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Effect of Different Soil Water Levels on Production and Abscission of Reproductive Organs of Soybean under High Temperature

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Abstract: An experiment was conducted during summer 1999 in and out sides of a glasshouse to evaluate the effect of different soil water levels on growth, physiological aspects and, production and abscission of flowers and pods of soybean. Three stress treatments were imposed by 40, 60 and 80% reduced water from flower initiation to maturity in the glasshouse. Two well-watered unstressed controls were also included for comparison of performances in and out sides of the glasshouse. Fluctuation in air temperature was 30 to 40°C in the glasshouse during reproductive period and the inside air temperature was 3 to 4°C higher than outside of the glasshouse. Leaf temperature, stomatal conductance, leaf transpiration, photosynthesis and leaf water potential decreased with increase in water stress which influenced the production and abscission of flowers and pods. Water stresses reduced pod number due to both increased flower and pod abscission and fewer flowers per plant with low photosynthesis, decreased leaf water potential and high leaf temperature. In case of well watered soybean, pod number decreased in the glasshouse (T_1) than the outside (T_o) treatment due to a little increase in abscission of flowers and pods or low photosynthesis due to high air temperature inside the glasshouse. The flower production was significant between T_o, T_1 and T2 treatments, while pod number and seed number were found to decrease in T_1 and T_2 treatments due to increase in abscission percent of flowers and pods with the variation of photosynthesis and its parameters. The data indicated that environmentally induced variation in pod numbers in soybean was the result of both changes in flower and pod abscission and the number of reduced flower production. With the variation of high air temperature in the glasshouse, pod and seed number were reduced in T_1 than in T_o treatment. Nitrogen accumulation of leaf declined drastically in T_1 treatment at R_6 stage which was limiting factor for photosynthesis and finally total dry matter as well as seed yield decreased in T_1 compare to T_o treatment. The stress treatments reduced all growth parameters, dry matter production and nitrogen accumulation thus seed yield decreased in T_2, T_3 and T_4 treatments, respectively. The differences in different soil water levels and temperature were reflected in lower production of total dry matter and seed yield.

Key words: Soybean, water stress, temperature, flower production, photosynthetic factors, seed yield

Introduction

Numbers of flower, pod and seed per plant are the most variable components of seed yield of soybean. Reduction in soybean yield is due to high percent of flower and pod abscission. A large proportion of the flowers and young pods of soybeans abscises rather than develop into mature pods even when grown adopting proper cultural management practices. This abscission is mainly regulated by the supply of assimilate to the reproductive organs of soybean including some other factors like internal hormones, water, light, temperature etc. Therefore, imposing any kind of water stress, the process of abscission is expected to increase and thereby reduce the yield of soybean. Water plays a major role in the growth and productivity of crop plants. Plant response to water stress was most severe during the periods of rapid growth and development (Robins and Domingo, 1953. Soybean belongs to Legume family and the legumes express a wide range of response to water stress and high temperature (Weaver *et al.,* 1985). Schou *et al.* (1978) suggested that pod set is regulated by the supply of assimilates to developing flowers and pods. Water is one of the most important raw materials for the production of assimilates. During inadequate water supply, leaves initiate stomata) closer, thus limits the process of photosynthesis (Morris *et al.,* 1983) and accelerates the abscission process of reproductive organs of soybeans. Many factors in the plant's environment have been reported to influence the rate of flower and pod abscission. Temperature extremes, low radiation intensities and water stress increase the rate of flower and pod abscission (Shaw and Laing, 1966; Mann and Jaworski, 1970; Saito *et al.,* 1970). As a subtropical crop, soybean requires temperatures in the range of 25 to 30°C for growth and physiological activities (Zhang and Smith, 1999). Flower set and pod retention in legumes are affected by high day temperature and low available soil moisture (Davis, 1945; Stobbe *et al.,* 1966; Fischer, 1973). Periods of hot weather imposing temporary heat and/or drought stresses during reproductive development enhanced flower and pod abscission (Konsens *et al*., 1991). Temperature above 40°C produced severe pod abscission in soybean (Mann and Jaworsky, 1970). High temperature also influenced crops to mature earlier (Suppiah, 1997). Lawlor (1997) reported that global temperature would increase 4°C by 2100AD and it would probably decrease the production of most crops about 25% for a 4°C rise in air temperature. Jiwu and Hong (1997) also reported that ascending air temperatures would create influence in the future soybean production (Jiwu and Hong, 1997). Plant water status has been used to determine the effect of soil water stress in the studies on soybean (Clark and Hiler, 1973; Turner *et al*., 1978; Reicosky and Deaton, 1979; Boyer *et al*., 1980). Tanner (1963) stated that plant temperature may be a valuable quantitative index to make differences in plant water regimes. Several studies reported that lower yield was caused by reduced seed or pod number (Board and Harville, 1993; Caviness and Thomas, 1980; McAlister and

Krober, 1958). Egli *et al.* (1984) cited several reports stating that yield was strongly correlated with genetic and environmental effects on length of the effective filling period. It is well known that water stress soybean yield (Doss *et al.,* 1974; Ashley and Ethridge, reduces 1978; Korte *et al.,* 1983b) and the effects of water stress on yield and yield components are influenced by the timing and severity of the stress (Sienit and Kramer, 1977; Ashley and Ethridge, 1978; Momen *et al.,* 1979; Korte *et al.,* 1983a). Soybean yield correlates closely to total nitrogen in plant because of the large amount of nitrogen accumulation in the seed. Nitrogen accumulation can also affect dry matter production. Past research reports clearly indicate that information regarding the effect of soil water stresses associated with high temperature on growth, physiological aspects, production and abscission of reproductive organs and yield of soybean are not well recognized. Global temperature is becoming higher day by day due to green house effect. Higher temperature develops water stress through higher rate of evapotranspiration. On the other hand it is difficult to differentiate between the separate effects of high temperature and water stress, since both stresses may occur simultaneously (Weaver and Timm,1988). Since temperature is increasing day by day, if water stress deveops along with increasing temperature at reproductive stage in summer what would be the fate of ecophysiological behavior, production and abscission of reproductive organs, as well as yield of soybean was the aim of this study. Therefore, the objectives of this study w as to evaluate the combined effect of different water stress levels and high temperature on plant growth parameters, physiological aspects, production and abscission of reproductive organs, yield *and* yield components of soybean.

Materials and Methods

This experiment was conducted in and out sides of glasshouse under the natural condition at Niigata University, Japan during the summer 1999. Before sowing soybean seeds (cv Miyagishirome, determinate type, maturity group IV-XI) were mixed with bacterial inoculum and three seeds were sown in a plastic pot (5 liter, pot height-19 cm) filled with Shinano alluvial soil on 15 May, 1999. Chemical fertilizers were applied at the rate of 0.52, 0.80 and 0.65 g per pot for N, P and K, respectively. One third of the nitrogen was applied at the time of soil filling into pots and the rest one third was applied as a basal dose at the vegetative growth and the last one third was applied at the beginning of flowering period. After the expansion of first trifoliate leaf, plants were thinned to one plant per pot. Water was supplied three times in a day to check the water stress for control treatments and the stress treatments were imposed. The plants were periodically sprayed with insecticide when needed. The number of flower and pod formation of five plants of each treatment was observed and counted at every node of the stem everyday from the beginning of flower opening to the end of pod formation. Vivid color of petal was usually the mark of difference between a new and an oid flower (Ikeda and Sato, 1997). Above ground parts of six plants of each treatment were harvested at maturity and dried at 60°C. The location and number of mature pods, seeds/pod and seed weight/pod were recorded. Abscission was determined per plant basis. Percent flower abscission {(abscised flower/total flowers) $\times$100} and percent pod abscission {(abscised pods/total number of pod formation or flowers- abscised flowers) $\times$ 100} were calculated separately. Combined flower and pod abscission were calculated (mature pods/total flowers $\times$ 100). It should be noted that combined pod and flower abscission do not equal the sum of the flower and immature pod abscission (Heindl and Burn, 1984). The plants were divided into four sections (from bottom to the top of the canopy) and the distribution of flowers and pods were also observed.

Treatments: Plants were grown in pots. Initially all the pots containing plants were kept in outside of the glasshouse and water supply treatments were started from the first day (21 July) of first flower opening within the treatments after transferring the pots into glasshouse. In the glasshouse, there were four types of water supply: T_1 = 500 ml (sufficient water), T_2 = 300 ml (40% reduced water), T_3 = 200 ml (60% reduced water) and T_4 = 100 ml (80% reduced water) water, respectively for each pot at morning, noon and afternoon per day. One set of pots was kept in outside of the glasshouse with sufficient water (T_o = 500 ml as T_1 treatment). Soil of the pots of T_o and T_1 treatments was wet during the treatment and a trace amount of excess water drained. T_0 and T_1 treatments were normal and other treatments (T_2, T_3 and T_4) developed water stress condition. Temperature in and out sides of the glasshouse was recorded every day using a thermometer from R_1 to R_5 stage at noon (12.30 to 13.00 PM). The windows and the door of the glass house were kept open for natural environment except rainy day.

Measurement of photosynthetic factors and leaf water potential: Rate of photosynthesis and leaf transpiration, leaf temperature, stomatal conductance from the second expanded leaflet of the top of main stem were measured at reproductive stage with a portable photosynthesis system (KIP-8150, Koito Co.Ltd, Japan) with a chamber of 8 cm^2 in cross sectional area and 4.5 cm in depth. Leaf water potential of its central leaflet *was* measured with a pressure chamber (Soil Moisture Equipment Corporation, Santa Barbara, CA, USA).

Plant growth parameters, dry matter and nitrogen percent: Three plants at R_5 stage and three plants at R_6 stage from each treatment were harvested and oven dried at 60°C for 48 h for the measurement of dry matter and nitrogen percent. The nitrogen percent was measured from plant parts by infra-Alyzer-260. (L4-1 68.2, Bran + Luebbe). Plant height and the number of leaf, node and branch were recorded and leaf area was measured by leaf area meter (Automatic area meter, Hayashi Denkoh Co. LTD, Tokyo. Japan) at R5 stage.

Statistical analysis: The data were analyzed by analysis of variance and the mean difference were compared by LSD test at the 0.05 probability level in Microsoft Excel 98.

Results

Air temperature in and out sides of the glasshouse: The midday temperature fluctuation of the glasshouse and the outside during reproductive stage of development is shown in Fig. 1. Difference in air temperature was 3 to 4°C between the glasshouse and the outside. Fluctuation in air temperature was recorded 30 to 40°C in the glasshouse during the reproductive period and the inside air temperature was 3 to 4°C higher than the outside of the glasshouse.

Plant growth parameters and dry matter: The variation in the soybean growth parameters observed at R_5 stage under the influence of different soil water levels is presented in Table 1, There were no significant differences in plant height, leaf number and leaf area between T_o and T_1 treatments (Table 1). Node number and branch number on the main stem in T_o, T_1 and T_2 treatments were also statistically similar (Table 1), though leaf number and leaf area varied within T_o, T_1 and T_2 treatments. At 60 and 80% reduced water stress conditions plant height, branch number, leaf number, node number and leaf area were affected in T_3 and T_4 than T_2 treatments. At 40, 60 and 80% reduced water, the decreasing percent of leaf area was 11.7, 36 and 53% in T_2, T_3 and T_4 treatments due to reduction in growth parameters (Table 6).

Table 1 also shows that total dry matter of all plant parts were greater in T_o than T_1 treatment in R_5 stage though there was a similarity in individual plant part. At 40, 60 and 80% reduced water total dry matter of all plant parts declined with increase of water stress in T_2, T_3 and T_4 treatments, respectively.

Physical and physiological parameters: Effect of different water stress levels on physical and physiological parameters at 18th day of reproductive stage in and out sides of the glasshouse is presented in Table 2. At sufficient water in and out sides of the glasshouse, a significant variation was observed in photosynthesis, leaf transpiration and leaf temperature in T_o and T_1 treatments. Rate of photosynthesis was higher in T_o than T, treatment, while leaf temperature and leaf transpiration were significantly lower in T_o than T_1 treatment. A decreasing trend in photosynthesis, leaf transpiration, stomata! conductance, and leaf water potential was observed with the sequential increase in water stress in T_2, T_3 and T_4 treatments. At 40, 60 and 80% reduced water, rate of photosynthesis drastically declined with 28, 60 and 75% in T_2, T_3 and T_4 treatments, respectively due to increasing leaf temperature and decreasing stomatal conductance with sequential increase in water stresses (Table 2).

Distribution of flower and pod at different sections of canopy: The maximum flowers were observed in section-1 in all the treatments and the number of flowers was found to decrease gradually with increase in section number (Table 4). However, number of flowers in T_0, T_1 and T_2 treatments was statistically similar in section-1. Similar trends were found in section 2 and section 3. In section-4, the flower number was not significantly distributed in all the treatments. Among all the treatments, T_4 was the most affected to produce flower in section-4. In case of pod distribution, the maximum pods were set in section-1 and then in section-2 in all the treatments, though there were statistical differences among them. At 40, 60 and 80% reduced water, T_2, T_3 and T_4 treatments of section-1 produced the highest pod than all other sections and T_2 and T_3 treatments of section-4 were most affected to set pod, while the section-4 of T_4 treatment (80% reduced water) failed to set pod. The pod set was equally affected in section 4 in all treatments.

Flower number: Insignificant differences in flower production were observed on the main stem and branches between the absence of water stress and with a little water stress in T_7 treatment (Table 3). Both T_0 and T_1 control treatments produced about 172 flowers in the absence of water stress which were statistically similar to the number of flowers produced in T_2 treatment with a little stress, while the flower number decreased drastically in T_3 and T_4 treatments with sequential increase of water stress. The reduction in flower numbers was 1.16, 18.98 and 36.92% for T_2, T_3 and T_4 treatments respectively, with reduced water supply of 40, 60 and 80%, respectively (Table 6). Flower number was most affected in T_4 treatment by 80% reduced water comparing to control treatments. There was a negative relation between flower number and pod number with leaf water potentials (Fig. 2).

Abscission of reproductive organs: Different water stress levels (Table 3) influenced the abscission of reproductive organs. Percent of flower abscission was found to increase with the increasing water stress (Table 3). Percent flower abscission was the highest in T_4 treatment than all other treatments. In plants treated with sufficient water, a statistical similarity with flower abscission was appeared between T_o and T_1 treatments, though the percent value of abscission of flowers and pods was not equal (Table 3). Pod abscission percent was the highest in T_2 and T_3 treatments, while a statistical similarity in percent pod abscission was appeared in T_0, T_1 and T_4 treatments (Table 3). Combined flower and pod abscission was in the trend of increasing with increase of water stress. At 60 and 80% reduced water, combined flower and pod abscission were the highest than those of control plants (sufficient water) as well as in little water stress (40% reduced water).

Nitrogen accumulation: In sufficient water, there was a similarity with nitrogen accumulation in stem, leaf, and pod between T_0 and T_1 treatments at R_5 stage, while nitrogen accumulation varied in stem, leaf and pod at Re stage (Fig. 3). Nitrogen accumulation declined drastically in leaf of T_1 than T_o treatment at R_6 stage. In both the stages of R_5 and R_5, nitrogen accumulation decreased with increase in water stress in T_2, T_3 and T_4 treatments compare to controls. Nitrogen accumulation of leaf declined severely at R_6 stage than R_5 stage in T_4 treatment due to early physiological maturity than other stress treatments.

Seed yield and yield components: Both seed yield and yield components were found to decrease with increase in water stress (Table 5). At 40, 60 and 80% reduced water, seed yields were affected with 24.16, 40.18 and 51.40% in T_2, T_3 and R_4 treatments, respectively (Table 6). In sufficient water, seed yield varied in T_0 and T_1 treatments in glasshouse and outside air temperature. At 80% reduced water, seed yield, seed and pod number were most affected in T_4 treatment than that of other water stress treatments. The number of pods per plant was observed to decrease gradually by 40, 60 and 80% reduced water in T_2, T_3 and T_4 treatments, respectively, while similar trend was followed in seed number per plant (Table 5). Seed yield was positively correlated to pods per plant (R^2 = 0.98). Seeds per pod were unaffected by the stress treatment. No significant difference ($p<0.05$) was found between treatments in mean seed weight and seed

Table 1: Effect of different soil water levels on growth parameters and dry matter at R, stage and R, stage of soybean

Treatment	T_0	T_1	T_2	T_3	T_4
Plant Characters: R_5 Stage:					
Plant hieght (cm)	75.0a	75.94a	68.0b	64.2bc	61.2c
Main stem node number	16.63a	16.83a	15.33a	14.67b	14.16b
Branch number	8.73a	8.93a	8.17a	6.67b	5.5c
Leaf number	50.33a	50.87a	42.67b	37.67c	26.33d
Leaf area (cm^2)	10040.67a	10217.33a	9019.01b	6527.12c	4760.61d
Stem and petiole dry weight (gm):					
R_5-stage	34.43a	34.96a	29.43b	24.33c	17.93d
R_6-stage	31.40a	30.36a	22.96b	21.5b	16.00c
Leaf dry weight (gm):					
R_5-stage	32.09a	32.89a	28.03a	22.73b	17.86c
R_6-stage	28.06a	27.03a	18.7b	17.76b	15.03b
Pod dry weight (gm):					
R_5-stage	12.9a	12.46ab	9.93bc	7.13cd	5.36d
R_6-stage	27.43a	26.46ab	24.16b	17.06c	12.76d

The values are the mean of three replications. Different letter indicate significant difference among the treatments at 5% level based on LSD test

Table 2: Effect of different soil water levels on leaf water potential, leaf temperature, stomatal conductance, leaf transpiration and photosynthesis rate of soybean at reproductive stage

Treatment	Water amount	Leaf water potential (-Mpa)	Leaf temperature (°C)	Stomata conductance (cm/sec)	Leaf transpiration (gm/dm^2hr^{-1})	Photosynthesis (mg/dm^2hr^{-1})
Outside						
T_0	sufficient	0.42d	35.1d	0.86a	3.28b	20.56a
Glasshouse:						
T_1	sufficient	0.44d	37.93c	0.80a	3.63a	18.03b
T_2	40% reduced	0.67c	39.53b	0.39b	1.92c	12.90c
T_3	60% reduced	1.156	42.26a	0.13c	1.03d	7.13d
T_4	80% reduced	1.34a	43.66a	0.09d	0.90d	4.4e

T_0 = Indicates the control treatment which was set in outside of glasshouse. Different letters indidcate significant difference among the treatments at 5% level based on LDS test

Table 3: Effect of different soil water levels on the production and abscission of reproductive organs of soybean

Treatment		Flower number	Flower abcission (%)	Pod abscission (%)	Combined flower and pod abscission (%)
	----------Plant^{-1}----------				
Outside					
	T_0	172.60a	41.80d	42.49b	66.60c
Glasshouse:					
	T_1	172.8a	42.31d	44.08b	67.63c
	T_2	170.8a	43.71c	54.00a	73.21b
	T_3	140.06	47.35b	54.30a	74.72e
	T_4	109.6c	51.93a	46.01b	74.04a

Different letters indicate significant difference among the treatments at 5% level based on LSD test

Table 4: Effect of different soil water levels on the production of flower and final pod numbers of different nodes position of soybean

Reproductive Characters	Treatment	Section-1	Section-2	Section -3	Section-4
Flower number					
Outside:					
Glasshouse:	T_0	104.4 a	38.4 a	22.6 a	7.2a
	T_1	103.4 a	39.4 a	22.6 a	6.4 b
	T_2	104.2 a	38.2 a	23.6 a	4.6 c
	T_3	93.8 b	26.2 b	27.4 b	4.4 c
	T_4	66.8c	24.8b	11.4c	0.2d
Final pod number					
Outside:					
	T_0	36.66a	12.5 a	7.5 a	1.8 a
Glasshouse:					
	T_1	31.34 b	11.5 a	6.67 a	1.4 a
	T_2	26.33 c	9.16 b	4.83 b	0.8 b
	T_3	23.66 d	6.33 c	1.83 c	0.4 c
	T_4	17.83 e	8.50 be	1.60 c	0.0

Section-1 = nodes 2-6, section-2 = nodes 7-10, section-3 = nodes 11-14, section-4 = nodes > 14. 1st trifoliate node is not counted. Different letters indicate significant difference among the treatments at 5% level based on LSD test

Table 5 : Effect of different soil water levels on yield and yield components of soybean

	Treatments	Seed yield (gm) Plant^{-1}	Pod number Plant^{-1}	Seed number Plant^{-1}	Seed number Plant^{-1}	Mean seed weight (gm/40 seed)
Outside						
	T_0	25.39 a	58.67 a	79.55 a	1.52	12.78 a
Glasshouse:						
	T_1	23.17 b	50.00 b	73.75 b	1.52	12.57 b
	T_2	17.57 C	40.50 c	59.75 c	1.55	11.77 c
	T_3	13.86 d	32.33 d	48.00 d	1.53	11.55 d
	T_4	11.26 e	28.00 d	41.25 e	1.54	10.93 e

Different letters indicate significant difference among the treatments at 5% level based on LSD test
*indicate not significant

Table 6: Reduction percent of growth parameters, flower number, yield and yield components with the influence of different soil water streses of soybean

Treatment	Water reduction (%)	Plant Height	Node number	Branch number	Leaf number	Leaf Area	Flower number	Pod number	Seed number	Seed yield
T_2	40	9.81	8.92	7.47	15.78	11.72	1.16	19.00	18.98	24.16
T_3	60	14.85	12.83	24.46	25.65	36.11	18.98	35.34	34.91	40.18
T_4	80	18.83	15.68	37.71	48.03	53.40	36.92	44.00	44.06	51.40

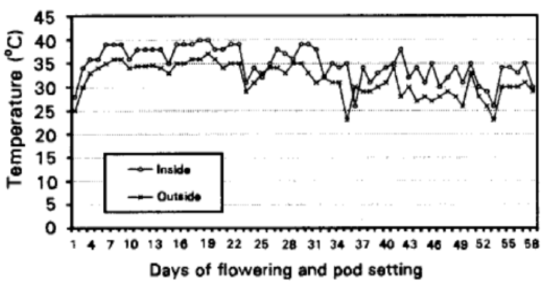

Fig. 1: Noon air temperature of glasshouse and outside at flowering and pod setting period

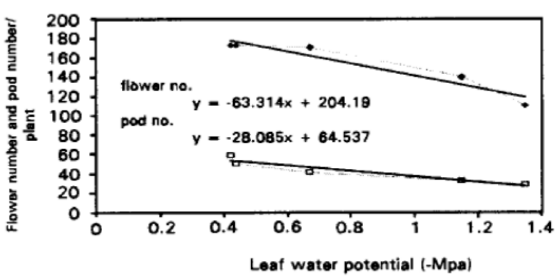

Fig. 2: Relationship between the flower number and pod number with leaf water potential (-Mpa)

number per pod, although there was a consistent trend of a reduction in seed yield, pod and seed number per plant in all stress treatments.

Discussion

Shortage of soil water during reproductive stage caused to reduce flower and pod number and yield. This result was expected because there are several reports showing that modification of the environment to reduce photosynthesis during reproductive growth causes reductions in yield and yield components (Schou *et al.,* 1978; Egli and Zhen-Wen, 1991). The reduction in pods reported here was the result of fewer flowers per plant and an increase in flower and pod abscission. As has been reported in the field (Ishag, 1973; Husain *et al.,* 1988; Pilbeam *et al.,* 1989)

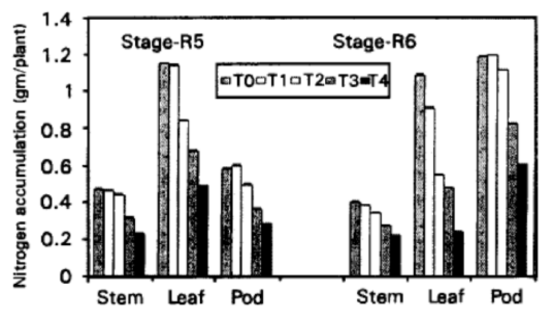

Fig. 3: Effect of different soil water levels on nitrogen accumulation based on the plant parts. The vertical bars represent standard error of three relications

seed yield was well correlated with the number of pods per plant. Pod set was reduced by water stress, particularly during the reproductive stage, due to the abscission of flowers and small pods. In our experiment, the significant number of flowers was produced in both the controls (T_o and T_1) and at 40% reduced water (T_2). From this report, it is suggested that flower production is not sensitive even at high temperature with a little water stress at leaf water potential of -0.67 Mpa. In our study, the flower number was decreased by 60 and 80% reduced water comparing to control at leaf water potential -1.15 Mpa and -1.34 Mpa, respectively. Mann and Jaworski (1970) reported that heat and temperature stresses affected flowers per plant and pod abscission of one soybean cultivar in the greenhouse. The lowest leaf temperature (37°C) was observed in control (T_0 treatment and highest 143°C) leaf temperature was observed in 'plants treated with 80% reduced water (T_4) in glasshouse at midday which were higher than air temperature. Isoda *et al.* (1994) reported that the temperature of Miyagishirome cultivars was higher than air temperature and also reported that Miyagishirome with large and thin leaflets could not control the leaf temperature in day time on clear days, due to its lower transpiration rate and inactive leaf movement. On the other hand, Wien *et al.* (1979) reported that midday values of temperature of well-watered soybeans were 2 to 7°C below the air temperature and Wien *et al.* (1979) also found that canopy temperature of water stressed soybeans was similar to air temperature which was differed in our experiment. At high temperature, net photosynthesis was found to decrease with the increase in water stress. It might be due to both respiratory loss and lack of sufficient leaf water to produce photosynthates. Fukui *et al.* (1965) reported that net photosynthesis of soybeans was very low at 40°C air temperature. Solar radiation and air temperature also affect leaf water status (Ishihara *et al.,* 1971; Lugg and Sinclair, 1981). Seed yield and short-term photosynthetic rates are reduced when soybean leaf water potentials fall below Mpa. (Boyer, 1970; Boyer *et al.,* 1980) through stomatal closure. Photosynthesis rate with decreased stomatal conductance decreased with increase in water stresses, while in control plants grown in glasshouse the photosynthesis rate was lower than control of outside due to high air temperature. Air temperatures above 40°C caused severe pod abscission (Mann and Jaworski, 1970). The levels of abscission in the control treatments in our experiment ranged from 41 to 74%, which is within the range reported by others (Van Schaik and Probst, 1958; Hansen and Shibles, 1978; Brevedan *et al.,* 1978; McBlain and Hume, 1981; Wiebold *et al.,* 1981). However, the level of abscission in stress treatments was a little bit larger. The relative importance of change in number of flowers per plant vs. abscission percentage varied within the treatments was involved in determining final pod number. Table 2 and 3 demonstrate the importance of flowers per plant, however, abscission was important in determining the changes in pod per plant within different water stresses. The control plants in glasshouse reduced pod number than control in the outside (high temperature effect). On the other hand, decreasing trend of pod number was observed with the increase in water stress. This difference was associated with more flowers per plant and smaller abscission percentage in well-watered soybean than the water stressed plants. Previous research tried to focus on the abscission process (Brun and Betts, 1984; Huff and Dybing, 1980; Heitholt *et al.,* 1986) with only a few reports on flower number (Mann and Jaworski, 1970; Neyshabouri and Hatfield, 1986). The data reported here clearly show that both parameters (flower number and abscission) are important. Water stress reduced flowers per node on main stem or per section of the canopy. The data reported here demonstrate that variation in flowers per plant is also important in environmentally induced changes in pod per plant. Variation in plant size (i.e., height, branch, nodes per plant) and flowers per node contributed to variation in flowers per plant. It is tempting to describe these processes as occuring in a temporal series with adjustments in nodes followed by flowers per node and finally flower abscission. However, node production in soybean continues after flowering begins for both indeterminate and determinate cultivars (Egli *et al.,* 1985) and flower production is continuous from R_4 to R_5 or later. Thus, it is likely that adjustments in node number, flowers per node and abscission) may occur simultaneously at different position on the plant. Leaf area per plant is a major determinant of photosynthesis per plant and pod or seed number. Water stress treatments reduced node number on the main stem and leaf number (Table 2) and leaf area and also reduced the stomatal conductance, which in turn reduced photosynthesis and affect the growth parameters. The data indicate that variation in pod number in response to environmental conditions) is not just a function of flower and pod abscission. On the other hand, changes in flower number due to changes in plant size (nodes) and flowers per node are also important. These several mechanisms serve to provide the plant with excess reproductive potential in a constantly changing environment. As water stresses developed, leaf water potential was found to decrease, leaves lost turgor and leaf area ws reduced due to wilting. Leaf number was reduced in water stress treatment due to declination of photosynthesis and stomata! conductance to low levels. Hence, seed yield has been reduced partly because of a reduction in the amount of photosynthate available for flowering pod set and seed filling under water stress condition. The number of flowers produced by all water stresses was reduced and T_4 treatment was most affected compared to control. Fewer flowers were produced by severe stress (80% reduced water), suggesting that the initiation of flowers *rather* than subsequent flower and pod development is more sensitive to water stress (Mwanamwenge *et al.,* 1999). Nitrogen accumulation of all plant parts in all water stress treatments declined at R5 and Re stages compared to well watered treatments due to high temperature effect on photosynthetic parameters and water stress which indicates earlier physiological maturity and lower dry matter production. Studies in controlled environment reported that high temperature and water stress have caused more rapid leaf senescence (Thorne *et al.,* 1968; Fischer, 1973). In glasshouse, nitrogen accumulation declined in leaf of T_1 treatment at R_6 stage compared to T_0 treatment in outside due to high transpiration rate in high air temperature which influenced to be early physiological maturity as well as low dry matter production and seed size. The seed yield reduced with 8.74% in T, comparing to T_0 treatment due to a little higher abscission percent of reproductive organs and lower dry matter production in high air temperature condition. Measurements of net photosynthesis on young crop canopies do not show a marked response to temperature (Jeffers and Shibles, 1969), but later in the growing season high temperature causes a marked decrease in photosynthesis (Barker *et al.,* 1972). A relative short-term severe stress may have no influence on grain yield if imposed during the vegetative stage of development (Claassen and Shaw, 1970). Longer period of less severe stress might have a greater influence on yield in soybean (Mayaki *et al.,* 1976). Short-term severe water stress during early flowering of soybean caused little reduction in seed yield, even though water stress caused flower abortion, the plant had time to generate more flowers after stress was removed (Shaw and Laing, 1966). The yield component almost influenced by water stress at flowering was the number of pods per plant. The effects of water stress on photosynthesis rates of soybean leaves are readily detectable at leaf water potentials of about -1.0 to -1.2 Mpa (Cure *et al.,* 1983). Plants grown in growth chambers show rapid reduction in photosynthesis at -0.6 to -1.2 Mpa (Boyer, 1970). The yield component associated with yield decreases in response to water stress varies with growth stage, the number of seeds and pods are affected by stress during flowering and early pod filling stage and seed size is affected by stress during seed filling (Constable and Hearn, 1978). Our results indicate that abscission of flowers and pods of water stressed plants, as well as the later decreases in seed size, may be at least partially a response to water stress although the effects of leaf water deficits on photosynthesis rates with resulting decreases in the concentration of assimilates in vegetative pools. High temperatures were responsible for severe pod drop (Mann and Jaworski, 1970) and cessation of pod growth was probably due to lower rates of photosynthesis, since net photosynthesis of soybean is very low at 40°C (Fukui *et al.,* 1965). In conclusion, the present study demonstrated that any kind of soil water stress associated with high temperature, hampered the physiological processes of soybean and influenced to decrease growth parameters, dry matter production and also the production of flower and increase the abscission of reproductive structures and finally decrease the yield of soybean. High temperature effect might be minimized applying sufficient water. Further study of water stress and chemical stress applying synthetic auxin (Ethyl 5-chloro-3(1H)-indazolylacetate) at high temperature to determine the flowering pattern and production of soybean will be done on the emphasis of sink-source relationship.

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