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Effect of Different Plant Densities and Planting Season on Soybean Traits (*Glycine max* L.)

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Abstract

In order to investigate the effects of plant density and planting season on phonological traits, yield and yield components of Soybean (Line 033) were carried out at Research Farm of Islamic Azad University, Qaemshahr Branch, in two consecutive years 2016 and 2017. This experiment was conducted as split plot in randomized complete block design with three replications. The planting season was in three levels: spring (May 17), summer (July 6) and summer delay (August 6) as main factor and sub factor including four plant densities (20, 40, 60 and 80 plants per m^2). The results showed that the plant height and the distance from the first pod to the surface of the ground for spring cultivation in the second year and for densities of 60 and 80 plants per m^2 were higher than the first year, while the number of branches for the first year was more than the second year. Yield was increased (38.1%) with increasing plant density up to 80 plants per m^2 while number of pods per plant and number of seeds per pod decreased. Maximum grain yield for the second year was obtained by spring planting and also in the same year with density 60 and 80 plants per m^2 because of increase in number of pods, number of seeds per pod and 100 seed weight. In general, soybean (line 033) with low stem production capacity in Mazandaran province, Iran is recommended for spring planting and density of 60 plants per m^2.

Keywords: Grain yield, Plant density, Planting season, Soybean and Year.

1. Introduction

Soybean is one of the most important annual crop sources that produce Edible oil and plant protein, which is among the top priority oily plants. It has also 50 percent of the world's oilseed production [13]. Suitable planting dates make optimal use of climatic factors such as temperature, humidity, day length, and also the adaptation of flowering times to appropriate temperatures [9]. Planting at the right time controls damages which caused by freezing in late spring and early fall, pests, diseases, weeds and matching the flowering time with a suitable temperature. Sowing date has significant effects on grain yield and delay planting decreased plant height, height of the first pod of soil surface, number of branches, harvest index and grain yield [5]. Early planting dates lead to more nodule formation and delayed planting which also leads to a linear reduction in grain yield [3]. The researchers noted that early planting date was the highest for traits such as number of pods per main stem, number of pods per lateral stem, number of pods per plant, number of double pods, number of triple pods and grain yields [21]. Researchers have reported that timely sowing of soybeans has had more seedlings and pods [4]. In order to attain maximum production, the density should not be so low that farm potential is not fully utilized and it must not be too high to reduced yield by reason of excessive competition of plants in terms of moisture, food and other factors affecting growth [13]. Increasing planting density, cause more competition to obtain for light, food and water, then less photosynthesis material were allocated to each seeds [17]. It was also reported that the effect of plant density on seed number was very significant, so that the

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number of seeds per plant decreased with increasing by plant density [11]. The researchers also showed that maximum grain yield was obtained from higher density. This increase can be attributed to the greater influence of light inside vegetation, reduced competition and the efficiency of photosynthesis. Also, with increasing plant distance on rows increased the number of lateral branches and number of pods, while decreased the distance between the first pods from ground level and yield [19]. Edwards and Purcell (2005) stated that increasing density in delay sowing increase crop yield. In this study, increasing plant density in late planting dates led to increased grain yield, therefore, to compensate for the loss of yield in late planting, should be used a higher plant density [20]. The purpose of this study was to estimate the optimum plant density in spring, summer, and late planting dates in soybeans.

2. Materials and Methods

This experiment was conducted in two consecutive years 2015-2016 and 2016-2017 at the research farm of Islamic Azad University, Qaemshahr Branch of Mazandaran province, Iran. The height of the test site from the sea level is 14.5 m, its longitude is 28° and 36′ east, and its latitude is 28° and 56′ north. Meteorological features are given in Table 1. The soil analysis showed clay loamy texture with acidity of 7.1, organic matter 1.8% and electrical conductivity of 0.26 dS/m. This experiment was conducted as split plots in randomized complete block design with three replications. The planting season was in three levels: spring (May 17), summer (July 6) and summer delay (August 6) as main factor and sub factor including four plant densities (20, 40, 60 and 80 plants per m^2). The planting operation was carried out by hand and with shovel and then irrigated immediately after planting. The irrigation was rainy system and was watered on appropriate dates. Thinning, weed and pest control was done by conventional control. Urea (200 kg/ha) and triple superphosphate (150 kg/ha) were used as soil analysis. Soybean was harvested when it's ripened enough and with moisture standard limitation (12%). Harvesting in each plot was done by eliminating the side effect in a square meter. The measured traits were plant height, number of branches, number of pods per plant, number of seeds per pod, 100 seed weight, and grain yield. Characteristics such as plant height, number of branches and number of pods per plant were calculated from the average of 12 plants per plot. The number of seeds per pod was calculated from the average number of seeds of 6 pods per 6 plants in each plot. 100 seeds were randomly counted in each plot and weighed by the scale in grams. Finally, grain yield was obtained by weighing seeds from plants per square meter of per unit area. The data were analyzed using MSTAT-C statistical software and variance analysis with Duncan's multiple range tests at 5% probability level. Drawing diagrams were done with Excel.

Table 1. Weather conditions in experimental site in Soybean growth stages.

Variable	Minimum temp. (°C)		Maximum temp. (°C)		Evaporation (mm)		Precipitation (mm)	
year	2016	2017	2016	2017	2016	2017	2016	2017
May	14.6	14	21.8	24	82.0	75	25.3	32
June	20.1	19	28.5	30	159.8	110	1.5	28
July	22.6	22	31.1	34	171.5	128	48.1	9.2
August	23.9	25	32.2	34	170.2	156	31.2	12.2
September	19.9	18	27.8	28	100.7	121	98.6	48
October	15.7	15	25.2	18	78.4	85	143.2	82
November	8.4	14	15.7	16	42.4	82	144.9	95

3. Result and Discussion

Plant height:

The plant height statistically showed a significant difference under the simple effects of year, planting season, plant density, interactions of year with planting season and year with plant density at 1% probability level (Table 2). The mean comparison of simple effects of traits showed that the maximum plant height was obtained for spring planting season (85.1 cm) and lowest plant height for summer planting and summer delay (73.8 and 69 cm) respectively. Other results showed that the shortest plant height was obtained for the density of 20 plants per m^2 (71 cm) and the highest plant height was attained for densities of 60 and 80 plants/m^2 (79.5 and 78.9 cm) (Table 3). Under the interaction of year with planting season, maximum plant height (98.9 cm) was achieved by spring cultivation in the second year and the minimum plant height (64.2 cm) was acquired with summer crop cultivation in the first year. The maximum plant height (87.6 cm) was obtained for the second year, with a density of 60 plants per m^2 and the shortest plant height for the first year with a density of 20 plants per m^2 (62 cm). The researchers showed that the planting dates of May 27th and June 5th had the highest plant height, and the lowest plant height belonged to the planting dates of June 15th and June 27th [16]. Razmi [2010] showed that the plant height of soybean cultivars significantly decreased with delay in planting from June 15th to August 1st. Razmi [2010] found that rising plant density increased plant height from 103.4 to 107.6 cm in density of 30 to 50 plants per m^2 respectively. Kobrayi et al. [2010] stated that plant height significantly increased with increasing planting density.

Number of branches:

The number of branches was statistically significant under the simple effects of year and plant density at 1% probability level under the effect of planting season and the interaction between year and planting season at 5% probability level (Table 2). Mean Comparison of traits simple effects illustrate that the number of branches in the first year was 75% higher than in the second year. The lowest number of branches was obtained for summer planting (0.4 sub branch). Also, under the influence of density, the highest number of branches for the density of 20 plants per m^2 (1/8 branches) and the lowest were obtained for 60 and 80 plants per m^2 (for each 0.3 branches) (Table 3). Under the interaction of year with planting season, the highest number of branches was obtained by spring planting (1/2 branch) and summer delay (1/6 branch) in the first year. During the study it was shown that the number of branches in spring planting was higher than the lateral branches produced in summer plantings, but there was no statistically significant difference between them, which can be attributed to the trend of branch changes Subordinate cultivars date from different planting dates [15]. On the other hand, the researchers stated that planting soybean at low densities could lead to an increase in the number of branches and an increase in the share of sub branch in yield, so that in high densities, the share of sub branches between 14 and 57 percent in the lower density, branches share in the final performance reaches 47 to 74% [10]. Other researchers also found that by increasing the density from 16 to 34 plants per m^2, decreased the number of branches per plant [1].

Number of pods per plant:

The number of pods per plant was statistically influenced by simple effect between planting season and plant density at 1% probability level (Table 2). The highest number of pods per plant was for the spring planting season (65.8 pods per plant). The highest number of pods per plant was obtained for the density of 20 plants per m^2 (73.3 pods) and it was 52.5% lower by increasing plant density to 80 plants per m^2 (Table 3). The number of pods depends on the number of nodes per plant, and delayed planting decreases the plant growth period length, as well as the formation of the pods and number of pods in the plant [2]. It was found that with increasing density, the competition between plants increased to receive resources, so that the number of pods per plant was significantly reduced, however, increasing the number of plants per unit area was compensated, reduce the number of pods per plant, so that at the highest density, the highest number of pods was obtained per unit area [17]. Number of pods per plant increased by increasing the distance on the planting row. It seems that by increasing the distance on the row, the competition over the growth space has been reduced and more growth resources were provided to the plant such as water, light and nutrients which increased the number of pods per plant [22].

Number of seeds per pod:

Seed number per pod was significant in Simple effects of planting season and plant density and the interaction of year with planting season at 1% probability level and the interaction of year with plant density at 5% probability level (Table 2). Mean Comparison traits simple effects demonstrated that the highest number of seeds per pod was obtained for spring planting season (2.61 seeds). Maximum number of seeds per pod was obtained for the density of 20 plants per m^2 (2.64 seeds), which decreased by 8.7% with increasing plant density to 80 plants/m^2 (Table 3). Under double interaction, the highest number of seeds per pod was gained for spring (2.7 seeds) for the first year and the lowest for the second year with summer delay cultivation (2.4 seeds). The researchers reported that delay in soybean planting decreased yield, number of seeds per pod and plant, and 100-seed weight [8]. By investigation in three densities (35, 40 and 55 plants per m^2) on three soybean cultivars in summer planting, it was found that with increasing density, number of pods per plant, number of seeds per plant and yield decreased, but did not change significantly the number of seeds per pod, 100 seed weight, Grain yield and harvest index [11].

100 seeds Weight:

The weight of 100 seeds was statistically significant under the simple effect of year and planting season, and interaction effects between years with planting season at the probability level of 1% (Table 2). 100 seeds weight in the second year was 1.5 g less than the first year. The maximum weight of 100 seeds (23.4 g) was attained by summer planting in the first year and the minimum of that (18.2 g) with summer delay cultivation in the second year (Table 3). The researchers were observed descending trend in a thousand seed weight by delayed planting [18]. The highest 1000-seed weight was due to the planting date of May 21st and the lowest 1000-seed weight was related to the sowing date of June 20th and it was reported that in the late sowing date, the plants before flowering do not have enough time to produce foliage and developing and also the period is very short for transfer of the photosynthetic material to the seeds in the pods (the seed filling stage), obviously, the weight of thousand seeds is significantly reduced compared to early planting date, which affected in final grain yield [6].

Grain yield:

Grain yield was significantly affected by planting season, plant density and interaction effects between year with planting season and year with plant density at 1% probability level. Maximum grain yield was obtained for spring cropping (541.5 g/m^2). Also, the highest grain yield was related to density of 80 plants per m^2 (459.5 g/m^2), which did not show significant difference with density of 60 plants/m^2 (434.8 g/m^2). The lowest was the density of 20 plants per square meter (Table 3). Growth period time limited due to the delay in planting, which decreased grain yield by decreasing in number of pods per plant, number of seeds per pod and 100 seeds weight decreased. Number of pods per plant and seeds per pod decreased by increasing plant density up to 80 plants per m^2, but grain yield (38/19%) increased because of number of plants per unit area. The highest grain yield (652.6 g/m^2) was obtained in spring in second year. Maximum grain yield was achieved in the second year with density of 80 and 60 plants per square meter, which were respectively 495.4 and 461.6 g/m^2. Due to the high sensitivity of soybean to the length of the light period and temperature, delay in planting has a negative effect on yield through decreasing vegetative and reproductive growth [12].

Table 2. Mean squares of traits effect by experimental treatments.

S.O.V	**df**	**Plant height**	**Number of lateral branches**	**The number of pods per plant**	**The number of seeds per pod**	**Weight of hundred grain**	**Grain yield**
Year (Y)	1	2768.920**	230.541**	270.227ns	0.040 ns	38.720**	5226.989 ns
Error	4	236.355	21.843	120.596	0.01	1.453	4814.447
Planting season (PS)	2	1623.151**	29.005*	3401.795**	0.164**	40.622**	561942.379**
Y × PS	2	1184.757**	29.005*	122.056 ns	0.148**	59.465**	294166.178**
Error	8	79.452	3.746	75.117	0.012	1.708	5759.703
Plant density (PD)	3	291.785**	163.260**	2475.898**	0.162**	1.869 ns	33097.919**
PD × Y	3	131.096**	4.809	125.294 ns	0.46*	2.330 ns	82176.827**
PS × PD	6	53.911 ns	2.413 ns	33.569 ns	0.014 ns	1.458 ns	4652.599 ns
Y × PS × PD	6	37.775 ns	0.408 ns	33.764 ns	0.024 ns	2.053 ns	25161.927 ns
Error	36	23.764	2.203	42.377	0.015	1.127	6802.925
CV (%)	-	6.41	14.10	9.51	4.84	5.27	15.15

ns, * and **: not significance and significance in 5 and 1 %, respectively.

Table 3. Mean Comparison of traits effect by experimental treatments.

Experimental factors	Plant height (cm)	Number oflateral branches	The number of pods per plant	The number of seeds per pod	Weight of hundred grain (gr)	Grain yield (gr/m^2)
Year						
2016	69.8^b	1.2^a	50.8^a	2.5^a	20.8^a	379.3^a
2017	82.2^a	0.3^b	46.8^a	2.5^a	19.3^b	409.3^a
Planting season						
Spring	85.1^a	0.9^a	65.8^a	2.61^a	20.7^a	541.4^a
Summer	73.8^b	0.4^b	48.2^b	2.51^b	21.0^a	405.2^b
Late Summer	69.0^b	0.9^a	32.4^c	2.45^b	18.6^b	236.0^c
Plant density						
20 plants per m^2	71.0^c	1.8^a	73.3^a	2.64^a	20.5^a	284.0^c
40 plants per m^2	74.5^b	0.6^b	48.4^b	2.53^b	19.8^a	398.6^b
60 plants per m^2	79.5^a	0.3^c	38.7^c	2.51^b	19.8^a	434.8^{ab}
80 plants per m^2	78.6^a	0.3^c	34.8^c	2.41^c	20.6^a	459.5^a

Same letter in column are not significantly different at 5% probability level.

With increasing plant density, the number of pods and yield components decreased but the maximum seed yield was founded from the distance between and within the low row, which could be due to the higher number of plants per unit area at high densities, that cause to more number of pods, grain, and 100 grain weight [19]. Grain yield decreased with increasing row spacing or decreasing density. Utmost yield reported in the high density (3 cm in row) and less yield was dominated in low density (12 cm in row) [22].

4. Conclusions

The results of this study showed that spring planting season provide a more favourable time for facing different soybean stages with appropriate weather conditions, because highest yield was affected by yield components in spring. On the other hand, with increasing plant density per unit area reduced single plant yield components. Final yield increased per unit area due to increased plant per unit area. However, it should be noted that between the two densities (60 and 80 plants/m^2), there was no significant difference in yield and other morphological traits. In addition, 60 plants/m^2 had more number of seeds per pod than 80 plants per m^2 that cause for reducing input costs and would bring economic benefits to the farmer. Therefore, in general, soybean (line 033) with less stem production capacity in Mazandaran province, Iran can be recommended for spring planting and density of 60 plants per m^2.

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