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NOTE

RESPONSE OF TWO SOYBEAN CULTIVARS TO MOISTURE STRESS[1]

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ABSTRACT

Although the effects of moisture stress, at different developmental stages of soybean [*Glycine max* (L.) Merr.], on yield and yield components have been studied extensively, no information is available in Isfahan region. Therefore, an experiment was conducted in 1985 and 1986 which included eight irrigation treatments and two soybean cultivars. The results showed that moisture stress decreased number of nodes per plant in all stress treatments, and decreased seed weight in all reproductive stages. Moisture stress in vegetative stage had less effect on yield reduction than stress at other stages. In all treatments, seed yield of Clark cultivar was significantly higher than Williams cultivar. The interaction effect between cultivars and stress treatments was only significant on the number of seeds. Irrigation of soybeans after 70 ± 3 mm of evaporation from class A pan produced the highest seed yield and water use efficiency. Moisture stress was effective on nodal distribution of yield components. The seed number and seed weight distributed differently throughout the stem for Clark and Williams cultivars, with a maximum near the central nodes.

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عکس العمل دو رقم سویا به تنش رطوبتی[1]

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خلاصه

گرچه اثرات تنش رطوبتی، در مراحل مختلف رشد و نمو، بر عملکرد و اجزاء عملکرد سویا بطور وسیعی مورد مطالعه و بررسی قرار گرفته است، اما هیچگونه اطلاعی در این زمینه در منطقه اصفهان وجود ندارد. بنابراین، طی سالهای ۱۳۶۴ و ۱۳۶۵ آزمایشهایی با ۸ تیمار آبیاری و ۲ رقم سویا انجام گرفت. نتایج بدست آمده نشان داد که تنش رطوبتی سبب کاهش تعداد گره و وزن دانه گردید، و تنش در مرحله رشد رویشی، نسبت به سایر مراحل، کمترین اثر را بر عملکرد دانه داشت. در کلیه تیمارها، عملکرد دانه رقم کلارک بیشتر از رقم ویلیامز بود. اثر متقابل بین رقم و تیمارها برای تنش فقط برای تعداد دانه معنی دار بود. آبیاری سویا پس از ۱۰۰±۳ میلیمتر تبخیر از طشت تبخیر کلاس A بیشترین عملکرد دانه و بالاترین راندمان مصرف آب را داشت. اثر تنش رطوبتی بر توزیع عمودی اجزاء عملکرد نیز موثر بود. اثر تنش بر اجزاء عملکرد در گره‌های میانی بیش از گره‌های فوقانی و تحتانی بود. تعداد دانه و وزن دانه در طول گره‌های مختلف ارقام کلارک و ویلیامز بطور متفاوتی توزیع شده و حداکثر مقدار بر گره‌های میانی منطبق بود.

INTRODUCTION

Water is a primary factor for successful crop production in most arid and semi-arid regions of Iran. Therefore, study of water quantity effects in crop production, including soybean [*Glycine max* (L.) merr.], is important. The land area of irrigated soybean is likely to increase as farmers start to recognize the value of soybean as a cash crop in Iran (13).

Many experiments have shown that soybean is more sensitive to moisture stress during reproductive development than during vegetative growth stages (5, 9, 18, 19). Karimi-Abadchi

(14) reported that the moisture stress effects on yield reduction of early maturing cultivars were more than those on late maturing cultivars. He also found that moisture stress decreased the yield components.

Consistent yield increase was achieved by irrigation during pod elongation, irrespective of seasonal differences in rainfall amounts (15, 16). Irrigation during the flowering period had no effects on seed yield (16). Brown *et al.* (1) indicated that moisture deficit at either flowering or podding stages reduced seed yield significantly. A moisture deficit initiated at podding stage reduced seed size and seed number significantly (1).

Cox and Jolliff (4) conducted a comparative study of crop growth, seed yield, and soil water extraction patterns of sunflower and soybean. The results showed that soil water deficits in the deficit and dryland treatments reduced seed yield of soybean by 27% and 87%, respectively. Also, pod number was the yield component most sensitive to soil water deficit in soybean.

Carlson *et al.* (2) conducted an experiment which included two soil moisture treatments and seven soybean cultivars with different maturity periods. The response of these soybeans varied in their expression of seed yield and vertical display of yield components. The reduction for individual components of yield, i.e. 100-seed weight, seed/pod, pods/node and node/plant varied from 0% to 30% over all cultivars. Hansen and Shibles (8) presented seasonal logs of both flowering and podding of field grown soybeans, which included the vertical distribution of relevant reproductive parameters. Carter (3) offers a very detailed analysis of the vertical yield structure for seven soybean cultivars seeded at different times.

The objectives of this research were: 1) to determine the response of two soybean cultivars to water stress at the various stages of development in Isfahan region, and 2) to study the effects of water stress on node per plant and nodal distribution of seed number, 100-seed weight and weight of seeds.

MATERIALS AND METHODS

The experiments in 1985 and 1986 were conducted at the Lavark Experimental Station, 32° N lat. and 51° E long., located 30 km south-east of the College of Agriculture, Isfahan University of Technology. The soil was camborthid clay loam with bulk density of 1.4 g cm^{-3}, pH of 7.5, field capacity of 23% and permanent wilting point of 10% by weight. The annual precipitation in 1985 and 1986 was 68.1 and 165.9 mm, respectively, which occurred during September through May. The maximum, minimum and average air temperatures and class A pan evaporation data during the growing periods are given in Table 1.

The experimental design was a split plot with eight irrigation treatments as the main plots and two soybean cultivars as the subplots, which were replicated four times. The irrigation treatments were as follows:

T_1 - Irrigation after 30 ± 3 mm evaporation from class A pan during the growing season. T_1 is not a stress treatment.

T_2 - Irrigation after 70 ± 3 mm evaporation from class A pan during the growing season. T_2 is the control treatment.

T_3 - Irrigation after 110 ± 3 mm evaporation from class A pan during the growing season.

T_4 - Moisture stress at vegetative stage.

T_5 - Moisture stress at flowering stage.

T_6 - Moisture stress at pod elongation stage.

T_7 - Moisture stress at seed formation stage.

T_8 - Moisture stress at maturity stage.

In treatments T_4 to T_8 the irrigation was cut at V_2, R_1, R_3, R_5, R_7 stages, respectively, and at stages of $V_{3.9}$, $R_{2.3}$, $R_{3.8}$, $R_{5.5}$, R_8 (when the leaf water potential was about -23 ± 0.5 bars at noon on sunny days) irrigation was started again (except in stage of R_8 at which the seeds were matured).

Table 1. Class A pan evaporation, minimum, maximum, and mean air temperatures during the growing seasons, May to October 1985 and 1986.

year	1985						1986					
parameter \ month	M	J	J	A	S	O	M	J	J	A	S	O
Evaporation (mm day^{-1})	9.4	12.6	12.4	10.5	9.1	6.5	8.5	11.5	11.5	10.4	8.3	6.4
Min. T, °C	12.9	18.6	20.6	18.3	13.6	7.7	12.4	17.1	20.2	18.5	12.4	10.5
Max. T, °C	28.0	34.5	36.7	33.0	32.1	25.9	26.5	33.0	35.3	33.6	30.8	28.0
Avg. T, °C	20.5	26.6	28.7	25.7	22.9	16.8	19.5	25.1	27.1	26.1	21.6	19.3

Identification of different growth stages and substages were carried out by the procedure described by Fehr and Caviness (7). The leaf water potential was measured with a pressure bomb, on 12 leaves of last fully-expanded trifoliate (three leaves from three plants of each replication). The average value of measurements was used to indicate the end of stress period. Treatments T_4 to T_8 were irrigated simultaneously with T_2 (irrigation after 70 ± 3 mm evaporation from class A pan) before and after imposing stress. The irrigation water was measured by installing a rectangular weir on irrigation ditch of each replication.

In both 1985 and 1986 experiments, the soybean cultivations were in rotation with wheat. After harvesting wheat, the field was plowed and fallowed until the soybeans were planted in late spring. In spring, 46 kg ha^{-1} N as ammonium sulfate and 45 kg ha^{-1} P as ammonium phosphate were incorporated into the surface soil during seed-bed preparation. Since seeds were not inoculated with *Rhizobium japonicum* at planting time, 46 kg ha^{-1} of N as ammonium sulfate were topdressed before the flowering stage.

Seeds of "Clark" and "Williams", which are medium maturing cultivars in the experimental area†, were planted on 16 May 1985 and 16 June 1986 at the rate of 220,000 seeds ha^{-1}. The row distance and planting depth were 45 cm and about 4 cm, respectively.

Each subplot consisted of 10 rows, each 4.5 m long. All yield data were collected from 2 m of the six center rows (i.e. 5.4 m^2). Also, in the first year, at maturity, when more than 95% of the pods in a plot were brown, the nodal distribution study was conducted using 10 plants randomly from each subplot from all four replications. In each plant, nodes were numbered from the bottom to the top of the plant.

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†On the basis of five years of field work by the second author.

The unifoliate node was counted as Node 1. The number of seeds and dry weight of seeds were determined for each node, and 100-seed weight was calculated by dividing seed weight by the number of seeds. Then, the nodal distribution was further consolidated into six nodal groups, each containing three nodes, counted from the 4th node. Although some plants had a few seeds on the first to 3rd and 22nd to 24th nodes, they were not included in the analysis.

The soil moisture content of each treatment (before applying irrigation water) was measured by gravimetric method.

Water-use efficiency of each irrigation treatment was calculated by dividing seed yield (kg ha^{-1}) by the amount of applied irrigation water (m^3 ha^{-1}).

RESULTS AND DISCUSSION

Seed Yield

Figure 1 shows the main effects of moisture stress at different soybean development stages and cultivars on the yields of 1985 and 1986. It shows that the yield in 1985 is more than that of 1986 (significant at 1% level). Reduction of yield in the second year is probably because of shorter growing period (112 days in 1986 as compared to 128 days in 1985[†]) due to later seed planting than in the first year. Moisture stress in vegetative stage (treatment T_4) had lesser effect on yield reduction than stress at other stages (T_5 - T_8). During both years, the highest and the lowest yields belonged to treatments T_2 and T_3, respectively. Treatment T_1 did not produce the highest yield because the application of too much irrigation water caused the plants to have a greater vegetative growth, than the T_2, and light intensity was low at the bottom of the

[†] This is the growing period for T_2. The crops in treatments T_1 and T_3 have been matured one week later and one week soon[er] than T_2, respectively.

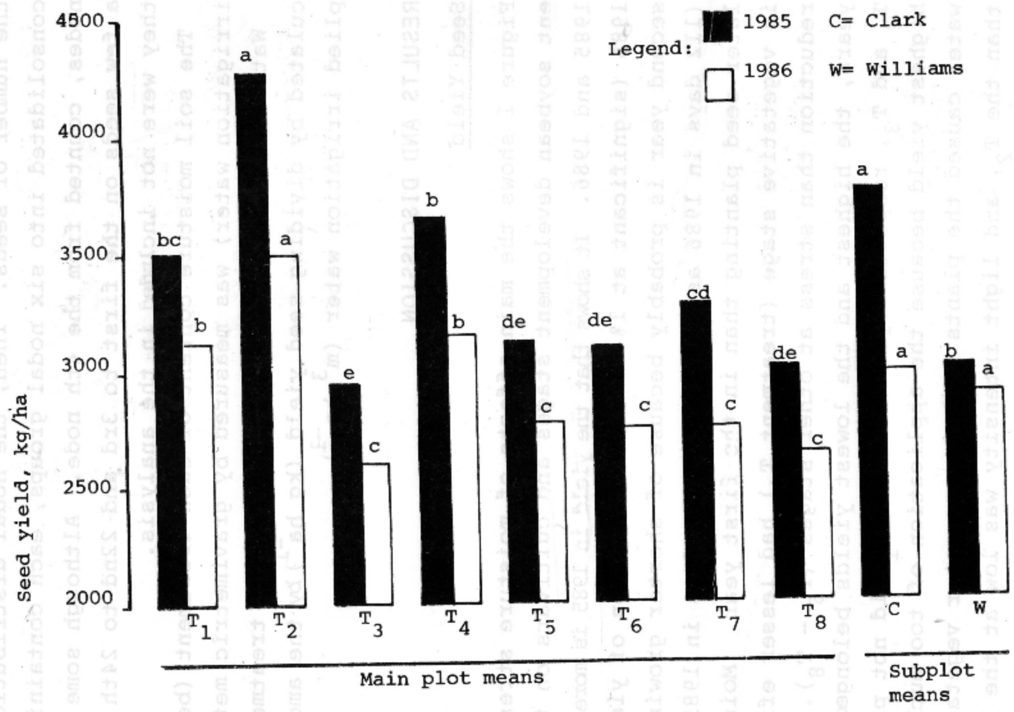

Fig. 1. Mean seed yield response of two soybean cultivars to the same moisture stress treatments. Vertical bars topped by the same letter indicate that means were not significantly different at 5% level.

plant canopy. Therefore, leaves at the lower parts of stem might have shed and number of seeds might have decreased on the main stem and branches (10). Also, the possible decrease in O_2 in root medium might have decreased seed yield in T_1 treatment.

In the first year, Clark cultivar had higher yield than Williams cultivar, but in the second year the yields were not different. The reason might be that in 1985 due to early planting, more seed yield was obtained on the branches of Clark cultivar, as it will be discussed later. It seems that in 1986, the difference in yield was not observed because of late planting.

The results of seed yield for T_1 to T_3 (Fig. 1) and the amount of applied irrigation water (Table 2) shows that when soybeans are irrigated abundantly (irrigation after 30 ± 3 mm evaporation from class A pan in T_1), or when they are not irrigated enough (irrigation after 110 ± 3 mm evaporation from class A pan in T_3), the seed yield will decrease. This experiment has shown that proper water application was irrigation after 70 ± 3 mm evaporation from class A pan in T_2. In Table 2, water-use efficiency varies between 0.44 to 0.73 which belongs to T_1 and T_2. Generally, too much water, too little water and water stress at different developmental stages of soybean have decreased water-use efficiency.

Yield Components

Table 3 shows the main effects of water stress on the yield components measured only in 1985. These data revealed that moisture stress has decreased number of nodes per plant in all moisture-stress treatments. The least number of nodes per plant belongs to T_3. The number of nodes per plant in T_1 and T_2 treatments are not significantly different. Stress at reproductive stages caused the seed weight per plant to decrease. Stress at T_7 caused the seeds to become larger since less seeds have formed, sink has been decreased and source has been able to fill the seeds well (10). The 100

Table 2. Amount of applied irrigation water, soil-moisture content at the time of irrigation, and water use efficiency.

parameter / treatment	applied water (m^3 ha^{-1})	soil moisture (% by wt)	depletion of available water (%)	water use efficiency (kg m^{-3})
T_1	8736	17.5-20.5	27.5-32.5	0.44
T_2	6370	15.5-17.5	47-53	0.73
T_3	5733	13.3-14.7	46.5-73.5	0.56
T_4	6188	12-13	77-83†	0.64
T_5	6188	12-13	77-83	0.55
T_6	6188	12-13	77-83	0.55
T_7	6188	12-13	77-83	0.58
T_8	5915	12-13	77-83	0.56

†At the end of stress period.

Table 3. Yield components at various irrigation treatments. Each number is average of four replications and two cultivars.

Irrigation Treatment	Yield components					
	No. of nodes $plant^{-1}$	No.of seeds $plant^{-1}$	seed wt $plant^{-1}$(g)	100-seed wt of plant(g)	No.of seeds on main stem	seed wt of main stem(g)
T_1	24.0 a*	141.1 ab	17.56 ab	12.44 ab	107.7 a	13.99 a
T_2	24.0 a	167.6 a	21.38 a	12.75 ab	107.8 a	14.08 a
T_3	21.0 f	129.0 b	14.68 b	11.38 bc	78.3 b	9.42 c
T_4	23.0 c	150.0 ab	18.19 ab	12.12 ab	106.6 a	13.24 ab
T_5	21.7 e	125.1 b	15.53 b	12.41 ab	82.5 b	10.46 bc
T_6	22.0 e	123.3 b	15.45 b	12.53 ab	76.5 b	10.41 bc
T_7	22.5 d	121.0 b	16.35 b	13.51 a	75.7 b	10.98 bc
T_8	23.5 b	140.3 ab	15.07 b	10.74 b	102.7 a	10.77 bc

*Means within any one column followed by the same letter are not significantly different at the 1% probability level by Duncan's multiple range test. In this table, yield components of all the nodes are taken into consideration.

-seed weight in T_8 is significantly less than T_2. The reason is that moisture stress at maturity has caused photosynthesis translocation of carbohydrates from leaves and stem to seeds, and consequently seed filling period to decrease (10).

Seed weight on the main stem in T_3 is significantly different from T_1 and T_2, since lesser and lighter seeds have formed in T_3. Seed weight on whole plant of T_2 treatment is significantly different from T_3, T_5 and T_8 treatments. Seed weights on main stem of T_5 to T_8 are not significantly different.

The yield components of Clark and Williams cultivars are compared in Table 4. The number of nodes and seed weight in the main stem of these cultivars are not significantly different. Therefore, the main reason for the yield difference between cultivars could be attributed to the differences in the yield of branches. Number of seeds/plant, seed weight/plant, and number of seeds/main stem of Clark cultivar is significantly greater than Williams cultivar. However, 100-seed weight of Williams is significantly greater than Clark.

Table 5 shows the seed number and seed weight of branches in Clark and Williams cultivars as influenced by the moisture stress treatments. These data revealed that in all treatments, the number of seeds on branches of Clark cultivar was more than Williams cultivar.

Nodal Distribution of Yield Components

Table 6 shows analysis of variance for seed number, 100-seed weight, and dry weight of seeds on the main stem. These data show that the interaction effect between moisture-stress treatment and cultivar is only significant for the number of seeds. Effect of nodal group on seed number 100-seed weight, and seed weight on the main stem was significant at 1% level. The three-way interaction between stress, cultivar and nodal group was significant only for the number of seeds.

The seed number and seed weight on the main stem were

Table 4. Yield components of cultivars. Each number is the average of four replications in eight main treatments.

Cv.	No. of nodes $plant^{-1}$ ns	No. of seeds $plant^{-1}$**	Seed wt $plant^{-1}$**	100-seed wt of plant (g)**	Seed No. of main stem*	Seed wt of main stem (g) ns	100-seed. wt of stem (g)**
Clark	22.8	158.2	18.71	11.8	96.8	11.71	12.09
Williams	22.7	116.2	14.85	12.8	89.0	11.46	12.87

**, *, ns indicate significance at 1%, 5%, and not significant, respectively.

Table 5. Seed number and seed weight of branches in Clark and Williams cultivars.

Irrigation treatment	Seed No.		Seed wt	
	Clark	Williams	Clark	Williams
T_1	44.6 f*	22.2 j	5.05 bcde	2.75 e
T_2	82.1 a	37.5 g	9.72 a	4.87 bcde
T_3	67.5 b	34.4 h	7.07 abc	3.90 cde
T_4	59.7 c	27.1 i	6.47 abcde	3.42 cde
T_5	60.1 c	25.0 ij	6.95 abcd	3.17 cde
T_6	53.3 e	28.8 i	6.60 abcde	3.47 cde
T_7	67.4 b	23.2 j	8.50 ab	3.00 de
T_8	60.0 d	28.7 i	6.07 abcde	3.10 cde

*Means for each yield component followed by the same letter are not significantly different at 1% level of probability as determined by Duncan's multiple range test.

Table 6. Analysis of variance for seed number, 100-seed weight and dry weight of seeds on main stem.

Variable	Degrees of freedom	Mean square		
		Seed No.	100-seed wt (g)	Dry wt of seeds (g)
Replication	3	51.263	19.798	1.3295
Moisture-stress treatment	7	297.179**	36.742**	3.8900**
Error "a"	21	30.244	8.930	0.5597
Cultivar (C)	1	326.252**	78.030**	0.0579^{ns}
MST×C	7	25.191**	7.341^{ns}	0.3500^{ns}
Error "b"	24	22.537	5.160	0.2702
Nodal group	5	4234.24**	48.053**	78.6068**
MST × NG	35	32.830**	1.252^{ns}	0.5012**
C × NG	5	33.713**	0.787^{ns}	0.7718**
MST×C × NG	35	6.314**	1.387^{ns}	0.0903
Error "c"	240	6.134	1.975	0.0998

**,*, and ns indicate significance at 1%, 5%, and not significant, respectively.

distributed differently for the two cultivars (Tables 7 and 8). The maximum value occurred near the central nodal groups. Maximum and minimum seed number of Clark cultivar belonged to T_2 and T_7, respectively, while in Williams cultivar, this happened in T_1 and T_6 (Tables 6 and 7). This indicates the interaction effect between moisture-stress treatment and cultivar for the number of seeds. Moisture stress decreased seed number in most of the nodal groups, (Table 6), but it was quite noticeable in the 5th and 6th nodal groups (Table 7).

Moisture stress caused a significant decrease in seed weight in most of the 3rd to 6th nodal groups (Tables 6 and 8). Application of too much irrigation water in T_1 had a negative effect on seed weight of the main stem. The effect of moisture stress on seed weight in the first and second nodal groups depends on cultivar and stage of stress. This shows the interaction effect between stress, cultivar and nodal group.

Mean values of 100-seed weight per nodal group is shown in Table 9. As these data reveal, moisture stress at seed filling stage (T_7) has increased 100-seed weight in all nodal groups (but not statistically significant). Although in treatments T_3 to T_6 and T_8, 100-seed weight has decreased in most of the nodal groups, it was not statistically significant.

Values of Table 10 are used for comparing means of different levels of main, sub, and sub-sub treatments and their interactions in Tables 7 to 9.

General Conclusions

The results of this experiment showed that the yield and yield components are affected by irrigation treatments. The largest seed yield belongs to treatment T_2 in which irrigation water is applied after 70 ± 3 mm of evaporation from class A pan, throughout the growing period.

Moisture stress decreases number of nodes $plant^{-1}$ in all

Table 7. Mean values of number of seeds per nodal group on the main stem.

Irrigation treatment	Cv.	Nodal group						Total
		1	2	3	4	5	6	
T_1	Clark	5.5	21.7	25.8	23.3	19.4	11.8	108.5
	Williams	3.6	21.3	25.6	25.3	19.0	7.5	102.3
T_2	Clark	6.3	22.2	25.b	28.6	21.7	10.9	115.3
	Williams	4.4	20.2	25.9	25.8	15.4	6.4	98.1
T_3	Clark	9.1	20.1	21.1	20.7	11.1	1.6	83.7
	Williams	7.0	20.9	21.3	16.0	6.7	1.0	72.9
T_4	Clark	6.3	24.2	24.5	26.7	19.5	9.9	111.1
	Williams	6.5	23.3	26.6	24.7	13.9	6.1	101.1
T_5	Clark	8.1	19.3	22.0	24.5	14.0	4.0	91.9
	Williams	6.1	18.2	19.8	17.7	8.0	1.8	71.6
T_6	Clark	4.4	20.4	20.7	19.1	14.4	4.7	83.7
	Williams	3.6	18.0	16.3	13.3	7.5	2.5	61.2
T_7	Clark	4.4	19.8	21.2	18.2	11.9	3.7	79.2
	Williams	3.1	19.8	19.4	17.2	9.3	2.2	71.0
T_8	Clark	5.5	20.0	26.0	23.1	15.8	6.1	96.5
	Williams	5.7	22.7	28.8	25.5	14.5	3.9	101.1

Table 8. Mean values of dry weight of seeds per nodal group in the main stem.

Irrigation treatment	Cv.	Nodal group						Total
		1	2	3	4	5	6	
T_1	Clark	0.63	2.63	3.35	3.08	2.44	1.38	13.51
	Williams	0.44	2.73	3.36	3.35	2.39	0.83	13.10
T_2	Clark	0.73	1.72	3.37	3.67	2.64	1.20	14.33
	Williams	0.61	2.87	3.66	3.62	2.07	0.75	13.58
T_3	Clark	1.00	2.39	2.35	2.39	1.17	0.60	9.90
	Williams	0.83	2.57	2.69	1.93	0.72	0.09	8.93
T_4	Clark	0.68	2.81	3.10	3.23	2.15	0.95	12.92
	Williams	0.83	3.12	3.64	3.35	1.74	0.72	13.40
T_5	Clark	0.98	2.40	2.75	1.98	1.68	0.40	11.19
	Williams	0.69	2.38	2.76	2.33	1.23	0.25	9.64
T_6	Clark	0.50	2.50	2.76	2.56	1.75	0.51	10.58
	Williams	0.61	2.88	2.31	2.34	1.24	0.32	9.70
T_7	Clark	0.54	2.69	3.06	2.50	1.49	0.46	10.74
	Williams	0.41	3.14	3.17	2.65	1.52	0.34	11.23
T_8	Clark	0.50	2.22	2.83	2.35	1.48	0.52	9.90
	Williams	0.65	2.66	3.27	3.12	1.56	0.39	11.65

Table 9. Mean values of 100-seed weight per nodal group in the main stem.

Irrigation treatment	Cv.	Nodal group 1	2	3	4	5	6	Mean
T_1	Clark	11.2	12.1	14.2	13.2	12.5	11.4	12.45
	Williams	12.1	12.7	13.0	13.2	12.3	10.9	12.81
T_2	Clark	11.6	12.3	13.2	12.8	12.0	10.7	12.43
	Williams	13.7	14.2	14.2	14.0	13.3	11.7	13.84
T_3	Clark	11.2	11.9	12.2	11.5	10.3	10.4	11.83
	Williams	11.9	12.3	12.6	11.9	10.6	8.7	12.25
T_4	Clark	10.9	11.6	12.7	12.0	10.1	9.5	11.63
	Williams	13.2	13.5	13.0	13.8	12.5	11.0	13.25
T_5	Clark	12.0	12.4	12.5	12.2	10.0	10.2	12.18
	Williams	11.5	13.1	14.2	13.2	14.1	14.4	13.46
T_6	Clark	11.4	12.3	13.2	13.3	12.1	10.8	12.64
	Williams	12.1	12.6	12.7	13.1	12.6	9.7	15.85
T_7	Clark	12.1	13.4	14.4	13.5	12.1	10.9	13.56
	Williams	13.7	14.5	15.4	14.4	13.6	12.8	15.82
T_8	Clark	9.0	10.8	11.2	10.6	9.5	8.5	10.26
	Williams	11.2	11.7	11.3	12.2	10.7	9.7	11.52

Table 10. Values of standard errors ($S_{\bar{x}}$) for comparing means of different levels of main, sub, and sub-sub treatments and their interactions.

Comparisons	100-seed wt	Seed dry wt	No. of seeds on main stem
Irrigation (Ir.)	0.431	0.108	0.794
Cultivar (cv.)	0.164	0.037	0.343
Nodal group (NG)	0.176	0.039	0.309
Cultivars at a fixed level of Ir.	0.464	0.106	0.969
Irrigations at a fixed level of cv.	0.542	0.017	1.048
Nodal groups at a fixed level of Ir.	0.497	0.012	0.875
Irrigations at a fixed level of NG	0.626	0.148	1.126
Nodal groups at a fixed level of cv.	0.248	0.056	0.438
Cultivars at a fixed level of NG	0.280	0.063	0.526
Nodal groups at a fixed level of cv.and Ir.	0.703	0.158	1.238
Cultivars at a fixed level of NG & Ir.	0.791	0.179	1.489
Irrigations at a fixed level of cv. & NG	0.840	0.195	1.542

stress treatments, and also decreases seed weight in all reproductive stages. Moisture stress in maturity causes the most reduction in seed yield (30%) and the smallest reduction in seed yield in vegetative stage (15%), although this difference was not significant statistically. Irrigation of soybean plants after 110 ± 3 mm evaporation from class A pan produces almost the same yield as the treatments which received moisture stress.

Moisture stress is also effective on nodal distribution of yield components. The Clark and Williams cultivars distribute both seed number and seed weight differently on the main stem, with a maximum near the central nodes.

In all treatments, seed yield of Clark cultivar was significantly more than Williams cultivar. The difference can be attributed to the seed yield of branches.

LITERATURE CITED

1. Brown, E.A., C.E. Caviness and D.A. Brown. 1985. Response of selected soybean cultivars to soil moisture deficit. Agron. J. 77: 274-278.
2. Carlson, R.E., M. Karimi-Abadchi and R.H. Shaw. 1982. Comparison of the nodal distribution of yield components of indeterminate soybeans under irrigated and rain-fed conditions. Agron. J. 74: 531-535.
3. Carter, O.G. 1974. Detailed yield analysis of the effect of different planting dates on seven soybean varieties. Iowa State J. Res. 48(4): 291-310.
4. Cox, W.J. and G.D. Jolliff. 1986. Growth and yield of sunflower and soybean under soil water deficits. Agron. J. 78: 226-230.
5. Doss, B.D., R.W. Pearson and H.T. Rogers. 1974. Effect of soil water stress at various growth stages on soybean yield. Agron. J. 66: 297-299.
6. Egli, D.B., L. Meckel, R.E. Phillips, D. Radcliffe and J.E. Leggett. 1983. Moisture stress and N redistribution

in soybean. Agron. J. 75: 1027-1031.

7. Fehr, W.R. and C.E. Caviness. 1980. Stages of soybean development. Iowa Coop. Ext. Serv., Agric. Home Econ. Exp. Sta. Spec. Rep. 80.

8. Hansen, W.R. and R. Shibles. 1978. Seasonal log of the flowering and podding activity of field grown soybeans. Agron. J. 70: 47-50.

9. Hsiao, T.C. and E. Acevedo. 1974. Plant response to water deficits, water-use efficiency and drought resistance. Agric. Meterorol. 14: 69-84.

10. Gardner, F.P., R.B. Pearce and R.L. Mitchell. 1985. Physiology of Crop Plants. Iowa State University Press, pp. 84-92.

11. Kadhem, F.A., J.E. Specht and J.H. Williams. 1985. Soybean irrigation serially timed during stages R_1 to R_6. I. Agronomic responses. Agron. J. 77: 291-298.

12. Kadhem, F.A., J.E. Specht and J.H. Williams. 1985. Soybean irrigation serially timed during stages R_1 to R_6. II. Yield component responses. Agron. J. 77: 299-304.

13. Karami, E. and A.M. Mansouji. 1977. Comparison of seed yield and other agronomic aspects of 24 soybean varieties. Report of Activities of Research Center, College of Agriculture, Shiraz University, No. 4: 61-67 (in Persian).

14. Karimi-Abadchi, M. M. 1979. Soil moisture stress effects on reproductive and vegetative components of soybeans. Unpublished Ph.D. thesis, Library, Iowa State University of Science and Technology, Ames, Iowa.

15. Korte, L.L., J.H. Williams, J.E. Specht and R.C. Sorensen. 1983. Irrigation of soybean genotypes during reproductive ontogeny. I. Agronomic responses. Crop Sci. 23: 521-527.

16. Korte, L.L., J.E. Specht, J.H. Williams and R.C. Sorensen. 1983. Irrigation of soybean genotypes during reproductive ontogeny. II. Yield component responses. Crop Sci. 23: 528-535.

17. Mederski, H.J. and D.L. Jeffers. 1973. Yield response of soybean varieties grown at two soil moisture stress

levels. Agron. J. 65: 410-412.

18. 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.

19. Sionit, N. and P.J. Kramer. 1977. Effect of water stress during different stages of growth of soybean. Agron. J. 69:174-178.