78	.120			DR	.129 b
I	80	.127	-----	.5210	MI	.112 c
R	78	.129			MR	.129 b
C x W			------------------------------	.0013		
1981	160	.128 (s = .017)				
D	80	.126	-----	.1943	DI	.129 a
M	80	.130			DR	.123 a
I	80	.128	-----	.9906	MI	.128 a
R	80	.128			MR	.133 a
C x W			------------------------------	.0884		
1980/81	318	.128 (s = .020)				
D	160	.131	-----	.0338	DI	.135 a
M	158	.125			DR	.126 b
I	160	.128	-----	.6500	MI	.120 c
R	158	.129			MR	.131 ab
C x W			------------------------------	.0002		
1980 x 1981			-------------------------	.7672		

†C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

††Yearly means followed by standard deviation in parentheses.

#Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

##Weight of seeds on plant divided by number of seeds on plant.

Table 22. Treatment means: Seeds on branches.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	160	66.9 ($\underline{s}$ = 60.5)				
D	80	89.$\bar{8}$	-----	.0128	DI	102.0 a
M	80	44.0			DR	77.5 a
I	80	81.2	-----	.0853	MI	60.3 ab
R	80	52.6			MR	27.7 b
C x W			--------------------------------	.7902		
1981	160	81.1 ($\underline{s}$ = 72.4)				
D	80	102.$\bar{3}$	-----	.0061	DI	115.4 a
M	80	60.0			DR	89.3 ab
I	80	95.3	-----	.0407	MI	75.3 bc
R	80	66.9			MR	44.6 c
C x W			--------------------------------	.8501		
1980/81	320	74.0 ($\underline{s}$ = 66.7)				
D	160	96.$\bar{0}$	-----	.0003	DI	108.7 a
M	160	52.0			DR	83.4 ab
I	160	88.2	-----	.0103	MI	67.8 bc
R	160	59.8			MR	36.2 c
C x W			--------------------------------	.7561		
1980 x 1981			--------------------------	.1734		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Undamaged above 10 cm.

Table 23. Treatment means: Seeds on stem.[##]

Yearly Factor Levels[†]	N	Mean[††]	OSL	Treatment	Mean[#]
1980	160	66.6 (s = 35.2)			
D	80	72.4	.1303	DI	82.2 a
M	80	60.9		DR	62.6 ab
I	80	77.0	.0149	MI	71.8 ab
R	80	56.3		MR	50.0 b
C x W			.8773		
1981	160	72.6 ($\underline{s}$ = 35.8)			
D	80	74.9	.6565	DI	74.5 a
M	80	70.3		DR	75.3 a
I	80	72.0	.9105	MI	69.6 a
R	80	73.2		MR	71.1 a
C x W			.9688		
1980/81	320	69.6 ($\underline{s}$ = 35.5)			
D	160	73.7	.1896	DI	78.4 a
M	160	65.6		DR	68.9 ab
I	160	74.5	.1133	MI	70.7 ab
R	160	64.7		MR	60.5 b
C x W			.9536		
1980 x 1981			.3268		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Undamaged above 10 cm.

Table 24. Treatment means: Seeds on plant.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	160	133.5 ($\underline{s}$ = 82.6)				
D	80	162.2	-----	.0200	DI	184.2 a
M	80	104.9			DR	140.1 ab
I	80	158.2	-----	.0379	MI	132.2 ab
R	80	108.9			MR	77.7 b
C x W			-------------------------------	.8053		
1981	160	153.7 ($\underline{s}$ = 94.8)				
D	80	177.2	-----	.0314	DI	189.9 a
M	80	130.3			DR	164.6 ab
I	80	167.4	-----	.1737	MI	144.8 ab
R	80	140.1			MR	115.7 b
C x W			-------------------------------	.9197		
1980/81	320	143.6 ($\underline{s}$ = 88.9)				
D	160	169.7	-----	.0012	DI	187.1 a
M	160	117.6			DR	152.3 ab
I	160	162.8	-----	.0121	MI	138.5 b
R	160	124.5			MR	96.7 c
C x W			-------------------------------	.8025		
1980 x 1981			-------------------------	.1619		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Sum of seeds on branches and seeds on stem.

Table 25. Treatment means: Weight of seeds on branches.##

Yearly Factor Levels†	N	Mean†† (g)		OSL	Treatment	Mean#
1980	160	8.56 ($\bar{s}$ = 7.94)				
D	80	12.04	-----	.0070	DI	14.31 a
M	80	5.08			DR	9.76 ab
I	80	10.52	-----	.0812	MI	6.74 b
R	80	6.60			MR	3.43 b
C x W			-----	.7637		
1981	160	10.27 ($\bar{s}$ = 9.47)				
D	80	12.86	-----	.0095	DI	14.95 a
M	80	7.69			DR	10.76 ab
I	80	12.27	-----	.0317	MI	9.59 b
R	80	8.28			MR	5.79 b
C x W			-----	.9046		
1980/81	320	9.42 ($\bar{s}$ = 8.74)				
D	80	12.45	-----	.0003	DI	14.63 a
M	80	6.39			DR	10.26 ab
I	80	11.40	-----	.0102	MI	8.16 bc
R	80	7.44			MR	4.61 c
C x W			-----	.7747		
1980 x 1981			-----	.2358		

†C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

††Yearly means followed by standard deviation in parentheses.

#Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

##Undamaged above 10 cm.

Table 26. Treatment means: Weight of seeds on stem.##

Yearly Factor Levels†	N	Mean†† (g)		OSL	Treatment	Mean#
1980	160	8.42 (s = 4.52)				
D	80	9.88	-----	.0130	DI	11.52 a
M	80	6.98			DR	8.23 b
I	80	9.74	-----	.0206	MI	7.96 b
R	80	7.11			MR	5.98 b
C x W	----------	----------	----------	.5053		
1981	160	9.29 (s = 4.44)				
D	80	9.38	-----	.8758	DI	9.24 a
M	80	9.19			DR	9.53 a
I	80	9.00	-----	.6565	MI	8.77 a
R	80	9.57			MR	9.61 a
C x W	----------	----------	----------	.8279		
1980/81	320	8.86 (s = 4.48)				
D	160	9.63	-----	.0582	DI	10.38 a
M	160	8.08			DR	8.88 b
I	160	9.37	-----	.1953	MI	8.37 b
R	160	8.34			MR	7.80 b
C x W	----------	----------	----------	.5553		
1980 x 1981	----------	----------	----------	.2782		

†C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

††Yearly means followed by standard deviation in parentheses.

#Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

##Undamaged above 10 cm.

Table 27. Treatment means: Weight of seeds on plant.[##]

Yearly Factor Levels[†]	N	Mean[††] (g)	OSL	Treatment	Mean[#]
1980	160	16.99 (s = 10.81)			
D	80	21.92	.0054	DI	25.83 a
M	80	12.06		DR	18.00 ab
I	80	20.27	.0383	MI	14.70 b
R	80	13.70		MR	9.41 b
C x W			.6494		
1981	160	19.56 (s = 12.19)			
D	80	22.26	.0464	DI	24.19 a
M	80	16.88		DR	20.29 ab
I	80	21.28	.1741	MI	18.36 ab
R	80	17.85		MR	15.40 b
C x W			.8446		
1980/81	320	18.27 (s = 11.52)			
D	160	22.08	.0006	DI	25.01 a
M	160	14.47		DR	19.14 b
I	160	20.77	.0155	MI	16.53 bc
R	160	15.78		MR	12.41 c
C x W			.6509		
1980 x 1981			.1890		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Sum of weight of seeds on branches and weight of seeds on stem.

Table 28. Treatment means: Weight of harvestable plus nonharvestable seeds on plant.[##]

Yearly Factor Levels[†]	N	Mean[††] (g)		OSL	Treatment	Mean[#]
1980	160	17.33 ($\underline{s}$ = 10.95)				
D	80	22.26	-----	.0056	DI	26.29 a
M	80	12.39			DR	18.22 ab
I	80	20.58	-----	.0404	MI	14.88 b
R	80	14.07			MR	9.91 b
C x W -------------------------------				.5833		
1981	160	19.70 ($\underline{s}$ = 12.18)				
D	80	22.48	-----	.0391	DI	24.23 a
M	80	16.92			DR	20.73 ab
I	80	21.31	-----	.1945	MI	18.40 ab
R	80	18.08			MR	15.43 b
C x W -------------------------------				.9122		
1980/81	320	18.54 ($\underline{s}$ = 11.59)				
D	160	22.37	-----	.0004	DI	25.26 a
M	160	14.66			DR	19.48 b
I	160	20.95	-----	.0147	MI	16.64 bc
R	160	16.08			MR	12.67 c
C x W -------------------------------				.5523		
1980 x 1981 -------------------------				.2268		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Sum of weight of seeds on plant plus weight of seeds below 10 cm plus one fifth the weight of loose seeds in collection bags (five plants per collection bag).

Table 29. Treatment means: Loose seed weight.[##]

Yearly Factor Levels[†]	N	Mean[††] (g)		OSL	Treatment	Mean[#]
1980	32	1.41 ($\bar{s}$ = 0.63)				
D	16	1.18	-----	.3517	DI	1.32 ab
M	16	1.64			DR	1.04 ab
I	16	1.08	-----	.1856	MI	0.82 b
R	16	1.75			MR	2.46 a
C x W				.0713		
1981	32	0.08 ($\bar{s}$ = 0.09)				
D	16	0.10	-----	.5433	DI	0.14 a
M	16	0.06			DR	0.06 a
I	16	0.12	-----	.2708	MI	0.10 a
R	16	0.04			MR	0.01 a
C x W				.9301		
1980/81	64	0.74 ($\bar{s}$ = 0.45)				
D	32	0.64	-----	.3601	DI	0.73 a
M	32	0.85			DR	0.55 a
I	32	0.60	-----	.1989	MI	0.46 a
R	32	0.89			MR	1.24 a
C x W				.0446		
1980 x 1981				.0001		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Weight of loose seeds in bottom of collection bags (five plants per collection bag).

Table 30. Treatment means: Seeds per node.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	160	8.62 (s = 5.03)				
D	80	10.74	-----	.0126	DI	12.01 a
M	80	6.50			DR	9.47 a
I	80	10.13	-----	.0540	MI	8.25 ab
R	80	7.10			MR	4.74 b
C x W			------------------------------	.7281		
1981	160	10.85 (s = 6.21)				
D	80	13.13	-----	.0044	DI	14.09 a
M	80	8.56			DR	12.18 ab
I	80	11.85	-----	.1317	MI	9.61 bc
R	80	9.84			MR	7.50 c
C x W			------------------------------	.9338		
1980/81	320	9.73 (s = 5.65)				
D	160	11.94	-----	.0001	DI	13.05 a
M	160	7.53			DR	10.83 ab
I	160	10.99	-----	.0162	MI	8.98 b
R	160	8.47			MR	6.12 c
C x W			------------------------------	.7609		
1980 x 1981			-------------------------	.0308		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Quotient of seeds on plant divided by nodes per plant.

Table 31. Treatment means: Seed weight per node.[##]

Yearly Factor Levels[†]	N	Mean[††] (g)		OSL	Treatment	Mean[#]
1980	160	1.10 ($\underline{s}$ = 0.67)				
D	80	1.45	-----	.0035	DI	1.68 a
M	80	0.75			DR	1.22 ab
I	80	1.30	-----	.0533	MI	0.92 bc
R	80	0.90			MR	0.58 c
C x W				.7429		
1981	160	1.38 ($\underline{s}$ = 0.81)				
D	80	1.65	-----	.0055	DI	1.79 a
M	80	1.11			DR	1.50 ab
I	80	1.51	-----	.1168	MI	1.22 bc
R	80	1.25			MR	1.00 c
C x W				.8397		
1980/81	320	1.24 ($\underline{s}$ = 0.74)				
D	160	1.55	-----	.0001	DI	1.74 a
M	160	0.93			DR	1.36 b
I	160	1.40	-----	.0194	MI	1.07 bc
R	160	1.07			MR	0.79 c
C x W				.7274		
1980 x 1981				.0426		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Quotient of weight of seeds on plant divided by nodes per plant.

Table 32. Treatment means: Percent immature pods on branches.[##]

Yearly Factor Levels[†]	N	Mean[††] (%)		OSL	Treatment	Mean[#]
1980	141	7.53 ($\underline{s}$ = 12.47)				
D	75	5.86	-----	.1348	DI	6.68 a
M	66	9.42			DR	4.93 a
I	74	7.16	-----	.7319	MI	7.74 a
R	67	7.93			MR	11.22 a
C x W	------------------------------			.2627		
1981	148	7.57 ($\underline{s}$ = 19.06)				
D	75	7.57	-----	.9969	DI	6.72 ab
M	73	7.58			DR	8.44 ab
I	77	9.42	-----	.1421	MI	12.05 a
R	71	5.57			MR	2.45 b
C x W	------------------------------			.0420		
1980/81	289	7.55 ($\underline{s}$ = 16.20)				
D	150	6.71	-----	.3228	DI	6.70 a
M	139	8.45			DR	6.73 a
I	151	8.31	-----	.3637	MI	10.04 a
R	138	6.72			MR	6.70 a
C x W	------------------------------			.3397		
1980 x 1981	-------------------------			.9805		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Quotient of immature pods on branches divided by mature pods on branches above 10 cm, multiplied by 100.

Table 33. Treatment means: Percent immature pods on stem.[##]

Yearly Factor Levels[†]	N	Mean[††] (%)		OSL	Treatment	Mean[#]
1980	158	8.71 ($\underline{s}$ = 13.90)				
D	79	6.30	-----	.1034	DI	4.41 b
M	79	11.12			DR	8.23 ab
I	80	9.55	-----	.5376	MI	14.69 a
R	78	7.85			MR	7.46 ab
C x W			------------------------------	.0676		
1981	160	9.34 ($\underline{s}$ = 39.59)				
D	80	6.80	-----	.4567	DI	6.21 a
M	80	11.87			DR	7.40 a
I	80	13.47	-----	.2362	MI	20.74 a
R	80	5.20			MR	3.01 a
C x W			------------------------------	.1808		
1980/81	318	9.03 ($\underline{s}$ = 29.75)				
D	159	6.55	-----	.1589	DI	5.31 b
M	159	11.50			DR	7.81 ab
I	160	11.51	-----	.1542	MI	17.71 a
R	158	6.51			MR	5.20 b
C x W			------------------------------	.0379		
1980 x 1981			------------------------	.8544		

[†] C x W = crop by water management system interaction,
1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Quotient of immature pods on stem divided by mature pods on stem above 10 cm, multiplied by 100.

Table 34. Treatment means: Percent immature pods on plant.[##]

Yearly Factor Levels[†]	N	Mean[††] (%)		OSL	Treatment	Mean[#]
1980	159	8.08 (s = 10.29)				
D	80	5.62	-----	.0527	DI	5.31 b
M	79	10.57			DR	5.94 ab
I	80	9.22	-----	.3299	MI	13.13 a
R	79	6.93			MR	7.96 ab
C x W	-----	-----	-----	.2274		
1981	160	7.37 (s = 21.71)				
D	80	6.74	-----	.6926	DI	5.74 ab
M	80	8.00			DR	7.74 ab
I	80	9.63	-----	.1784	MI	13.53 a
R	80	5.11			MR	2.48 b
C x W	-----	-----	-----	.0646		
1980/81	319	7.73 (s = 17.01)				
D	160	6.18	-----	.1109	DI	5.53 b
M	159	9.28			DR	6.84 b
I	160	9.43	-----	.0813	MI	13.33 a
R	159	6.02			MR	5.18 b
C x W	-----	-----	-----	.0193		
1980 x 1981	-----	-----	-----	.7061		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Quotient of immature pods on plant divided by mature pods on plant above 10 cm, multiplied by 100.

Table 35. Treatment means: Branch to stem seed number ratio.##

Yearly Factor Levels†	N	Mean††		OSL	Treatment	Mean#
1980	157	1.17 (s = 1.76)				
D	79	1.40	-----	.0568	DI	1.50 a
M	78	0.94			DR	1.29 ab
I	80	1.36	-----	.1010	MI	1.22 ab
R	77	0.98			MR	0.65 b
C x W			-----	.4066		
1981	160	1.78 (s = 3.28)				
D	80	2.01	-----	.5204	DI	2.70 a
M	80	1.54			DR	1.32 a
I	80	2.42	-----	.0996	MI	2.14 a
R	80	1.13			MR	0.94 a
C x W			-----	.9038		
1980/81	317	1.48 (s = 2.64)				
D	159	1.71	-----	.2253	DI	2.10 a
M	158	1.25			DR	1.31 a
I	160	1.89	-----	.0346	MI	1.68 a
R	157	1.06			MR	0.80 a
C x W			-----	.8614		
1980 x 1981			-----	.1149		

†C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

††Yearly means followed by standard deviation in parentheses.

#Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

##Quotient of number of seeds on branches divided by number of seeds on stem.

Table 36. Treatment means: Branch to plant seed number ratio.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	158	0.42 (s = 0.23)				
D	80	0.49	-----	.0022	DI	0.52 a
M	78	0.34			DR	0.46 ab
I	80	0.44	-----	.1387	MI	0.37 bc
R	78	0.39			MR	0.31 c
C x W			-----	.6804		
1981	160	0.45 (s = 0.22)				
D	80	0.50	-----	.0556	DI	0.56 a
M	80	0.41			DR	0.44 ab
I	80	0.53	-----	.0063	MI	0.50 a
R	80	0.38			MR	0.32 b
C x W			-----	.4148		
1980/81	318	0.44 (s = 0.22)				
D	160	0.49	-----	.0006	DI	0.54 a
M	158	0.38			DR	0.45 a
I	160	0.49	-----	.0022	MI	0.44 a
R	158	0.38			MR	0.31 b
C x W			-----	.4528		
1980 x 1981			-----	.2034		

[†]C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††]Yearly means followed by standard deviation in parentheses.

[#]Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##]Quotient of number of seeds on branches divided by number of seeds on plant.

Table 37. Treatment means: Branch to stem yield ratio.##

Yearly Factor Levels†	N	Mean††		OSL	Treatment	Mean#
1980	157	1.21 ($\underline{s}$ = 2.16)				
D	79	1.36	-----	.2610	DI	1.46 a
M	78	1.05			DR	1.26 a
I	80	1.43	-----	.1135	MI	1.40 a
R	77	0.97			MR	0.68 a
C x W			-----	.3328		
1981	160	1.67 ($\underline{s}$ = 3.10)				
D	80	1.88	-----	.5360	DI	2.72 a
M	80	1.46			DR	1.05 a
I	80	2.38	-----	.0607	MI	2.04 a
R	80	0.97			MR	0.88 a
C x W			-----	.7037		
1980/81	317	1.44 ($\underline{s}$ = 2.67)				
D	159	1.62	-----	.3382	DI	2.09 a
M	158	1.26			DR	1.15 a
I	160	1.90	-----	.0210	MI	1.72 a
R	157	0.97			MR	0.78 a
C x W			-----	.9017		
1980 x 1981			-----	.2259		

†C x W = crop by water management system interaction,
1980 x 1981 = yearly effect.

††Yearly means followed by standard deviation in parentheses.

#Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

##Quotient of weight of seeds on branches divided by weight of seeds on stem.

Table 38. Treatment means: Branch to plant yield ratio.[##]

Yearly Factor Levels[†]	N	Mean[††]		OSL	Treatment	Mean[#]
1980	158	0.41 ($\underline{s}$ = 0.23)				
D	80	0.48	-----	.0050	DI	0.51 a
M	78	0.34			DR	0.45 ab
I	80	0.44	-----	.1558	MI	0.37 bc
R	78	0.38			MR	0.31 c
C x W			-----	.6953		
1981	160	0.45 ($\underline{s}$ = 0.22)				
D	80	0.49	-----	.0634	DI	0.56 a
M	80	0.40			DR	0.43 ab
I	80	0.53	-----	.0046	MI	0.50 a
R	80	0.37			MR	0.31 b
C x W			-----	.4904		
1980/81	318	0.43 ($\underline{s}$ = 0.22)				
D	160	0.49	-----	.0014	DI	0.53 a
M	158	0.37			DR	0.44 b
I	160	0.48	-----	.0021	MI	0.43 b
R	158	0.38			MR	0.31 c
C x W			-----	.5639		
1980 x 1981			-----	.2582		

[†] C x W = crop by water management system interaction, 1980 x 1981 = yearly effect.

[††] Yearly means followed by standard deviation in parentheses.

[#] Treatment means within years followed by the same letter are insignificantly different at the 0.05 level as determined by Duncan's New Multiple Range Test.

[##] Quotient of weight of seeds on branches divided by weight of seeds on plant.

VITA

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