Journal of Experimental Biology and Agricultural Sciences

<http://www.jebas.org>

ISSN No. 2320 – 8694

SOYBEAN MANAGING FOR MAXIMIZE PRODUCTION: PLANT POPULATION DENSITY EFFECTS ON SEED YIELD AND SOME AGRONOMICAL TRAITS IN MAIN CROPPED SOYBEAN PRODUCTION

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Received – January 01, 2017; Revision – January 25, 2017; Accepted – February 26, 2017

Available Online – February 28, 2017

DOI: [http://dx.doi.org/10.18006/2017.5\(1\).031.037](http://dx.doi.org/10.18006/2017.5(1).031.037)

KEYWORDS

Arisoy

Main crop

Plant density

Seed yield

Soybean

ABSTRACT

Plant density is an essential agronomic practice and affects the productivity of crops. Hence, the optimum plant density to achieve the maximum productivity may vary from crop to crop, genotype to genotype and location to location. Therefore, the current research has been carried out for two consecutive seasons of 2013 and 2014 at the research station of Cukurova University and, the aim of the study was to determine the effect of plant density on seed yield and some agronomical traits in main cropped soybean production. Results of study revealed that seed yield of soybean depends on plant density and highest seed yield (5820.8 kg ha⁻¹) was obtained from the 70 cm x 4 cm spacing, while the lowest mean values (3804.5 kg ha⁻¹) was obtained from 70 cm x 10 cm spacing. Based on these results, it can be concluded that the maximum seed yield of soybean could be possible with the optimum planting pattern 70 cm x 4 cm or 70 cm x 5 cm for medium early (maturity group 3) varieties in main cropped soybean farming in Adana, Turkey.

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Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

Production and Hosting by Horizon Publisher India [HPI]
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1 Introduction

Soybean (*Glycine max* L. Merr.) is one of the most important source of edible oil and protein. Chemical analysis revealed that soybean seed contains approximately 20% oil, 40% protein, 30% carbohydrates, 10% total sugar and 5% ash. Further, soybean meal also has high content of minerals, particularly calcium, phosphorus and iron (Ita, 1992; Iita, 1993) and its seed oil is rich in essential fatty acids (Acikgoz et al., 2009).

Plant density is an important agronomic aspect which may influences crop growth and productivity (Caliskan et al., 2007). Further, Egli (1988) suggested two general concepts to describe the relationship between row spacing or plant densities and yield, among these, first one suggested that maximum yield can be obtained when the plant community produce enough leaf area to provide maximum interception of light during reproductive growth while the second one suggested that, equidistant spacing between plants will maximize yield because it minimizes inter plant competition for space, water, nutrients and light. Higher plant density increases competition among plants at early stage which caused reduction in leaf area expansion, crop growth rate and seed yield. While suitable plant spacing induced development of branches and increases the node number and pod per plant (De Bruin & Pedersen, 2008; Saitoh, 2011).

Several experiments were conducted on row and plant spacing under different soil and climatic conditions and these indicated that higher yield and yield components can be obtained from high planting densities than for low planting densities (Ablett et al., 1984; Aslam et al., 1993; Zaimoglu et al., 2004; Worku & Astatkie, 2011; Cox & Cherney, 2011; Akond et al., 2013; Chauhan & Opena, 2013; Kolaric et al., 2014). Further, Biomass weight per m² were increased with increasing population (Gan et al., 2002; Cox & Cherney, 2010; Worku & Astatkie, 2011; Chauhan & Opena, 2013). Present study was undertaken to find out the optimum plant density for main cropped soybean cultivation of the Arisoy variety in the Cukurova region, and to investigate the effect of plant density (in-row distance) on yield and yield components.

2 Materials and Methods

2.1 Experimental site and Materials

This research was carried out for two consecutive seasons of 2013 and 2014 as a main crop, between May and October at the Cukurova University Research area, Adana, Turkey (Southern Turkey, 36°59'N and 35°18'E with 23m elevation). Arisoy (Group Maturity III), the popularly grown soybean variety in Turkey, was used as the test crop. Study area soil texture was clay loam and the soil has low salt content with pH of 7.6, high K₂O and low content of organic matter, nitrogen and P₂O₅ concentrations. The maximum air temperature for Adana was 35.13°C (August) in 2013 and was 34.52°C in

2014. The average rainfall during growing period of was 101.8 mm and 153.34 mm in 2013 and 2014, respectively (Anonymous, 2015).

2.2 The experimental setup

The study was conducted in a Randomized Complete Block Design (RCBD) with three replications. The lands were fertilized with 200 kg ha⁻¹ of DAP (36 kg ha⁻¹ N, 92 kg ha⁻¹ P) during final land preparation. The plot size was 14.0 m² (5.0 m x 2.8) and each plot had four rows. Plots were planted by hand in the first week of May in both years, maintaining 70 cm space between-row. Plant spacing were maintained as 70 cm x 4 cm (285.71 plants ha⁻¹), 70 cm x 5 cm (357.14 plants ha⁻¹), 70 cm x 6 cm (237.14 plants ha⁻¹), 70 cm x 7 cm (202.86 plants ha⁻¹), 70 cm x 8 cm (177.14 plants ha⁻¹), 70 cm x 9 cm (157.14 plants ha⁻¹) and 70 cm x 10 cm (142.86 plants ha⁻¹) in this study. Traften (Trifluralin) was applied at 2.0 lt ha⁻¹ before planting in both years for weed control.

2.3 Data collection and measurement

Twenty plants from each plot were harvested randomly at maturing stage for measuring plant height (cm), pod height (cm), number of branches plant⁻¹, number of pods plant⁻¹ and number of seed pod⁻¹. Per plot yield data were measured in a similar way from all remaining plants excluding the every end on each side of the two central rows (4.0 m x 1.4 m). Weight of 100-seed (g), harvest index (%), and protein and oil content (%) data were obtained after harvest by the method given by Zaimoglu et al. (2004). At the physiological maturity (growth stage 7), biomass weight was determined by randomly choosing 20 plants from the first and fourth rows of each plot and biomass weight was assessed after drying the pants at 70°C in an oven, and then biomass weight per m² was calculated as the quotient of twenty plants dry weight (g m⁻²) (Gulluoglu et al., 2006).

2.4 Data analysis

The recorded data of different parameters were tabulated in proper form for statistical analysis and analyzed with the help of computer package MSTAT. The differences among the treatments were adjusted by Duncan's Multiple Range Test (Gomez & Gomez, 1984).

3 Results and Discussions

3.1. Plant height and lowest Pod height

Plant height was significantly higher in 2014 as compared to 2013, it might be due to the rainy weather prevails after the emergence of seeds resulting higher elongation of plant height in 2014. Average plant height for both years varied from 110.3 cm to 117.3 cm (Table 1).

Table 1 Effect of soybean plant density on plant and pod height.

Plant (cm)	Spacing	Plant Density (ha^{-1})	Plant Height (cm)			Lowest Pod Height (cm)		
			2013	2014	Average	2013	2014	Average
70cm x 4cm		357.14	106.8	127.8 ^a	117.3 ^a	19.2	31.8 ^a	25.5 ^a
70cm x 5 cm		285.71	106.5	127.0 ^{ab}	116.8 ^a	17.4	31.7 ^a	24.5 ^{ab}
70cm x 6 cm		237.14	106.4	126.9 ^{ab}	116.7 ^a	17.2	30.9 ^{ab}	24.1 ^{ab}
70cm x 7 cm		202.86	105.3	124.0 ^{ab}	114.7 ^{ab}	17.0	28.8 ^{ab}	22.9 ^{abc}
70cm x 8 cm		177.14	103.5	123.2 ^{ab}	113.4 ^b	17.0	27.8 ^{ab}	22.4 ^{abc}
70cm x 9 cm		157.14	103.2	122.2 ^{ab}	112.7 ^{bc}	16.2	26.6 ^{ab}	21.4 ^{bc}
70cm x 10cm		142.86	102.8	117.7 ^b	110.3 ^c	15.8	25.3 ^b	20.5 ^c
LSD (5%)			NS	9.60	2.99	NS	6.16	3.41

Values without common letter differ significantly as per LSD test.

Similar results were observed by various researchers (Ablett et al., 1984; De Bruni&Pedersen, 2008; Cox & Cherney, 2011; Akond et al., 2013; Chauhan & Opena, 2013; Ohshima et al., 2013).

Plant density significantly influenced the soybean pod height in 2014 and also it has significant effect on the average of the lowest pod length. The range of Lowest pod heights were 15.8 to 19.2 cm in 2013 while it reached upto 25.3 to 31.8 cm in 2014 (Table 1). Further, lowest pod height was 20.5 cm and it was reported at lowest plant density (142.860 plant ha^{-1}), it increased up to 25.5 cm at high plant density (357.140 plant ha^{-1}). These results are in agreements with the findings of Ablett et al. (1984) and Aslam et al. (1993).

3.2 Branch Number and Pods Number

Like plant and pod height, plant densities significantly influenced the number of branches plant⁻¹ for both the years (Table 2). The average of two years for number of branches plant⁻¹ varied from 1.85 to 3.75. The highest number of

branches plant⁻¹ (3.75) was achieved from the lowest plant density (70 cm x 10 cm) and the minimum value (1.85 branches plant⁻¹) was achieved from the highest plant density. These findings are supported by Zaimoglu et al. (2004), Cox & Cherney (2011), Saitoh (2011), and Worku & Astatkie (2011).

Further, significant effect of plant density was also reported on the number of pods plant⁻¹. The number of pods plant⁻¹ varied from 46.6 to 72.3 and 36.1 to 63.0 for the both years respectively (Table 2). The widest spaced plants (70cm x 10cm) produced 79% more pods plant⁻¹ at than the closest spaced plants (70cm x 4cm). The number of pods plant⁻¹ is one of the most important yield contributing traits which changes in the response of plant density (Zaimoglu et al., 2004). According to Ohshima et al. (2013) soybean productivity mainly depends on the number of pods plant⁻¹ and it was reported higher in low density which resulted in the enhanced in branching of plant⁻¹. Similar findings of the study was provided by Aslam et al. (1993), Zaimoglu et al. (2004), Cox & Cherney (2011), Saitoh (2011), and Akond et al. (2013).

Table 2 Effect of plant density on branch number (plant⁻¹) and pods number (plant⁻¹) of soybean crop.

Plant Spacing (cm)	Plant Density (ha^{-1})	Branch Number (Plant ⁻¹)			Pod Number (Plant ⁻¹)		
		2013	2014	Average	2013	2014	Average
70cm x 4cm	357.14	2.1 ^c	1.6 ^d	1.85 ^d	46.6 ^e	36.1 ^e	41.4 ^f
70cm x 5 cm	285.71	2.1 ^{bc}	1.6 ^d	1.85 ^d	52.7 ^{de}	40.7 ^{bc}	46.7 ^e
70cm x 6 cm	237.14	2.8 ^{abc}	2.5 ^c	2.65 ^c	57.9 ^{cd}	46.3 ^b	52.1 ^d
70cm x 7 cm	202.86	2.5 ^{bc}	2.6 ^{bc}	2.55 ^c	62.2 ^{bc}	48.3 ^b	55.3 ^c
70cm x 8 cm	177.14	2.9 ^{abc}	3.0 ^b	2.95 ^{bc}	64.9 ^{abc}	57.0 ^a	61.0 ^b
70cm x 9 cm	157.14	3.2 ^{ab}	3.6 ^a	3.40 ^{ab}	68.3 ^{ab}	58.8 ^a	63.5 ^b
70cm x 10cm	142.86	3.8 ^a	3.7 ^a	3.75 ^a	72.3 ^a	63.0 ^a	67.6 ^a
LSD (5%)		1.13	0.49	0.49	8.76	8.38	2.90

Values without common letter differ significantly as per LSD test

Table 3 Effect of plant density on seed number (pod^{-1}) and 100 seed weight (g) in soybean crop.

Plant Spacing (cm)	Plant Density (plants ha^{-1})	Seeds Number (No. pod^{-1})			100 Seeds Weight (g)		
		2013	2014	Average	2013	2014	Average
70cm x 4cm	357.14	2.39	2.49	2.44	16.21 ^b	15.96 ^b	16.09 ^b
70cm x 5 cm	285.71	2.34	2.46	2.40	16.62 ^b	17.97 ^a	17.30 ^a
70cm x 6 cm	237.14	2.26	2.48	2.37	16.87 ^{ab}	18.84 ^a	17.86 ^a
70cm x 7 cm	202.86	2.24	2.42	2.33	17.07 ^{ab}	18.15 ^a	17.61 ^a
70cm x 8 cm	177.14	2.23	2.43	2.33	17.10 ^{ab}	18.72 ^a	17.91 ^a
70cm x 9 cm	157.14	2.24	2.38	2.31	17.12 ^{ab}	18.59 ^a	17.86 ^a
70cm x 10cm	142.86	2.24	2.36	2.30	17.84 ^a	18.28 ^a	18.06 ^a
LSD (5%)		NS	NS	NS	1.127	1.382	1.109

Values without common letter differ significantly as per LSD test

3.3 Seeds Number per Pod and 100 Seeds Weight

There was no remarkable difference among the plant densities on the production of number of seeds pod^{-1} in both years and the average values. The number of seeds pod^{-1} was varied from (2.23 to 2.39 and 2.36 to 2.49) in both years, respectively. The widest spaced plants produced the minimum number seeds pod^{-1} (Table 3). Similar types of findings were reported by Cox & Cherney (2011), Saitoh (2011), Worku & Astatkie (2011) and Akond et al. (2013).

Results showed a significant differences among the plant densities on the 100 seed weight in the both seasons are presented in Table 3. The highest average weight of 100 seed (18.06 g) was obtained from the 10 cm inter - plant spacing while the lowest mean value (16.09 g) was obtained from the 4 cm inter-plant spacing. At low plant density, the competition was reduced between the plants, pods and seeds. For these reason, the seeds were larger and heavier in low plant density. These results are in agreement with the findings of Saitoh (2011), Worku & Astatkie (2011), and Akond et al. (2013).

3.4 Harvest Index and Biomass Weight

The data belonging to harvest index and biomass weight under different plant densities are presented in Table 4. There were

statistically significant differences on the harvest indexes among the plant densities in both years, which ranged from 38.33 to 46.33% in 2013 and from 40.61 to 46.35% in 2014 (Table 4). The harvest index gradually decreased with the decreasing plant density in both years. The highest and the lowest harvesting index (46.34 and 39.47% respectively) was observed at 70cm x 10cm and 70cm x 4cm spacing respectively. The competition among the plants for absorption of nutrient and photosynthesis become severe and inhibit production and partitioning of food materials resulting tall, thin and slender stems under high planting density (Ohyama et al., 2013). For this reason, the harvest index significantly decreased with reducing plant density.

Plant densities significantly influenced the biomass weights for both the years. The biomass was decreased with decreasing plant density in both years. In a two-year average, biomass weights varied between 878.5-1390.9 g m^{-2} (Table 4). However, the lowest biomass weight (878.5 g m^{-2}) was recorded at the lowest plant density (142.860 plant ha^{-1}), it increased up to 1390.9 g m^{-2} at highest plant density (357.140 plant ha^{-1}). These findings are supported by Cox & Cherney, (2011), Worku & Astatkie, (2011) and Chauhan & Opena, (2013).

Table 4 Effect of soybean plant density on harvesting index (%) and biomass weight (g m^{-2}) in Adana, Turkey.

Plant Spacing (cm)	Plant Density (plants ha^{-1})	Harvest Index (%)			Biomass Weight (g m^{-2})		
		2013	2014	Average	2013	2014	Average
70cm x 4cm	357.14	46.33 ^a	46.35 ^{ab}	46.34 ^a	1325.3 ^a	1456.6 ^a	1390.9 ^a
70cm x 5 cm	285.71	44.67 ^{ab}	44.77 ^a	44.72 ^{ab}	1270.7 ^a	1198.2 ^b	1234.4 ^b
70cm x 6 cm	237.14	43.00 ^{ab}	44.04 ^{ab}	43.52 ^{abc}	1131.3 ^{ab}	1082.3 ^{bc}	1106.8 ^c
70cm x 7 cm	202.86	41.67 ^{ab}	43.83 ^a	42.75 ^{abc}	939.3 ^{bc}	974.4 ^c	956.9 ^d
70cm x 8 cm	177.14	41.00 ^b	43.58 ^{ab}	42.29 ^{abc}	918.7 ^{bc}	963.5 ^c	941.1 ^d
70cm x 9 cm	157.14	39.00 ^b	41.96 ^{ab}	40.48 ^{bc}	848.0 ^c	931.6 ^c	889.8 ^d
70cm x 10cm	142.86	38.33 ^b	40.61 ^b	39.47 ^c	834.0 ^c	923.1 ^c	878.5 ^d
LSD (5%)		7.24	3.13	4.41	212.8	160.2	108.6

Values without common letter differ significantly as per LSD test.

Table 5 Effect of soybean plant density on seed yields per hectare (kg ha⁻¹) in Adana, Turkey.

Plant Spacing (cm)	Plant Density (plant ha ⁻¹)	Seed Yield (kg ha ⁻¹)		
		2013	2014	Average
70cm x 4cm	357.14	5793 ^a	5849 ^a	5820.8 ^a
70cm x 5 cm	285.71	5239 ^b	5150 ^b	5194.1 ^b
70cm x 6 cm	237.14	4777 ^{bc}	4616 ^{bc}	4696.5 ^c
70cm x 7 cm	202.86	4385 ^{cd}	4275 ^{cd}	4330.3 ^d
70cm x 8 cm	177.14	4005 ^{de}	4176 ^{cd}	4090.6 ^{de}
70cm x 9 cm	157.14	3733 ^e	4028 ^d	3880.5 ^e
70cm x 10cm	142.86	3589 ^e	4020 ^d	3804.5 ^e
LSD (5%)		536.9	568.9	326.9

Values without common letter differ significantly as per LSD test

3.5. Seed Yield

Table 5 represented the data belonging to seed yield at different intra-row spacing (plant density). Plant densities remarkably influenced the seed yields for both the years. The seed yield varied from 3589 to 5793 kg ha⁻¹ and 4020 to 5849 kg ha⁻¹ for both the years respectively (Table 5). The highest average seed yield (5820.8 kg ha⁻¹) was obtained from 70cm x 4cm spacing while the lowest mean value (3804.5 kg ha⁻¹) was obtained from 70cm x 10 cm plant spacing. Soybean produced 53% higher seed yield at the highest seeding rates (357.14 plants ha⁻¹) compared with the lowest seeding rates (142.86 plants ha⁻¹). The seed yield ha⁻¹ continuously increased as inter-plant spacing decreased from 10 to 5 cm (Table 5). Narrow row spacing increases canopy leaf area and greater light interception. These changes in canopy formation increased crop growth rate, dry matter accumulation, and seed yield (De Bruin & Pedersen, 2008). The plants compete with each other for light, water and nutrients. Gaseous exchange between the crop and atmosphere depends on the canopy architecture of plants (Zhou et al., 2010).

3.6. Oil and Protein Content

No significant variation was observed among the plant densities on the oil and protein content in the observed years.

The two years average of oil and protein content were varied from 17.37 to 18.04% and 36.56 to 36.90% respectively (Table 6). Moreover, oil and protein content were decreased in the next cropping seasons of 2014. These results are in partial agreement with the findings of Gulluoglu et al. (2016) who found the oil content among peanut varieties was insignificant in main cropped growing season. On the other hand, Islam et al. (2016) observed that lower plant population produced the higher percentage of protein and oil content.

4 Conclusions

The current research indicated that seed yield of soybean depends on the density of plant. The seed yield was significantly influenced by the plant spacing and it was reported that the seed yield increased with increasing plant density. The highest seed yield (5820.8 kg ha⁻¹) was obtained from the 70cm x 4 cm spacing, while the lowest mean values (3804.5 kg ha⁻¹) was obtained from the 70x10 cm spacing. The seed yield continuously increased as inter-plant spacing decreased from 10 to 5 cm. Based on these results, the suitable planting pattern could be suggested as 70cm x 4 cm or 70 cm x 5cm for maturity group 3 (medium early) varieties in main cropped soybean farming at Adana in Turkey.

Table 6 Effect of plant density on oil and protein content of soybean crop.

Plant Spacing (cm)	Plant Density (plants ha ⁻¹)	Oil Content (%)			Protein Content (%)		
		2013	2014	Average	2013	2014	Average
70cmx4cm	357.14	19.16	16.07	17.61	37.37	36.35	36.86
70cmx5cm	285.71	19.36	16.59	17.97	37.20	36.61	36.90
70cmx6cm	237.14	19.31	15.90	17.60	37.16	36.42	36.78
70cmx7cm	202.86	19.08	15.68	17.37	37.17	36.31	36.73
70cmx8cm	177.14	19.43	16.67	18.04	37.03	36.67	36.85
70cmx9cm	157.14	19.29	16.01	17.65	36.41	36.71	36.56
70cmx10cm	142.86	19.58	16.23	17.90	36.64	36.80	36.71
LSD (5%)		NS	NS	NS	NS	NS	NS

Values without common letter differ significantly as per LSD test

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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