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Research Article

RESPONSE OF SOYBEAN CULTIVARS TO WATER STRESS AT REPRODUCTIVE STAGES

Kazem Ghassemi-Golezani* and Ramin Lotfi

University of Tabriz, Faculty of Agriculture, Department of Plant Eco-physiology, Tabriz, Iran
*Corresponding author, e-mail: golezani@gmail.com

ABSTRACT : A split plot experiment on the basis of RCB design with four replications was conducted in 2011, to investigate the effects of different irrigation treatments (I_1, I_2, I_3 and I_4: well-watering after 70 mm evaporation from class A pan and irrigation disruptions during flowering, during grain filling and during flowering and grain filling stages, respectively) on ground cover and yield of three soybean cultivars (Clark, Williams and L17). Water stress at reproductive stages reduced percentage and duration of ground cover, plant biomass, pods per plant, grains per plant, mean grain weight, harvest index and grain yield per unit area. However, grains per pod did not differ significantly among irrigation treatments. Reduction in grain yield was increased with increasing duration of water stress at reproductive stages. Williams was a superior cultivar in ground cover, plant biomass, mean 100 grain weight and grain yield per unit area. Interaction of cultivar × irrigation was not significant for yield and yield component. Plant biomass was statistically similar for Clark and L_{17}. Grain yield of L_{17} was 4.49 % and 17.33 % less than that of Clark and Williams, respectively. It is, therefore, essential to provide sufficient water during flowering and grain filling stages in order to prevent yield loss in soybean cultivars.

Keywords: grain yield, ground cover, soybean, water stress, yield components

INTRODUCTION

In a large part of the agricultural areas in the world, water deficit is an important factor limiting growth and productivity of the crops [1, 2]. To survive against the stress, plants have involved a number of morphological, physiological and biochemical responses [3, 4]. Morphological and phenological traits such as plant type, root systems and early flowering play a major role in adaptation of plants to specific drought conditions [5]. Photosynthesis and cell growth are the primary processes which are affected by stress [6]. The effect of drought stress on growth and yield depends on function of genotype, duration of stress, weather conditions, growth, and developmental stages of crops [7]. Moderate to high drought stress can reduce plant biomass, number of pods and seeds, days to maturity, harvest index, seed yield and seed weight in common bean [5], soybean [8] and pinto bean [9].
The flowering and pod setting stages appear to be the most sensitive stages to water stress in chickpea [10] and soybean [11]. Ghobadi *et al*., [12] indicated that the effect of water deficit during reproductive growth was more than that during vegetative growth of rapeseed. The objective of this research was to evaluate the response of soybean cultivars to irrigation disruption during flowering and grain filling stages.

MATERIAL AND METHODS

This research was carried out at the Research Farm of Tabriz University, Tabriz, Iran (latitude 38.05°N, longitude 46.17°E, Altitude 1360 m above sea level) in 2011. The climate is characterized by mean annual precipitation of 245.75 mm, mean annual temperature of 10˚C, mean annual maximum temperature of 16.6˚C and mean annual minimum temperature of 4.2˚C. The experimental design was split plot on the basis of randomized complete block in four replicates, with the irrigation treatment (I_1, I_2, I_3 and I_4: well-watering on the basis of 70 mm evaporation from class A pan and irrigation disruptions at flowering, grain filling and during flowering and grain filling stages, respectively) in main plots and soybean cultivars (Clark, Williams and L_{17}) in sub plots.

Seeds of soybean cultivars were treated with 2 g kg^{-1} Benomyl and then were sown by hand on 11 May 2011 in 5 cm depth of a sandy loam soil. Each plot consisted of 6 rows of 5 m length, spaced 25 cm apart. Seeding rate was 60 seeds m^{-2}. All plots were irrigated immediately after sowing and after seedling establishment, plants were thinned to 45 plants m^{-2}. Subsequent irrigations were carried out on the bases of 70 mm evaporation from class A pan up to flowering. Thereafter, irrigation disruptions were applied according to the treatments. Hand weeding of the experimental area was performed as required.
Ground cover percentage (PGC) was measured every 10 days by viewing the canopy through a wooden frame (50 cm × 75 cm), divided into 100 equal sections. The sections were counted when more than half of each filled with soybean plants.
At maturity, the plants in 1 m^2 of each plot were harvested and pods per plant, grains per pod, grains per plant, mean 100 grain weight, grain yield, biological yield and harvest index were determined.
All the data were analyzed on the basis of experimental design, using MSTATC and SPSS softwares. The means of each trait were compared according to Duncan multiple range test at $p \leq 0.05$. Excel software was used to draw figures.

RESULTS AND DISCUSSION

Regression curves (Figure 1) showed that in all treatments (irrigations and cultivars) ground green cover increased with proceeding plant growth, up the points where maximum values were achieved. Thereafter, percentage ground cover (PGC) decreased with further plant development. Percentage and duration ground cover were sharply reduced due to water stress at later stages of plant development. Maximum PGC under well watering (I_1) and water disruption at reproductive stages (I_2, I_3 and I_4) was obtained at 95 and 85-95 days after sowing, respectively (Figure 1a). At the most stages of development PGC of L_{17} was lower than that of other cultivars. Reduction in PGC during reproductive stages of Clark was greater than that of Williams. However, during vegetative growth PGC was almost similar for all cultivars. Maximum PGC for Clark and Williams obtained at 95 days after sowing, while for L_{17} it was recorded at about 85 days after sowing (Figure 1b).

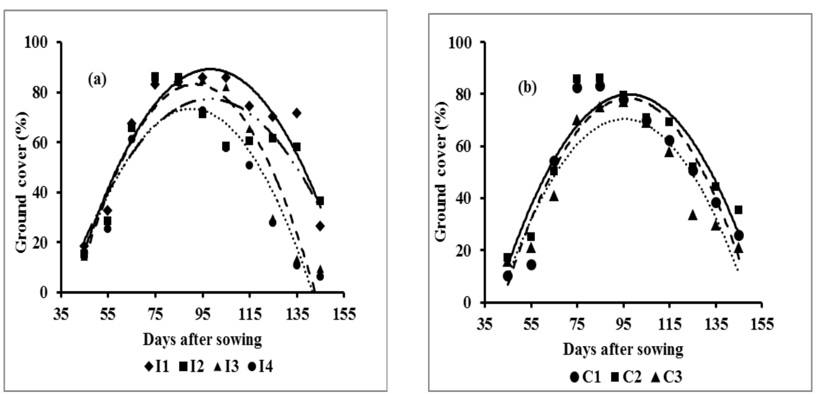

Figure 1. Changes in percentage ground cover (PGC) of soybean for different irrigation treatments and cultivars

I_1, I_2, I_3 and I_4: Well watering and Irrigation disruptions at flowering, grain filling and during flowering and grain filling, respectively (a). C_1, C_2 and C_3: Clark, Williams and L17, respectively (b).

Reduction in percentage and duration of soybean ground cover due to water stress at reproductive stages (Figure 1) can potentially reduce grain yield. Since there is a linear relationship between ground cover and light interception [13], reduction of this growth index can reduce photosynthesis, plant biomass, yield components and consequently grain yield (Table 2). Similar results were reported for maize [14], faba bean [15], chickpea [13] and pinto bean [9]. It has also the practical advantage of quick, simple and non-destructive measurement, which makes frequent sampling available [5].

Analysis of variance of the data for yield and yield components showed that 100 grain weight, biological yield and grain yield per unit area were significantly affected by irrigation and cultivar. The effect of irrigation treatments on pods per plant, grains per plant and harvest index was also significant. The interaction of irrigation × cultivar was not significant. Grains per pod did not differ significantly among irrigation treatments and cultivars (Table 1).

Table 1. Analysis of variance of the dada for yield and yield components of soybean cultivars under different irrigation treatments

Source	df	Pods per plant	Grains per pod	Grains per plant	100 Grains weight (g)	Biological yield	Grain yield	Harvest index
Replication (I)	3	4.266	0.014	27.296	0.717	2361.763	662.607	0.004
Irrigation	3	534.226**	0.068 ns	3611.25**	27.853**	149349.434 **	41527.593**	0.048 **
E_a	9	12.912	0.024	107.704	0.614	7171.18	1776.241	0.003
Cultivar (C)	2	13.902 ns	0.027 ns	28.493 ns	1.675*	18406.391 **	2549.868*	5.257 ns
I*C	6	6.746 ns	0.007 ns	37.028 ns	0.478 ns	761.186 ns	604.187 ns	0.002 ns
E_b	24	6.528	0.013	47.192	0.344	3286.058	694.909	0.003
Total	47							
CV%		16.79	4.84	19.39	5.88	21.54	27.320	11.55

*,** Significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

Pods per plant, grains per plant, plant biomass, grain yield per unit area and harvest index were reduced under water stress at reproductive stages. Maximum loss in yield and yield components was observed under I_4 (Irrigation disruption during flowering and grain filling). The highest grain weight was recorded under I_1 and I_2, that was significantly more than that under I_3 and I_4. Mean grain weight, plant biomass and grain yield of Williams were significantly higher than that of other cultivars, but mean grain weight and grain yield for Clark and Williams were statistically similar (Table 2).

Table 2. Means of the yield and yield components of soybean for irrigation treatment and cultivars.

Treatment	Pods per plant	Grains per plant	100 Grains weight (g)	Biological yield (g m^{-2})	Grain yield (g m^{-2})	Harvest index (%)
Irrigation						
I_1	24.12 a	54.35 a	10.84 a	475.85 a	198.42 a	42.12 a
I_2	13.78 b	31.61 b	11.52 a	348.06 b	127.93 b	36.77 b
I_3	14.96 b	34.87 b	8.090 c	325.24 b	116.88 b	35.74 b
I_4	8.00 c	17.18 c	9.453 b	203.57 c	54.87 c	26.92 c
Cultivars						
Clark	16.25 a	37.41 a	9.996 ab	324.26 b	120.11 ab	35.57 a
Williams	14.93 a	35.5 a	10.29 a	376.85 a	138.77 a	35.21 a
L17	14.45 a	34.85 a	9.643 b	313.44 b	114.71 b	35.38 a

Different letter in each column indicate significant difference at $p \leq 0.05$

I_1, I_2, I_3, I_4: well-watering and irrigation disruption at flowering, grain filling and during flowering and grain filling, respectively.

Reduction in plant biomass under water stress can be attributed to competition of plants for water and nutrients [9]. Ball *et al*., [16] reported that the number of grains per plant was directly proportional to the crop biomass. Water disruption during flowering and grain filling stages (I_4) may increase flower and pod abortion, thus decreasing the seed number per plant (Table 2). Similar results were reported for chickpea [10, 13, 17], soybean [8, 18], pinto bean [9] and dill [19].

The superiority of Williams in ground cover (Figure 1) led to the production of higher biological yield, larger grains and the highest grain yield per unit area, compared with other cultivars (Table 2). Grain yield of L_{17} was 4.49 % and 17.33 % less than that of Clark and Williams, respectively. Yield differences among soybean cultivars mainly resulted from differences in ground cover and mean 100 grain weight (Table 2). No significant interaction of irrigation × cultivar indicates that Williams was superior cultivar both under well and limited irrigation conditions.

CONCLUSION

Soybean is a sensitive crop to water stress at reproductive stages. Water disruption during flowering and grain filling stages (I_4) can lead to severe loss in yield and yield components of soybean cultivars. Percentage ground green cover is a reliable index for estimating yield potential of soybean cultivars in the field. Williams is a high yielding cultivar under well and limited irrigation conditions.

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