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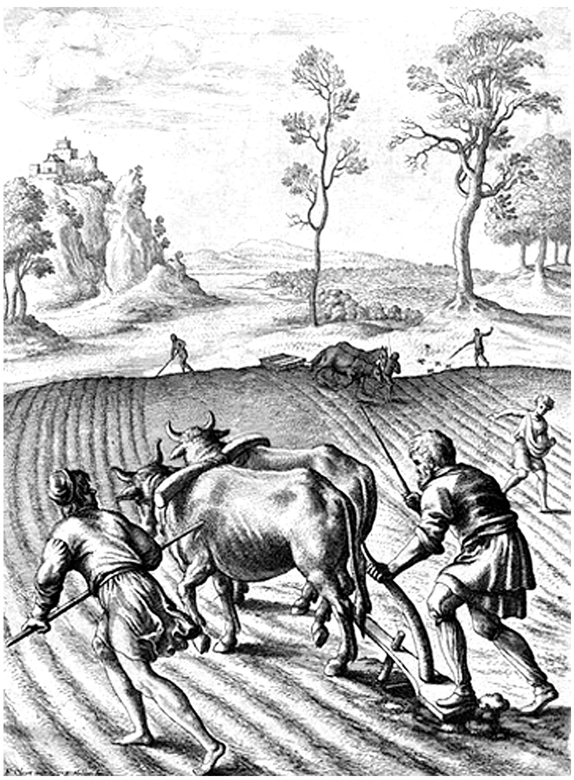

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Effects of Some Plant Growth Regulators and Nutrient Complexes on Above-ground Biomass and Seed Yield of Soybean Grown under Heat-stressed Environment

[1]Leyla Gulluoglu, [2]Halis Arioglu and [3]Mehmet Arslan
[1]Department of Field Crops, Faculty of Agriculture, Harran University, Sanliurfa, Turkey
[2]Department of Field Crops, Faculty of Agriculture, Cukurova University, Adana, Turkey
[3]Department of Field Crops, Faculty of Agriculture, Mustafa Kemal University, Hatay, Turkey

Abstract: A two-year study was conducted to determine the effects of some Plant Growth Regulators (PGRs) and nutrient complexes on biomass weight, seed yield and yield components of both main and double cropped soybean grown under hot and dry conditions. The experimental design was Randomized Complete Block with four replications. Atonik, Biomaster, GA_3, Kinetic, Maxicrop, Cytozyme and Megahix were used as plant growth regulators. The soybean cultivar was A3935 (MG III). Application of PGRs had different effects on biomass weight, seed yield and yield components of both main and double cropped soybean. The highest biomass weight (1054.0 g^{-2}) was obtained from Maxicrop and the lowest (891.8 g^{-2}) was obtained from Megahix applied plots in main cropped soybean. Under double crop conditions, however, the highest biomass weight (857.6 g^{-2}) was obtained from Cytozyme and the lowest (780.0 g^{-2}) was obtained from control. Application of PGRs increased the seed yield and yield components of soybean under both main and double cropped conditions. The highest seed yield was obtained from Atonik with 3876 kg ha^{-1} for main crop soybean and 3447 kg ha^{-1} for double cropped soybean. The lowest seed yields were obtained from no chemical applied control plots of both main and double cropped soybean with 3386 and 2838 kg ha^{-1}, respectively. Application of Atonik, Cytozyme and Maxicrop could be suggested to alleviate heat stress and increase seed yield of both main and double cropped soybean grown under hot and dry conditions.

Key words: Soybean, growth regulator, biomass, seed yield, yield components, heat stress

INTRODUCTION

At the completion of southeastern Anatolia project, an integrated regional development project, 1.7 million hectares of land will be available for irrigated farming. In the Harran Plain, opened to irrigation under the southeastern Anatolia project in 1996, cropping pattern has begun to change with the start of irrigation. Ten percent of the irrigated land has been planned to plant soybean. The plain is under the influence of both the continental and the Mediterranean climate. The maximum day temperature exceeds 35°C and relative humidity drops till to 28% in June, July and August that adversely affects soybean growth and development. Currently, soybean is produced in a minor scale in the plain (150-200 ha) due to some production problems caused by extended hot and dry conditions and as well as marketing problems (Anonim , 2003). Considering 152 000 ha irrigable land, the plain has a great production potential for both main and double crop soybean if the limiting factors for soybean growth can be eliminated by the application of cultural techniques.

Optimum temperature for soybean growth and development is between 25 and 30°C. Extreme temperatures above 35°C cause heat stress, which has harmful effects on flowering and pod set of soybean. Extended high temperature causes leaf sun scald, flower abortion, reduce pod set and seed size. Effects of heat stress on soybean much more harmful when dry conditions coincide with high temperatures. Sensitivity of photosynthesis to heat mainly may be due to damage to components of photo system II located in the hyracoid membranes of the chloroplast and membrane properties (Al-Kati and Paulsen, 1999). When air temperature increases from 35 to 40°C net assimilation rate decreases by 20% (Whigham and Minor, 1978). Like high temperature, low humidity negatively effects photosynthesis. When relative humidity decreases from 80 to 45%, total biomass, number of pods/plant, number of seeds/plant and seed yield are reduced

Corresponding Author: Dr. Mehmet Arslan, Department of Field Crops, Faculty of Agriculture, Mustafa Kemal University, Hatay, Turkey Tel: +90 326 2455845

(Whigham and Minor, 1978). Soybean cannot synthesize some of the necessary hormones in a sufficient level to control its growth and development under high temperature and low humidity, consequently, the plant cannot show its real yield potential. High temperature decreases pollen viability and accelerates ethylene production that increase flower abortion and plant senescence (Marking, 1986). In soybean, variation in flower abortion (20 to 80%) occurs due to ongoing climate and applied cultural techniques. Soybean cultivars differ in their sensitivity to high temperatures (Sapra and Anaele, 1991). However, growing cultivars tolerant to heat stress alone is not enough for maximum yield in hot and dry environments. Application of PGRs could not only regulate plant growth and development but also increase plant resistance to various environmental stresses, such as drought, salinity and low temperature. Proper application of plant growth regulators may improve some of the plant characteristics of soybean grown under stressed environment (Arıoğlu and Işler, 1989).

The purpose of this study was to determine the effects of some plant growth regulators and nutrient complexes on biomass weight, seed yield and yield components of soybean grown under main and double crop conditions.

MATERIALS AND METHODS

The experiment was carried out at the Research Farm of Harlan University, Sanliurfa located 37°09' N and 38°47' E of Turkey, in 2002 and 2003. The soil at the experimental site is classified as Harran soil series (vertic calciorthid aridisol) and clay textured, with 1.1% organic mater, 9% sand, 63% clay, 27% silt and pH 7.9. Based on soil analysis and local recommendations, fertilizer was applied prior to planting at a rate of 36-92-0 kg ha^{-1} NPK. Recommended practices were used for weed and insect control. During the growing season, total precipitation in the site of study was 66.9 mm in 2002 and 61.0 mm in 2003. Maximum and minimum air temperature was 12 and 43°C, respectively in both years. Mean air temperature was about 26°C at cropping period (May-October) in both years, while the mean relative humidity was around 47% and 42% during growing periods in 2002 and 2003, respectively (Table 2).

Soybean cultivar A 3935 was planted as a main crop at the rate of 25 seeds in 1 meter on May 9 and 10 in 2002 and 2003, respectively. After wheat harvest cultivar A 3935 was planted as a second crop at the rate of 25 seeds in 1 meter on June 8 and 10 in 2002 and 2003, respectively. The experimental design was Randomized Complete Block with 4 replications. Plots consisted of four 6 m rows, planted 0.7 m apart, that were end trimmed to final length of 5 m prior to harvest of the center two rows. In both years, seed germination and plant emergence were helped by light sprinkler irrigation. Flood irrigation method was applied every 15 days interval after emergence. After emergence weeds were controlled with hoe or rotovator in each year. The recommended dosage of GA_3, Atonik (sodium-5-nitroguaiacolate, sodium 1-nitrophenolate+sodium 4-nitrophenolate), Megahix (1,1-dimethylpiperidiniumchloride), CtyozymeCrop+Extra, Biomaster (a nutrient complex), Maxicrop (a sea weed extract) and Kinetic (a nutrient complex) were applied as foliar spray when the crops reach recommended growth stage for the application of each PGR (Table 1).

Reproductive growth stages were determined at weekly and 3-day intervals as the plants approached physiological maturity (growth stage R7) using the scale of Fehr and Caviness (1977). At physiological maturity, biomass weight was determined by randomly chosen 20 plants from first and fourth rows of each plot and biomass weight was assessed after drying the plant at 70°C in an oven. Twenty plants were harvested at maturity from first and fourth rows of each plot for measuring number of pods/plant and number of seeds/pod. Seed yield was estimated by harvesting 5 m of two central rows at maturity. Seed weight was determined by counting 300 seed from each yield sample, weighing the sample and then dividing the weight by three. Harvest index was determined by dividing seed weight of randomly selected 20 plants to their total dry biomass.

Table 1: Growth regulators, application rates and development stages of the crop for main and double-cropped soybean

Growth regulators	Application rate	Application time: Main crop	Application time: Double crop
GA_3	25 ppm	R_1	V_2
Atonik	1.5l ha^{-1}	R_1+R_2+R_5 (0.5+0.5+0.5l ha^{-1})	R_1+R_2+R_5 (0.5+0.5+0.5l ha^{-1})
Megahix	1.0l ha^{-1}	R_2	R_2
Cytozyme	1.0l ha^{-1}	R_2	R_2
Biomaster	1.25l ha^{-1}	R_5	R_5
Maxicrop	1.0 kg ha^{-1}	R_1+R_2 (0.5+0.5 kg ha^{-1})	R_1+R_2 (0.5+0.5l ha^{-1})
Kinetic	2.0l ha^{-1}	R_1+R_2 (1.0+1.0l ha^{-1})	R_1+R_2 (1.0+1.0l ha^{-1})

Table 2: Climatic data belonging to the months this study was carried out

Months	Year	Max. Temp. (°C)	Min. Temp. (°C)	Precipitation (mm)	Relative humidity (%)	Soil temperature (°C) 5 cm	Soil temperature (°C) 10 cm
April	2002	20.2	10.1	47.3	69.5	17.2	17.0
	2003	21.7	10.9	21.6	62.3	18.1	17.5
May	2002	28.2	15.2	7.4	50.9	24.8	24.3
	2003	31.2	17.8	11.0	42.4	27.3	26.0
June	2002	35.4	21.7	0.3	38.3	33.6	32.2
	2003	35.5	21.4	5.2	35.1	33.9	31.2
July	2002	43.0	23.5	4.6	37.2	37.4	36.0
	2003	39.7	25.8	-	28.5	39.1	36.7
August	2002	37.5	23.8	-	43.7	36.3	35.4
	2003	40.3	26.0	-	32.2	38.5	36.9
September	2002	34.3	20.2	0.7	47.7	31.7	31.2
	2003	34.0	20.2	0.1	42.4	32.1	31.7
October	2002	28.7	16.7	6.6	48.6	24.7	24.7
	2003	28.4	16.0	23.1	51.5	24.3	24.8

Table 3: Two years' average data (2002-2003) belonging to biomass, harvest index, seed yield, pod number/plant, seed number/plant and seed weight for main cropped soybean

Treatments	Biomass (g m^{-2})	Harvest index (%)	Seed yield (kg ha^{-1})	Pod no./plant	Seed no./pod	Seed weight (g)
GA_3	928.5	34.3	3718	79.5	2.26	15.8
Atonik	1005.0	34.2	3876	82.9	2.47	16.2
Megahix	891.8	32.8	3492	73.9	2.21	15.4
Cytozyme	1053.0	32.1	3716	80.1	2.41	15.9
Biomaster	907.3	32.8	3640	73.8	2.17	15.4
Maxicrop	1054.0	31.7	3668	78.8	2.28	15.7
Kinetic	949.9	31.7	3695	73.0	2.11	15.6
Control	916.1	31.0	3386	72.9	2.09	15.2
LSD (0.05)	86.94	2.09	220.6	5.34	0.17	NS

Measured plant parameters data were subjected to analysis of variance using the General Linear Models (GLM) procedure in the Statistical Analysis System software package (SAS Institute, 1996). Means of measured plant parameters were compared by using Fisher's protected least significance difference (LSD) at type I error of 0.05. Simple correlations were obtained with the ANOVA procedure and the MANOVA option.

RESULTS AND DISCUSSION

Mean maximum temperatures were higher for April, May, June and August in 2003 compared with 2002 (Table 2). During the growing season, mean rain fall was not enough to grow soybean in the Harran plain, thus flood irrigation was applied when the plants were needed. Relative humidity varied between 28 and 70% and the lowest relative humidity was recorded in the months of July and June while the highest was recorded in April for both years.

According to the results of a two-year combined data, application of plant growth regulators had varying level of effects on biomass, number of pods/plant, number of seeds/pod, seed weight, harvest index and seed yield in main cropped soybean (Table 3). The highest levels of biomass increase were obtained from Maxicrop, Cytozyme and Atonik, respectively, while the lowest biomass yield was obtained from control and Biomaster treatments. Biomass weight was significantly and positively correlated with seed yield ($r = 0.43$), number of pods/plant ($r = 0.57$), number of seeds/pod ($r = 0.68$) and seed weight ($r = 0.58$), whereas biomass weight was negatively correlated with harvest index ($r = -0.10$). Application of PGRs significantly affected number of pods/plant and number of seeds/pod. The highest pod number/plant was obtained from Atonik with 82.9 pods/plant and the lowest was obtained from control with 72.9 pods/plant. Number of seeds/pod varied among PGRs. The highest seed number/pod was obtained from Atonik and Cytozyme, respectively. Application of PGRs increased 100 seed weight of soybean, however the increase was not significant for all of the applied PGRs. Harvest index of the plant were significantly affected by the application of PGRs. The highest values for harvest index were obtained from GA_3, Atonik, Megahix and Biomaster. Compared with control, application of GA_3, Atonik, Cytozyme and Maxicrop significantly increased seed yield while Megahix, Biomaster and Kinetic did not. In the current study, seed yield increase by the application of growth regulators or nutrient complexes was within the limit of previously reported for soybean (Shukla *et al.*, 1997; Kamal *et al.*, 1995; Dashora *et al.*, 1994; Kwon and Guh, 1987).

Planting soybean after wheat harvest as a double crop reduces seed yield (Tanner and Hume, 1978; Boerma and Ashley, 1982; Egli *et al.*, 1987; Kane *et al.*, 1997;

Table 4: Two years' average data (2002-2003) belonging to biomass, harvest index, seed yield, pod number/plant, seed number/plant and seed weight for double-cropped soybean

Treatment	Biomass (g m^{-2})	Harvest index (%)	Seed yield (kg ha^{-1})	Pod No./plant	Seed No./pod	Seed weight (g)
GA_3	828.7	44.9	3215	79.0	2.28	16.6
Atonik	853.1	45.7	3447	89.5	2.39	17.0
Megahix	778.2	44.8	2923	81.1	2.18	16.8
Cytozyme	857.6	43.7	3386	85.1	2.29	16.9
Biomaster	804.1	45.2	2977	84.6	2.26	16.4
Maxicrop	793.8	46.2	3339	83.6	2.30	16.9
Kinetic	783.0	43.2	2999	81.5	2.26	16.5
Control	780.0	43.4	2838	79.0	2.19	16.2
LSD (0.05)	53.37	1.80	177.4	NS	0.11	0.52

Wesley, 1999). Yield reduction associated with delayed sowing was primarily related to reduction in crop biomass, seed number per plant, lower pod number per area, shorter duration of grain filling periods (Egli and Bruening, 1992; Egli and Yu, 1991; Board *et al.*, 1999; Ball *et al*, 2000; Egli and Bruening, 1992; Calvino *et al.*, 2002). Seed yield increase for late planted soybean has been reported by correcting environmental stress that slow crop growth rate during the emergence and R5 period (Board and Harville, 1996). Reduced seed yields in wheat-soybean double cropping system mainly resulted from shorter day lengths and lower levels of solar radiation during vegetative and reproductive periods (Boerma and Ashley, 1982; Egli and Bruening, 2000; Calvino *et al.*, 2002). Shortened day length decreases the period from emergence to R5, consequently, plants have little vegetative growth for optimum yield (Egli *et al.*, 1987). Application of PGRs significantly increased all of the investigated plant parameters, except for number of pods/plant (Table 4). Biomass weights varied between 7800 and 8576 g m^{-2} among PGRs. The highest values were obtained from Cytozyme, Atonik and GA3, respectively. However, biomass increase was not significant for Maxicrop, Kinetic and Megahix. Application of PGRs increased number of pods per plant however, the increase was not significant. Number of seeds per pod significantly varied among PGRs. The highest and the lowest values were obtained from Atonik and control, respectively. Application of PGRs significantly increased seed weight. The highest seed weight was obtained from Atonik with 17.0 g and the lowest was obtained from control with 16.2 g. Compared with control GA_3, Atonik, Megahix and Maxicrop significantly increased harvest index whereas Cytozyme and Kinetix did not. Seed yield values varied between 2838 and 3447 kg ha^{-1} among PGRs under double cropped conditions. The highest and the lowest values were obtained from Atonik and control, respectively. Biomass weight was significantly and positively correlated with seed yield (r = 0.75), number of pods/plant (r = 0.56), number of seeds/pod (r = 0.74) and seed weight (r = 0.37), whereas biomass weight was not significantly correlated with harvest index (r = 0.07).

CONCLUSIONS

Application of PGRs GA_3, Atonik, Cytozyme, Maxicrop reduced the effects of heat stress on both main and double cropped soybean and increased biomass yield, seed yield and yield components of main cropped soybean as well as double-cropped soybean grown under extended head and dry conditions. Our findings suggested that GA_3, Atonik, Cytozyme, Maxicrop coubld be used to increase seed yield of both main and double cropped soybean.

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