International Journal of Biology; Vol. 5, No. 3; 2013
ISSN 1916-9671 E-ISSN 1916-968X
Published by Canadian Center of Science and Education

Investigation of the Effects of Plant Density and Planting Date on the Quantitative and Qualitative Yields of Two Advanced Soybean Lines

Alireza Daneshmand[1], Mohammad Yazdanpanah[1], Hassan Nik Khah Koochaksaraee[1] & Esmaeil Yasari[2]

[1] Department of Agronomy and Plant Breeding, Faculty of Agricultural and Natural Resources, Islamic Azad University, Qaemshahr Branch, Iran

[2] Department of Agricultural Science, Payame Noor University, Iran

Correspondence: Associate Professor Esmaeil Yasari, Department of Agricultural Science, Payame Noor University, Iran. E-mail: e_yassari@yahoo.com

Received: November 23, 2011 Accepted: April 15, 2013 Online Published: May 15, 2013

doi:10.5539/ijb.v5n3p37 URL: http://dx.doi.org/10.5539/ijb.v5n3p37

Abstract

A split split plot experiment in the format of randomized complete block design with three replications was carried out in the experimental field of the Islamic Azad University of Qaemshahr in 2010. The treatments included the planting dates (28th April and 14th June) as the main plot, the soybean lines 032 and 033 as the sub plot, and the plant density (20, 28 and 40 plants per square meter) as the sub-sub plot. Results obtained showed that the plant density was only significant concerning the features of the number of seeds and the number of pods per plant, the planting date was also only significant regarding the harvest index, the percentage seed oil content was also just influenced by the cultivar used and by the mutual effects of the planting date and the cultivar and also by the mutual effects of the planting date and the cultivar. The summer crop was superior to the spring crop in all the features studied, because it seemed that the high temperature and the very little rainfall before and after pollination and flowering reduced seed and pod formation in the spring crop, as compared to the summer crop. In most of the features studied, line 033 performed better than line 032. Moreover, the most desirable density for obtaining the highest seed and oil yield was 20 plants per square meter, because at this density features such as the number of seeds per plant, the number of pods per plant, the 100-seed weight, and seed oil content were superior. Soybean planted after harvesting wheat (i.e. the summer crop) exhibited greater potential regarding seed yield as compared to the crop planted after harvesting canola (i.e. the spring crop).

Keywords: planting date, plant density, line, percentage seed oil content

1. Introduction

Soybean (*Glycine max* Merril) is one of the most important oil crops, has many applications in agriculture and industry; and in the past it was considered as one of the five sacred grains (wheat, millet, barley, rice and soybean). The high status of this crop is due to its high seed oil and protein content (20 and 40% of the total seed weight, respectively) (Latifi, 1993). Choosing the suitable planting date is one of the cultural strategies agricultural producers can take advantage of to increase seed yield and the economic returns of planting soybean (De Bruin & Pedersen, 2008). Plant density is considered to be one of the main factors of production which greatly influences light absorption into the plant cover (Board, 2002). The spatial distribution of plants in a plant community is related to light absorption, and this feature plays a determining role in the photosynthetic capacity and in yield. The balanced plant density is also dependent on the planting date (Boguest et al., 1990); therefore, the highest cultivar and environmental potentials can be realized by combining the best planting date with the best plant density. In his study, Norsworthy (2005) stated that, on the average, the seed yield of the main stem in narrow rows comprised 14 to 57% of the total seed yield, while the seed yield in the main branch in wide rows, on the average, made up 47 to 74% of the total seed yield. Singh et al. (2000) carried out research on 7 soybean cultivars at densities of 100 to 600 hundred thousand plants per hectare and concluded that the density of 400000 plants per hectare performed better than those of less than and similar to 600000 plants per hectare. Ball et al. (2000), Board et al. (1990), and Norsworthy et al. (2005) reported that the number of pods per plant and the number of seeds per plant compensated for low plant densities. Jason and Emerson (2005) announced that low plant densities in soybean may result in an increase in the number of lateral branches and in a greater contribution of these lateral branches to the total yield. Vasilia et al. (2005) reported that oil and protein contents increase at low plant densities with the protein content varying from 13 to 24 and the oil content from 9 to 24 g. Kg depending on the plant density. Wittaker and Holshouser (2002) reported that by reducing the distance between rows of the planted crop, and hence by increasing the plant density, the height at which the first pod formed and the distance from the first lateral branch to the soil surface increased. Egli and Cornelius (2009) found out that soybean responded to very early and very late planting dates. Robinson et al. (2009) have reported that if there was a delay in planting soybean, the average percentage of seed oil declined while the average percentage of seed protein increased. Many studies have shown that planting date influences the seed yield of soybean; and that delayed planting of soybean, compared to the desired planting date, results in a decline in seed yield (Bruening & Egli, 2000). William et al. (2008), in their study of the effects of planting date on the growth and development of seeds in the northeast United States, reported that soybean planted in late May (the early part of the last month of spring) required 6 to 15 more days to reach full maturity, that the crop planted in mid-May (late part of the second month of spring) resulted in more seed formation and more pods , and that in the crop planted in the late part of the last month of spring had shorter pods and less seed yield compared to the crop planted in the late part of the second month of spring. Pedersen et al. (2004) conducted an experiment and stated that earlier planting led to an increase in the number of seeds, in the number of pods, and in the harvest index, but that the number of seeds per pod declined, compared to later planting dates. Pop et al. (2002) concluded, from the experiment they had conducted, that if the planting of cultivars with unlimited growth was delayed from the 23rd day of the second month in spring to the 15th day of the first month in summer, the height of the plants and the number of nodes on the main stem would decrease , while in cultivars with unlimited growth planted after the end of spring these features did not show a decline and decreases in yield were observed in crops planted after the first half of the last month of spring. McWilliams et al. (2004) evaluated the effects of minimizing delays in planting and the environmental stresses on optimizing seed yield , and found out that second crop or late planted soybean, compared to the first crop soybean, was influenced by the two important factors of temperature and day length (which increased and decreased, respectively, in summer). Because of the desirable features of the soybean plant, and due to the influence of various factors in achieving maximum seed yield, this project was executed in the region to determine the best plant density for the advanced soybean lines of 032 and 033 at different densities.

2. Materials and Methods

In order to study the effects of plant density and planting date on new soybean lines, an experiment was conducted in the cropping year of 2010 in the research field of the Islamic Azad University of Qaemshahr (in the province of Mazandaran, Iran), which has a latitude of 36˚72´, a longitude of 52˚46´ east, an altitude of 14.7 meters above sea level, and an average annual rainfall of 727.8 mm. The soil at the experimental site had a clay loamy texture with a pH of 7.8 and its EC was 0.52 ds.m. The experiment was conducted using the split-split plot form in the randomized complete block design with three replications. The planting dates (the 18th day of the second month in spring and the 4th day of the first month of summer) were considered as the main factor, the soybean lines (032 and 033) as the sub factor and the plant density (20, 30, and 40 plants. m^2) the sub-sub factor. Each experimental plot had an area of 12 m^2 (including 5 rows each 4 meters long, and a distance of 60 cm between rows). All the stages of land preparation, fertilizer application, and insect, disease, and weed control operations were carried out according to the standards followed in the region. After inoculating the seeds with the rhizobium bacteria, they were planted in furrows at a depth of 3 to 5 cm. The field was irrigated several times, taking the crop water requirement and the amount and the timing of rainfall into consideration. In this research, the features of seed yield and its components, the qualitative features such as seed oil content and seed oil yield, and also the biological yield and the harvest index were studied. All measurements were made after leaf fall, when the pods had dried and turned grey, by eliminating the margins of each plot and harvesting the three middle lines. From each plot, ten plants were cut at ground level and taken to the laboratory, where the number of pods per plant and the number of seeds per pod were counted and their means calculated and recorded. To measure the seed and the biological yields, the margins of plots were omitted and the plants in an area of two square meters in the middle of each plot were harvested. The whole plants were weighed to determine the biological yield in kilograms per hectare, and then the seeds were separated from the pods to calculate the seed yield in kilograms per hectare. Of the seeds obtained from 10 plants in each plot, 300 seeds were divided into three groups and weighed, and the mean weight of these three groups was recorded as the 100-seed weight of the plot. From each plot, some seeds were sent to the chemistry laboratory, where the oil in the seeds was extracted using an NMR (Nuclear Magnetic Resonance) machine. Through multiplying the seed yield in kilograms per hectare by the percentage seed oil content, the oil yield was calculated in kilograms per hectare. The harvest yield was determined by dividing the seed weight by the total weight of the plants, and the resulting figure was converted into percentages and recorded. Analysis of the variance of the data obtained from the experiment was performed using the SAS software. To compare the means, Duncan′s multiple range test at the significance level of 5% was employed (Steel & Torri, 1980).

3. Results and Discussion

3.1 The Number of Seeds per Plant

As is shown in Table 1 (the analysis of the variance), only the individual effects of plant density on the feature of the number of seeds per plant is significant; other effects did not cause a significant difference in this feature (at α = 5%). In following Duncan′s method of the test of comparison of the means, it was observed that at the density of D3 (20 plants.m^2), the number of seeds per plant was 27.7% larger than that at the density of D2 (28 plants.m^2) (Table 2). This result is consistent with the findings of Esechie (1993). Since the number of pods per plant decreases with an increase in plant density; therefore, the decrease in the number of seeds per plant is as expected. The largest number of seeds per plant (68.7) was found in the summer crop (Table 2); therefore, these observations are in line with the findings of Nabizadeh (2009). Rezaee zadeh et al. (2001), in their study on the relationships between the yield components of soybean, discovered that the number of seeds per plant had the highest positive correlation with the seed yield; and in this experiment also, a positive and significant correlation (r^2 = 0.79) was found between the number of seeds per plant and the seed yield. The largest number of seeds per plant (55.9) was recorded in line 033 (Table 2). As for the mutual effects of the cultivar, the plant density, and the planting date, the largest number of seeds per plant (94.7) was observed in the summer crop in line 033 at the density of D3 (20 plants.m^2) (Figure 1), which can be attributed to the large number of pods per plant in that line.

Table 1. Analysis of variance of a number of cultural features as influenced by the plant density and the planting date of two soybean lines

Sources of Variation (S.O.V)	Degree of Freedom (d.f)	Seed Yield	No. of pods per plant	No. of seeds per plant	100-seed weight	Percentage seed oil	Seed oil Yield	Harvest Index	Biological Yield
Replications	2	0.214 ns	56.119 ns	20.28 ns	2.484 ns	0.842 ns	156.682 ns	15.279 ns	5.583 ns
Date of planting	1	1.093 ns	102.01 ns	6330.85 ns	13.201 ns	0.001 ns	518.555 ns	1219.174*	14.361 ns
Error a	2	0.508	95.117	1146.471	7.501	0.305	281.294	20.267	10.144
cultivar	1	0.413 ns	18.778 ns	9.818 ns	0.054 ns	5.444*	81.947 ns	0.902 ns	0.13 ns
Planting date x cultivar	1	0.0001 ns	11.334 ns	68.89 ns	3.610 ns	0.694*	4.493 ns	23.523 ns	1.727 ns
Error b	4	0.502	18.805	1683.306	0.667	0.055	232.685	4.467	11.396
Plant density	2	0.396 ns	386.869 ns	1350.936*	2.3 ns	0.734 ns	222.939 ns	1.542 ns	5.578 ns
Planting date x plant density	2	0.515 ns	19.641 ns	1015.392 ns	0.864 ns	2.542*	272.807 ns	5.089 ns	1.068 ns
Cultivar x plant density	2	1.166 ns	112.127 ns	1133.929 ns	2.954 ns	0.189 ns	547.747 ns	6.812 ns	1.188 ns
Planting date x Cultivar x Plant density	2	0.524 ns	5.137 ns	333.716 ns	0.992 ns	0.430 ns	242.653 ns	8.853 ns	3.092 ns
Error		0.459	37.471	398.091	1.211	0.397	215.956	7.948	3.861
CV %		28.51	23.35	29.97	7.44	2.94	30.82	10.04	30.79

Ns: not significant; * significant at 5%.

Table 2. Comparison of the means of the features under study as influenced by the mutual effects of the plant density and planting date in two soybean lines

S	V	D	Treatment Biological yield (Kg.h)	Seed Yield (Kg)	No. of pods per plant	No. of seeds per plant	100-seed weight (g)	Percent seed oil	Oil yield (Kg.h)	Harvest Index (%)
1	*	*	2047a	24.52a	42.20a	15.40a	21.41a	43.88a	22.24b	6.44a
2	*	*	2395a	27.89a	68.72a	14.18a	21.42a	51.47a	33.88a	5.18a
*	1	*	2114a	25.48a	54.94a	14.75a	21.81a	46.16a	28.22a	5.87a
*	2	*	2328a	26.93a	55.98a	14.83a	21.03b	49.18a	27.90b	5.75a
*	*	1	2312a	19.66b	49.77b	14.86a	21.51a	49.78a	27.65a	6.59a
*	*	2	2011a	29.14a	48.91b	14.32a	21.14a	42.71a	28.27a	5.33a
*	*	3	2339a	29.82a	67.70a	15.19a	21.60a	50.53a	28.26a	5.51a
1	*	1	2222a	17.32c	33.57c	15.77a	21.10ab	47.04a	21.55b	7.36a
1	*	2	1989a	28.93ab	45.97bc	14.87ab	21.63a	43.08a	23.20b	6.16ab
1	*	3	1928a	27.33ab	47.08bc	15.57a	21.52a	41.53a	21.98b	5.80ab
2	*	1	2402a	22.02bc	65.98ab	13.97b	21.93a	52.52a	33.75a	5.82ab
2	*	2	2034a	29.35ab	51.87bc	13.87b	20.65b	42.36a	33.35a	4.50b
2	*	3	2749a	32.32a	88.33a	14.82ab	21.70a	59.54a	34.55a	52.22ab
1	1	*	1936a	23.24a	40.30a	15.68a	21.67a	42.02a	23.21b	6.28a
1	2	*	2157a	25.81a	44.11a	15.12ab	21.17b	45.74a	21.28b	6.60a
2	1	*	2291a	27.73a	69.59a	13.83c	21.96a	50.32a	33.23a	5.46a
2	2	*	2499a	28.06a	67.87a	14.54bc	20.90b	52.63a	34.53a	4.90a
*	1	1	1972a	15.42b	44.43b	14.63cb	21.92a	43.27a	28.60a	6.53a
*	1	2	2259a	30.28a	59.58ab	13.92b	21.65a	48.90a	28.35a	5.75a
*	1	3	2110a	30.77a	60.82ab	15.72a	21.87a	46.34a	27.72a	5.33a
*	2	1	2652a	23.92a	55.12ab	15.10ab	21.12ab	52.29a	26.70a	6.65a
*	2	2	1764a	28.00a	38.25b	14.73ab	20.63b	36.54a	28.20a	4.91a
*	2	3	2567a	28.88a	74.60b	14.67ab	21.35ab	54.72a	28.82a	6.95a

Similar letters in each column indicate that the differences are not significant at the 5% level using the Duncan test.

S1: the spring crop, S2: the summer crop, L1: line 032, L2: line 033, D1: density at 40 plants per square meter, D2: density at 28 plants per square meter, D3: density at 20 plants per square meter.

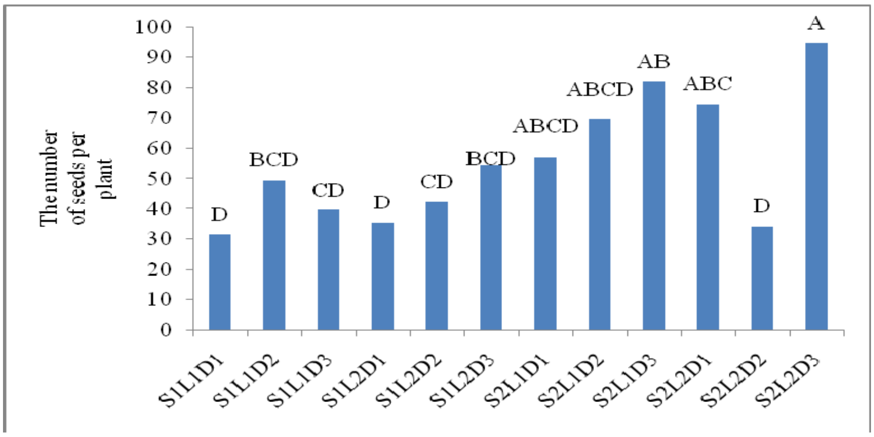

Figure 1. Comparison of the means of the mutual effects of the planting date, the cultivar, and the plant density on the number of seeds per plant

S1: the spring crop, S2: the summer crop, L1: line 032, L2: line 033, D1: density of 40 plants.m^2, D1: density of 28 plants.m^2, D3: density of 20 plants.m^2.

3.2 The Number of Pods per Plant

The analysis of the variance (Table 1) showed that only the individual effects of the plant density on the feature of the number of pods per plant was significant, while the other effects did not bring about a significant difference in this feature (at $\alpha = 5\%$). In using Duncan's method of the test of comparison of the means, it was found that the number of pods per plant at the density of D3 (20 plants.m^2) was 34.2% larger than that at the density of D1 (40 plants.m^2) (Table 2). These results are compatible with the findings of Kashiri (2006), and Parvez et al. (1989). It seems that at high plant densities the number of fertilized flowers declines due to the increase in the competition for sunlight and plant nutrients; on the other hand, with an increase in the number of plants per unit area of land, the space and plant nutrients available for each plant declines and, in the end, leads to a reduction in the number of pods per plant. The largest number of pods per plant (27.8) was obtained in the summer crop (Table 2), which is in agreement with the findings of Nabizadeh (2009). Due to the increase in yield in the summer crop; the increase in the number of pods per plant in this crop was as expected. Line 033 had the biggest number of pods per plant (26.9) (Table 2). As for the mutual effects of the cultivar, the plant density, and the planting date, the largest number of pods per plant (33.83) was observed in the summer crop in line 032 at the density of D3 (Figure 2). The higher number of pods per plant in line 033 is one of the reasons for the increase in the yield of this line compared to that of line 032.

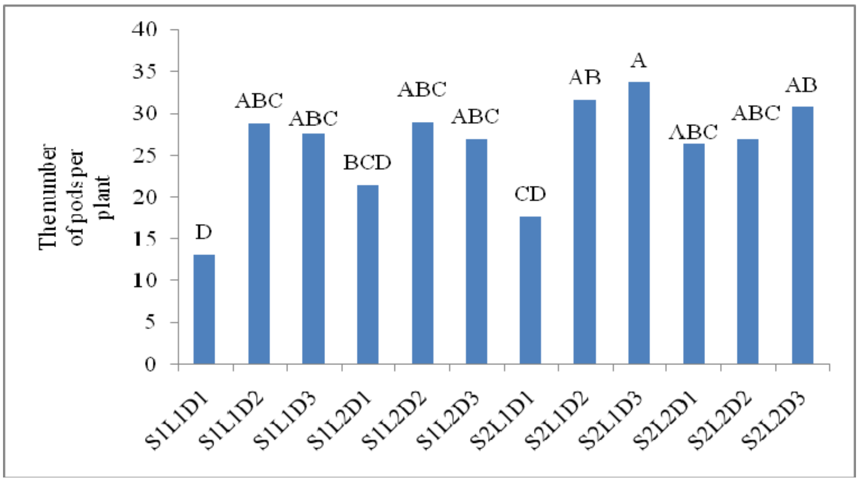

Figure 2. Comparison of the means of the mutual effects of the planting date, the cultivar, and the plant density on the number of pods per plant

S1: the spring crop, S2: the summer crop, L1: line 032, L2: line 033, D1: density of 40 plants.m^2, D1: density of 28 plants.m^2, D3: density of 20 plants.m^2.

3.3 The 100-Seed Weight

As can be observed in Table 1 (the analysis of the variance), none of the individual or mutual influences of the cultivar, the plant density, and the planting date on the feature of the 100-seed weight showed a significant difference (at α = 5%). In employing Duncan′s method of the test of comparison of the means, it was found that in the spring crop the 100-seed weight was 8.4% more than that of the summer crop (Table 2). Although the 100-seed weight is mainly influenced by the amount of photosynthetic materials, the number of seeds, and the capacity of each seed, the genotype and weather conditions during the growth and development of the plants also affect the 100-seed weight (Khadem et al., 2004). Therefore, it appears that the reduction in the 100-seed weight in the summer crop is due to the prevailing weather conditions in the year the experiment was conducted (Figures A and B); because these weather conditions led to an increase in the number of seeds per plant in the summer crop. The maximum 100- seed weight (15.1 g) was obtained at the plant density of D3 (20 plants.m^2) (Table 2). These results are in conformity with the observations of Boquet (1990) and Mehmet (2008). Insufficient photosynthetic materials during the filling of the seeds at high plant densities could be a reason for the reduction in the 100-seed weight at such densities. Line 033 exhibited the largest 100-seed weight (14.8 g) (Table 2). As for the mutual effects of the cultivar, the plant density, and the planting date on the 100-seed weight, the highest weight (16.7 g) was that of the 033 line planted in spring at the density of D3 (Figure 3). It must be said that there was no significant differences between these two lines regarding this feature. The superiority of 033 in this respect could be due to its high genetic potential in producing larger seeds.

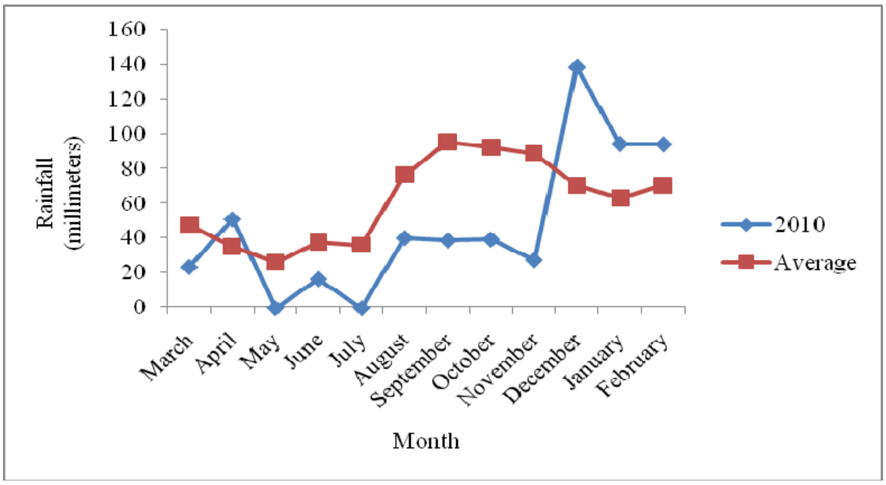

Figure A. Comparison of the rainfall in 2010 with that of the 29- year average

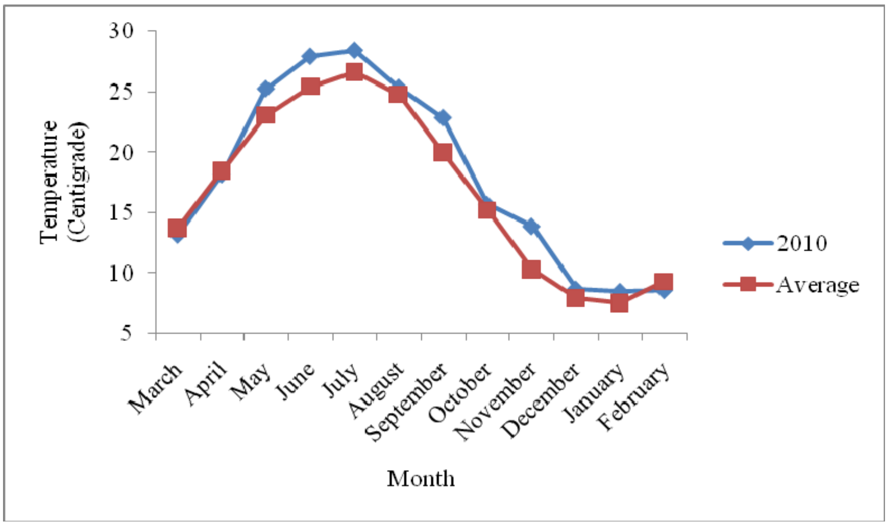

Figure B. Comparison of the temperatures in 2010 with the 29-year averages

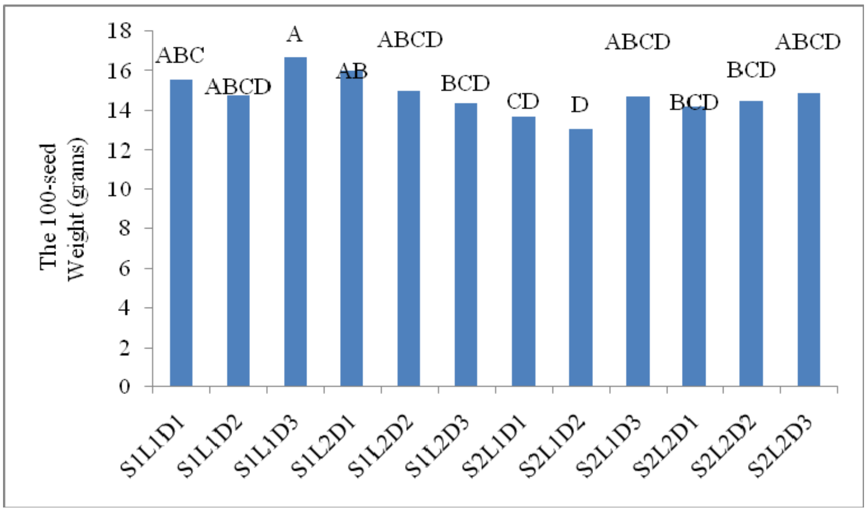

Figure 3. Comparison of the means of the mutual effects of the planting date, the cultivar, and the plant density on the 100-seed weight

S1: the spring crop, S2: the summer crop, L1: line 032, L2: line 033, D1: density of 40 plants.m^2, D1: density of 28 plants.m^2, D3: density of 20 plants.m^2.

3.4 The Seed Yield

The analysis of the variance showed that, none of the individual or mutual effects of the cultivar, the plant density, and the planting date on the feature of seed yield caused any significant differences (at $\alpha = 5\%$). In using Duncan's method of the test of comparison of the means, it was found that the seed yield of the summer crop was 14.5% more than that of the spring crop (Table 2), which conforms with the findings of Nabizadeh (2009), Taleshi et al. (2002), Pedersen and De Bruin (2008), and Ikeda (1992). The largest seed yield (2339 Kg.h) was achieved at the density of D3 (20 plants.m^2) (Table 2), which is in agreement with the results obtained by Kashiri (2006), Board (2003) and Epler et al. (2008). Line 033 showed the maximum seed yield (2328 Kg.h) (Table 2). It was observed that the mutual effects of the cultivar, the planting date, and the plant density were greatest regarding seed yield (3021 Kg.h) in the summer crop in line 033 at the density of D3 (20 plants.m^2) (Figure 4).

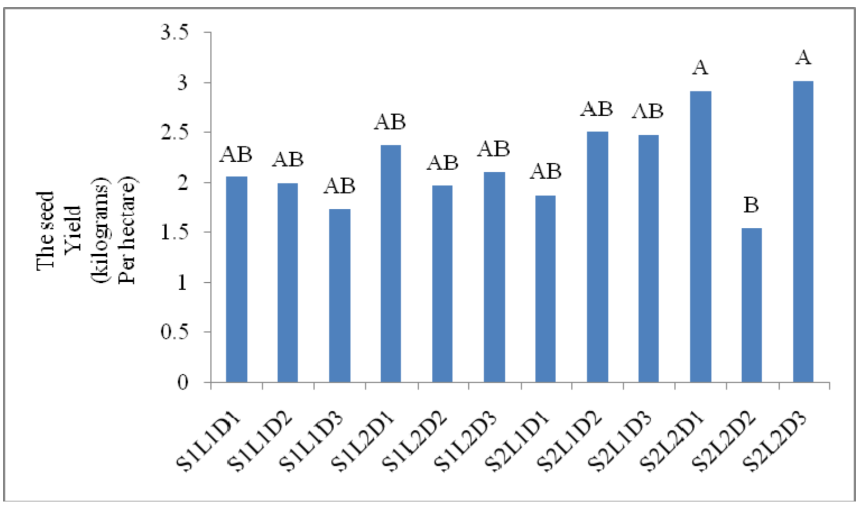

Figure 4. Comparison of the means of the mutual effects of the planting date, the cultivar, and the plant density on seed yield

S1: the spring crop, S2: the summer crop, L1: line 032, L2: line 033, D1: density of 40 plants.m^2, D1: density of 28 plants.m^2, D3: density of 20 plants.m^2.

Flowering of the spring crop began from the middle of the first month of summer and continued till the end of that month, and pod formation started from the late part of the second month of summer and continued until the middle part of the next month. Taking the weather figs of the region in the year the test was conducted (Figures A and B) and the pronounced differences in temperature and rainfall between this year and the previous 29 years into consideration, the reduction in the seed yield of the spring crop can be attributed to the concurrence of the periods of pre- and post-pollination and pre- and post-flowering with periods of high temperatures and very little rainfall (which may have led to the sterility of pollens and to a reduction in seed and pod formation capacity). The ability of soybean to compensate for low plant densities is the reason why there is not much difference in soybean seed yield at different plant densities (Kratochvil et al., 2004). The higher seed yield at the density of D3 (20 plants.m^2) is due to the fact that the maximum 100-seed weight and the largest number of seeds per plant were achieved at this density. Moreover, the greater seed yield of line 033 could be because it has the maximum number of pods and the largest number of seeds per plant.

3.5 The Biological Yield

As can be observed in Table 1 (the analysis of the variance), none of the individual or mutual effects of the planting date, the cultivar, and the plant density showed any significant differences (at α = 5%). Comparison of the means of the individual effects of the planting date indicated that the biological yield in the spring crop (in Kg.h) was 20.3% higher than that of the summer crop (Table 2), which is in conformity with the observations of Azizi et al. (2005) and Dennis Beuening (2000). Dry matter yield is directly related to the radiation absorbed by the leaves during the period between planting and harvest; and delays in planting reduce the capacity to produce dry matter (Weeden, 2000). The maximum biological yield (6595 Kg.h) was achieved at the density of D1 (40 plants.m^2) (Table 2). Differences in dry matter production at various densities can be attributed to differences in the absorption of radiation effective in photosynthesis and also to differences in the efficiency of the plants in using the light absorbed at various plant densities. The maximum biological yield (5875 Kg.h) was that of line 032 (Table 2). The mutual effects of the plant density, the planting date, and the cultivar on dry matter production were greatest (8187 Kg.h) in the spring crop of line 033 at the density of D1 (40 plants.m^2) (Figure 5). The higher biological yield of line 032 can be attributed to the greater height of the plants and to the greater number of leaves on the stems of plants of this line.

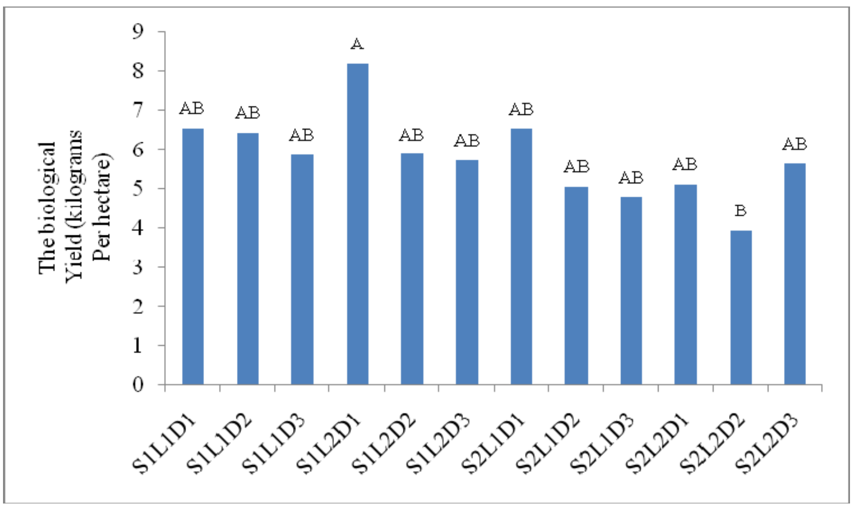

Figure 5. Comparison of the mutual effects of the planting date, the cultivar, and the plant density on the biological yield

S1: the spring crop, S2: the summer crop, L1: line 032, L2: line 033, D1: density of 40 plants.m^2, D1: density of 28 plants.m^2, D3: density of 20 plants.m^2.

3.6 The Harvest Index

Table 1 (the analysis of the variance) shows that only the individual effects of the planting date on the feature of harvest index were significant, while the other effects did not cause a significant difference in this feature (at α = 5%). When Duncan's method of comparison of the means was employed, it was observed that the harvest index of the summer crop was 34.3% higher than that of the spring crop (Table 2), which is in agreement with the observations of Khadem Hamzeh et al. (2004). The superior harvest index of the summer crop can be attributed to its higher seed yield, which has increased the economic yield of this crop; and it can also be pointed out that there is a negative correlation between the biological yield and the harvest index. The maximum harvest index (26.2%) was achieved at the density of D3 (20 plants.m^2). Since at the density of D3 (20 plants.m^2) the largest number of seeds per plant, and hence the maximum economical yield, was obtained, the superior harvest index at this density was as expected. The maximum harvest index (28.2) belonged to line 032 (Table 2). The mutual effects of the plant density, the cultivar, and the planting date showed that the maximum harvest index (35.4%) belonged to the summer crop of line 033 at the density of D3 (20 plants.m^2) (Figure 6). Harvest index is influenced more by genetic factors; and it increases, or decreases, with an increase, or decrease,in the biological yield (Aziz et al., 2005).

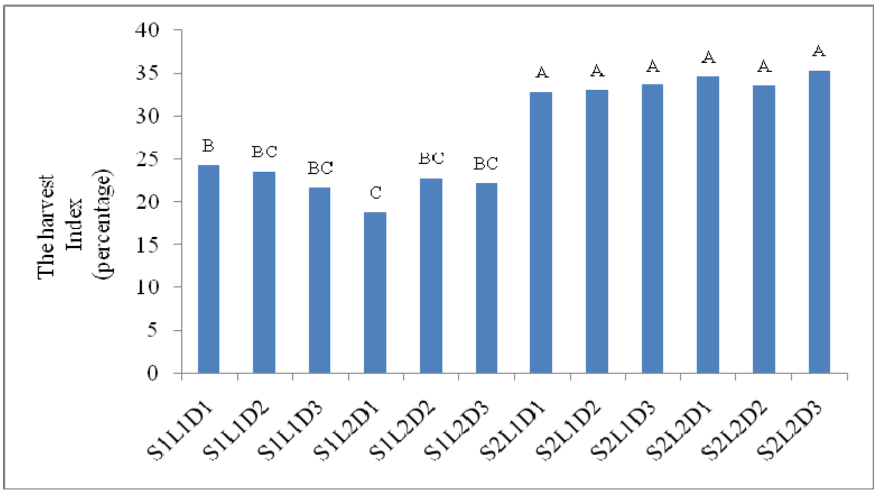

Figure 6. Comparison of the mutual effects of the planting date, the cultivar, and the plant density on the harvest index

S1: the spring crop, S2: the summer crop, L1: line 032, L2: line 033, D1: density of 40 plants.m^2, D1: density of 28 plants.m^2, D3: density of 20 plants.m^2.

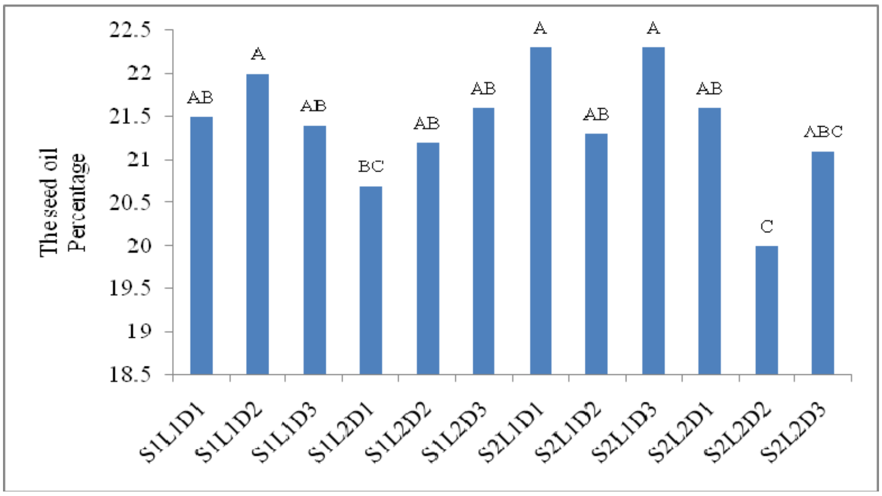

Figure 7. Comparison of the mutual effects of the planting date, the cultivar, and the plant density on the seed oil percentage

S1: the spring crop, S2: the summer crop, L1: line 032, L2: line 033, D1: density of 40 plants.m^2, D1: density of 28 plants.m^2, D3: density of 20 plants.m^2.

3.7 The Percentage Oil Content

Table 1 (the analysis of the variance) indicates that the individual effects of the cultivar, and the mutual effects of the planting date and the cultivar, and the plant density and the planting date, caused a significant difference, but that the other effects on this feature did not (at α = 5%). The use of Duncan′s method of comparison of the means revealed that the oil content of line 032 was 3.6% more than that of line 033 (Table 2), which is compatible with the report by Koochaki et al. (1988) that there is a negative correlation between the percentage protein content and the percentage oil content. The maximum percentage of oil content (21.96%) was observed in the summer crop of line 032, and the minimum (20.9%) in the summer crop of line 033 (Table 2), which are consistent with the findings of Nabizadeh (2009), and which could be due to the genetic features of the cultivars used in the experiment. The maximum percentage of oil content (21.93%) was achieved in the summer crop at the density of D1 (40 plants.m^2), and the minimum (20.65%) in the summer crop at the density of D2 (28 plants.m^2) (Table 2). The higher percentage of oil content in the summer crop can be attributed to the lower temperature during the maturing of the crop and to the concurrence of the maturing period of soybean with the cool weather prevailing at the end of the growing season (Azizi et al., 2005). The mutual effects of the plant density, the cultivar, and the planting date showed that the greatest percentage of oil content was obtained in the summer crop of line 032 at the density of D3 (20 plants.m^2) (Figure 7). Shamsee and Kebraee (2009) observed that the percentage oil content did not change considerably with changes in plant density.

3.8 The Seed Oil Yield

As is shown in Table 1 (the analysis of the variance), none of the individual or mutual effects of the planting date, the cultivar, and the plant density on the feature of oil yield caused a significant difference (at α = 5%). Employing Duncan′s method in the comparison of the means revealed that the oil yield of the summer crop was 14.7% more than that of the spring crop (Table 2). This superiority could be attributed to the high seed yield and to the high percentage oil content of the summer crop. The maximum oil yield (505.3 Kg.h) was obtained at the density of D3 (20 plants.m^2) (Table 2). This was as expected, since the maximum seed yield and the highest percentage of oil content was achieved at the density of D3. The maximum oil yield (491.8 Kg.h) was reported in line 033 (Table 2). The mutual effects of the cultivar, the plant density, and the planting date indicated that the maximum oil yield (63.74 Kg.h) was obtained in the summer crop of line 033 at the density of D3 (20 plants.m^2) (Figure 8). Since there is a negative correlation between the percentage oil content and the percentage protein in lines 032 and 033, line 032 had a higher percentage of oil content; however, as the seed yield in line 032 is less than that of line 033, and oil yield has a positive correlation ($r^2 = 0.993$) with seed yield, hence the superiority of line 033 in the feature of oil yield is as expected.

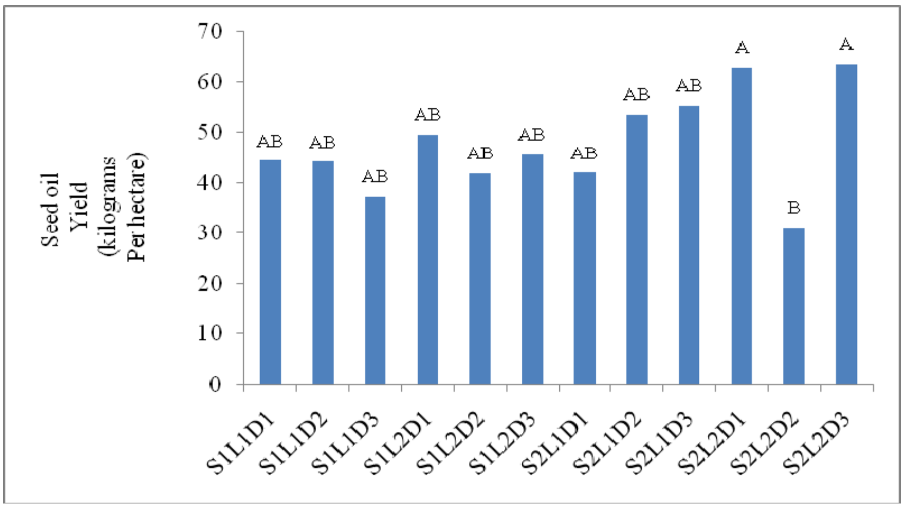

Figure 8. Comparison of the means of the mutual effects of the planting date, the cultivar, and the plant density on seed oil yield

S1: the spring crop, S2: the summer crop, L1: line 032, L2: line 033, D1: density of 40 plants.m^2, D1: density of 28 plants.m^2, D3: density of 20 plants.m^2.

4. Discussion

From the results obtained, it can be gathered that planting soybean after harvesting the wheat crop (i.e. the summer crop) can show a greater potential than planting it after harvesting canola (i.e. the spring crop) as far as seed production is concerned. Because of the prevailing weather conditions in the region in the year the experiment was conducted, the irrigated summer crop enjoyed better growing conditions than the irrigated spring crop; and hence its seed yield was 348 Kg.h higher than that of the spring crop, and its other features, such as the percentage oil content and the harvest index, were also at their maximum. Line 033 exhibited the greatest potentials in achieving high yields due to its larger number of pods, its greater 1000-seed weight, and its larger number of seeds per plant. The percentage oil content in line 032 (21.8%) was at its highest. The best density to obtain the maximum seed yield was at 20 plants.m^2, the reason for which could be the higher number of seeds per plant, the higher number of pods per plant, and the greater 100-seed weight obtained at this density. Moreover, at this density, the percentage oil content and the oil yield were at their maximum. Therefore, it can be said that the maximum oil yield was achieved in the summer crop of the line 032 at the density of 20000 plants per hectare.

References

Abadi. (1988). *Principles of crops growth and development physiology* (p. 345). Mashhad Publication.

Azizi, M., Faramarzi, A., & Abdi, M. (2005). Evaluation of effects of different planting dates on four cultivars of soybean in Mianeh. *Journal of Agricultural New Science, 1*(2), 213-218.

Ball, R. A., Purcell, L. C., & Vories, E. D. (2000). Optimizing soybean plant population for a short-season production system in the Southern U.S. *Crop Sci., 40*, 757-764. http://dx.doi.org/10.2135/cropsci2000.403757x

Board, J. E. (2002). A regression model to predict soybean cultivar yield performance at late planting date. *Agron. J., 94*, 483-492. http://dx.doi.org/10.2134/agronj2002.0483

Board, J. E. (2003). A regression model to predict soybean cultivar yield performance at late planting date. *Agron. J., 94*, 483-492.

Board, J. E., Harville, B. G., & Saxton, A. M. (1990). Narrow-row seed-yield enhancement in determinate soybean. *Agron. J., 82*, 64-68. http://dx.doi.org/10.2134/agronj1990.00021962008200010014x

Boquet, D. J. (1990). Plant population density and row spacing effects on soybean at post-optimal planting dates. *Agron. J., 82*, 59-64. http://dx.doi.org/10.2134/agronj1990.00021962008200010013x

De Bruin, J., & Pedersen, P. (2008). Soybean seed yield response to planting date and seeding Rate in the upper Midwest. *Agron. J., 100*, 696-703. http://dx.doi.org/10.2134/agronj2007.0115

Dennis, B., & Beuening, W. P. (2000). Potential of early maturing soybean cultivars in late Planting. *Agron. J., 3*, 532-537.

Egli, D. B., & Bruening, W. P. (2000). Potential of carly maturing soybean cultivars in late plantings. *Agron. J., 92*, 532-537. http://dx.doi.org/10.2134/agronj2000.923532x

Egli, D. B., & Cornelius, P. L. (2009). A regional analysis of the response of soybean yield to planting date. *Agron. J., 101*, 330-335. http://dx.doi.org/10.2134/agronj2008.0148

Epler, M., & Staggenborg, S. (2008). *Soybean yield and yield component response to plant density in harrow row systems*. Kansas State University, Manhattan.

Esechie, H. A. (1993). Effect of density of planting on yield of two soybean cultivars. *Arab-Golf Journal of Scientific Research, 11*, 83-89.

Hamzeh, K., Karimi, M., Rezaee, E., & Ahmadi, M. (2004). Effects of plant density and planting dates on soybean agronomical traits and yield components. *Iranian Journal of Agricultural Science, 35*(2), 357-366.

Holshouser, D. L., & Wittker, J. P. (2002). Plant population and row spacing effects on early soybean production systems in the Mid- Atlantic USA. *Agron, 94*, 603-611. http://dx.doi.org/10.2134/agronj2002.0603

Ikeda, T. (1992). Soybean planting pattern to yield and yield components. *Agron. J., 84*, 923-926. http://dx.doi.org/10.2134/agronj1992.00021962008400060002x

Jason, K. N., & Emerson, R. S. (2005). Effect of row spacing and soybean genotype on main stem and branch yield. *Agron. J., 97*, 919-923. http://dx.doi.org/10.2134/agronj2004.0271

Keshiri, H., Keshiri, M., Bagheri, M. (2006). Investigation of row spacing and plant density on three summer soybean cultivars. *Journal of Agricultural Science and Natural Resources, 13*(2), 123-127.

Kouchaki, A., Rashed, M. M., Nasiri M. M., & Sadr L. N. R. (1993). *Soybean Agronomy* (p. 282). Mahshah Publication.

Kratochvil, R. J., Pearce, J. T., & Harrison, Jr. M. R. (2004). Row spacing and seeding rate effects on glyphosate-resistant soybean for Mid-Atlantic production systems. *Agron. J., 96*, 1029-1038. http://dx.doi.org/10.2134/agronj2004.1029

McWilliams, D. A., Berglund, D. R., & Endress, G. L. (2004). Soybean-growth andmanagement. North Dakota State University, Fargo, North Dakota.

Mehmet, O. Z. (2008). Nitrogen rate and plant population effects on yield and yield components in soybean. *Academic Journals, 3*(5), 290-295.

Nabizadeh, M. (2009). *Evaluation of effects of planting dates on seed yield and yield cultivars of soybean cultivars* (MSc. thesis) (p. 121). Islamic Azad University, Qaemshahr University.

Norsworthy, J. K., & Shipe, E. R. (2005). Effect of row spacing and soybean genotype on main-stem and branch yield. *Agron. J., 97*, 919-923. http://dx.doi.org/10.2134/agronj2004.0271

Parvez, A. Q., Gardner, F. P., & Boote, K. J. (1989). Determinate - and indeterminate - type soybean cultivar responses to pattern, density, and planting date. *Crop Sci., 29*, 150-157. http://dx.doi.org/10.2135/cropsci1989.0011183X002900010034x

Pedersen, P., & Lauer, J. G. (2004). Response of soybean yield components to management system andplanting date. *Agron. J., 96*, 1372-1381. http://dx.doi.org/10.2134/agronj2004.1372

Pop, M. P., Keisling, T. C., Mc New, R. W., Oliver, L. R., Dillon, C. R., & Wallace, D. M. (2002). Planting date, cultivar, and tillage system effects on drylandsoybeanproduction. *Agron. J., 84*, 81-88. http://dx.doi.org/10.2134/agronj2002.0081

Rezaee Zadeh, A. B., Yazdi, S., Ahmadi, R., & Zeniali, H. (2001). Relationship between soybean yield and yield components via principle components. *Journal of Agriculture and Natural Resources Science and Technology, 5*(3), 107-114.

Robinson, A., Conley, S., Volence, J., & Santini, J. (2009). Analysis of high yielding, Early-planted soybean in Indiana. *Agron. J., 101*, 131-139. http://dx.doi.org/10.2134/agronj2008.0014x

Saadat Lajevardi, N. (1981). *Oilseeds* (p. 217). University of Tehran.

Sharikian, M., & Babaeeian, N. (2000). Effects of plant density on yield and yield components of soybean cultivars (Glycine max). *Journal of Agricultural Science and Natural Resources, 3*, 3-12.

Singh. A., & Singh, K. V. (2000). Influence of planting time and plant geometryl density on periodic dry matter accumulation and seed yield of soybean. *Crop Research, 20*, 76-80.

Steel, R. G. D., & Torri, J. H. (1980). *Principles and procedures of statistics*. Mc Grow Hill. USA.

Vasilia, A., Fasoula. A., & Roger, B. (2005). Divergent selection at ultra-low plant density for seed Protein and oil content within soybean cultivars. *Field Crops Research, 91*, 217-229. http://dx.doi.org/10.1016/j.fcr.2004.07.018

Weeden, B. R. (2000). *Potential of sugerbeet*. Rural industrial Research Development Cooperation.

William. S. C., Shields, E., & Cherney, S. H. (2008). Planting date and seed treatment effects on soybean in the Northeastern United States Entomology.