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EFFECTS OF PLANTING DATES AND ROW DISTANCE ON SUGAR CONTENT, ROOT YIELD AND SOLAR RADIATION ABSORPTION IN SUGAR BEET AT DIFFERENT PLANT DENSITIES

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ABSTRACT

Two experiments were conducted in 2008 and 2009 in Mashhad, Agricultural Research Station (59°20′ E and 36°13′ N), Esfahan (Khorasan) province, Iran, in order to evaluate the effects of planting dates, row distance and plant densities on yield and yield components of sugar beet. A Split-split plot layout within a randomized complete block design with four replications was used in each year. Main plots were planting dates (May 5th, June 10th), subplots were row distances (50 and 60 cm) and Split-subplots were plant densities (8, 10 and 12 plants per m^2). In both 2008 and 2009, the highest values of root yield were related to plantation on 5th May. There were not significant differences in sugar content between the two planting dates in 2008 and 2009. However, the value of potassium, sodium and amino-N content of root were lower on 5th May than those of 10th June, in 2008 and 2009. The maximum root yield and sugar content were obtained for 50 cm distance between rows. The highest sugar content and appropriate root yield were achieved in 10 plants per m^2 in both 2008 and 2009. Planting date on 5th May and 50 cm distance between rows obtained higher value for time of maximum light interception and time of final harvesting in both 2008 and 2009. Although, 12 plants per m^2 produced the highest maximum solar radiation absorption in time of maximum light interception and the highest solar radiation absorption in time of final harvesting in both 2008 and 2009, the differences as compared with 10 plants per m^2 were not significant. Plantation on 5th May and 50 cm distance between rows resulted in the highest value for maximum LAI and total dry matter not only in 2008, but also in 2009. Appropriate LAI and total dry matter in these two years were also obtained with 10 plants per m^2. Planting at 50 cm distance between rows and 10 plants per m^2 gave the best yield and yield components. This planting procedure is suggested for fields under the condition similar to the present study.

Key words: planting date, row distance, sugar content, root yield, plant density, sugarbeet.

INTRODUCTION

Appropriate agronomical managements are necessary to meet the growing needs for food production (Abdel-Motagally and Attia, 2009; Hassanli et al., 2010; Nadali et al., 2010). It is known that a sugar beet variety is valuable for production when it is in accord with the ecological conditions of the cultivated land and reacts properly to agronomical managements (Fabeiro et al., 2003; Draycott, 2006; Romaneckas et al., 2009). In particular in sugar beet, which is an industrial crop, yield prediction is very important for optimizing the sugar factories,processing campaigns (Kenter et al., 2006; Sohrabi and Heidari, 2008). Puscas et al. (2008) reported that plant density represents one of the factors that condition the sugar beet production level. Kenter et al. (2006) demonstrated that the yield potential of sugar beet depends primarily on site and year effects, whereas the influence of agronomic practices is much lower. For high root and sugar yields, plant establishment should be 70000-110000 plants ha^{-1} (Ramazan, 2002). Nassar (2001), found that sucrose content and recoverable sugar percentages decreased linearly with the reduction in plant density; furthermore, root yield and sugar yield were maximized with plant density of 42000 plants ha^{-1}. Jadidi et al. (2010) also noted the range of 30.22 to 47.49 tons ha^{-1} for root yield; Parsa et al. (2007) reported that the final yield

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of total dry matter varied from 15670 to 25920 kg per ha. Hoffmann and Kluge-Severin (2010) stated that yield formation in sown beets can most likely limited by the sink capacity and changes in the composition of the storage root. Farajzadeh Memari Tabrizi et al. (2008) noted that the maximum sugar percentage in their experiment was 19%. The usage of appropriate both planting date and plant density in sugar beet production is one of the basic prerequisites of high and stable yield (Refay, 2010). O'Conner (1983) reported that sugar beet of higher chemical and physical quality was obtained from high plant densities and narrow row widths; moreover, in his experiment, evidence is presented to show that optimum yields and high-quality beet resulted from a row width of 50 cm and density of 80000 plants per ha. Dor et al. (1971) reported that root and sugar yields of sugar beet cv. Polyrave were significantly higher at low plant densities (70000 beets/ha) at wide row spacing (60 cm) than at plant densities and between-row spacing of 92000/ha and 50 cm. The cultivation of autumn sown sugar beets is expected to result in large yield increase due to more light absorption (Hoffmann and Kluge-Severin, 2010). Hoffmann and Kluge-Severin (2010) reported that a leaf area index of 3.5, and therefore canopy closure, was reached 3-4 weeks earlier than in spring sown beets resulting in extra absorption of light. Bhullar et al. (2010) reported that planting density of 100000 plants per ha produced the highest sugar yield and beet root. Knott et al. (1976) concluded that plant populations and row spacing did not affect sugar content. He also noted that within some limits plant population did not greatly influence root yield, but with the high increase of the plant population per ha, yield was reduced significantly. Sadre et al. (2012) reported that plant density had significant influence on root yield and white sugar yield, the highest values being achieved at 12 plants per m^2. Milford and Burks (2010) noted that early sowing of sugar beet is encouraged to take full advantage of longer growing season to maintain and increase yield. Awal et al. (2006) reported that the intensity of solar radiation will remain relatively constant and represents a resource that could be used more efficiently for crop production. It seems that lack of enough knowledge about this topic of research is a serious problem for cultivation of sugar beet. Having information on best planting dates, plant density and row distance between rows is necessary to design a profitable management system.

MATERIAL AND METHODS

Plant material and growth condition

Two experiments were conducted in 2008 and 2009 in Mashhad Agricultural Research Station ($59^{o}20^{/}$ E and $36^{o}13^{/}$ N), Khorasan province, Iran, to evaluate the effects of planting dates and row distance on sugar content and root yield of sugar beet (Ic1 var.) at different plant densities. The research field features a steppe climate (Köppen BSk) with 250 mm of precipitation per year; the research field altitude is 958 m.

A Split-split plot layout within a randomized complete block design with four replications was used in each year. Main plots were planting dates (May 5^{th}, June 10^{th}), subplots were row distances (50 and 60 cm) and Split-subplots were plant densities (8, 10 and 12 plants per m^2). The soil preparation consisted of moldboard ploughing (20-25 cm) followed by disking and smoothing with a land leveler. Each experimental plot had 10 rows with length of 12 m. The field was fertilized with 120 kg ha^{-1} P from triple superphosphate was used. 90 kg N per ha was also used from urea before planting. The first irrigation was done immediately after see ding. Top dressed urea was applied at the rate of 45 kg N per ha when seedlings had 6 leaves. After the first irrigation, irrigation intervals were 10 days. To control narrow-leaf and broad-leaf weeds, 5 kg ha^{-1} Piramin and 5 l ha^{-1} Betanal were mixed and applied after 2-leaf stage of sugar beets. The insecticide Subsidin (2:1000) was used for controlling Conorrhynchus brevirostris (Gyll.). In addition, leaf-feeding pests were controlled by Ekatin (2:1000). Powdery mildew was also controlled during early-summer by the fungicide Calixin (2:1000).

Experimental characteristics measurement

In this experiment, root yield (t ha^{-1}), sugar content (SC) (%), potassium (meq/100 g), sodium (meq/100 g) and Amino-N content of root (meq/100 g) were measured after harvesting. In addition to measuring the radiation above and under the canopy, the plots were sampled. The highest solar radiation absorption in the maximum time of light interception for the first planting date and the second planting date were measured 110 days and 74 days after germination, respectively, in 2008. The maximum solar radiation absorption for the time of final harvesting, for the first planting date and second planting date, were determined 180 days and 144 days after germination, respectively, in 2008. In 2009, the time of maximum light interception for the first and second planting date were measured 115 days and 79 days after germination, respectively. The maximum solar radiation absorption for final of harvest in first and second planting date were measured 190 days and 154 days after germination, respectively, in 2009. Shading percentage, maximum LAI (m^2/m^2) and total dry matter (g/m^2) were also evaluated.

To measure the yield and some important qualitative traits of sugar beet roots, the first and sixth rows and 0.5 m from both ends of the rows were removed from experimental plots at the end of season and the remaining plants were taken as the statistical population. Root yield of each plot was determined in a 3 m^2 area. In addition, dry matter, sugar percentage and some qualitative characteristics were measured by Betalyser (Soleymani et al., 2012). Leaf area of leaves was measured using leaf area meter (Portable Model C1-201) (Shayanfar et al., 2011). The portable Lux Meter LX-101 was used in this experiment. For determination of solar radiation absorption (A), equation number 2 was used, before it, light transmission was evaluated (Equation number 1) (Soleymani and Shahrajabian, 2012).

$$T=1/10 \times 100 \quad (1)$$

$$A= 100 - T \quad (2)$$

Soil analysis

On the basis of soil analysis, the soil texture was Silt- loam and pH at the depth of 0-30 cm in 2008 and 2009 was 8.1 and 8.1, respectively.

Statistical analysis

Analysis of variance (ANOVA) was used to determine the significant differences. The Duncan'S Multiple Range Test was used to perform the separation of means (5% level probability). All statistics was performed with MSTAT-C program (version 2.10).

RESULTS AND DISCUSSION

Planting date had significant effect on root yield, sodium content, and Amino-N content of root in 2008; moreover, its effect on root yield and potassium content in 2009 was significant. In this experiment, sugar content was not affected by planting date in both years, which is different from the result of Refay (2010). The effect of row distance was significant on root yield in both 2008 and 2009. Root yield in 2009 was the only characteristic significantly influenced by planting date and row distance interaction. Plant density effect on root yield and Amino-N content of root in 2008 and 2009 was significant. None of the experimental characteristics were influenced by planting date x plant density interaction, and row density x plant density interaction. Interaction of planting date x row distance x plant density had no significant effect on experimental characteristics (Table 1). The effect of the year reflects the weather conditions during the vegetative and reproductive period, which influence plant growth, and also affects the dates of sowing and harvest and thus the length of the growing season (Freckleton et al., 1999; Kenter et al., 2006). Sadre et al. (2012) also reported that plant density had significant effect on root yield; however in their experiment; sugar yield was also influenced by plant density.

Table 1. Analysis of variance for experimental characteristics

S.O.V	d.f	2008					2009				
		Root yield	Sugar content (SC)	K	Na	Amino-N content of root	Root yield	Sugar content (SC)	K	Na	Amino-N content of root
Block	3	29.36	1.060	0.362	0.053	0.120	110.67	0.388	2.012	1.051	0.047
Planting date	1	1781.93**	0.025	0.145	0.824**	0.963*	16570.02**	0.531	8.383*	0.030	0.435
Error (a)	3	43.31	0.275	0.077	0.017	0.033	166.64	0.196	0.460	1.012	0.279
Row distance	1	854.02**	0.013	0.005	0.125	0.132	933.07*	2.104	0.025	2.842	3.096
Planting date × row distance	1	128.25	0.013	0.0001	0.086	0.110	514.11*	0.619	0.065	2.208	0.146
Error (b)	6	34.75	0.343	0.151	0.157	0.179	82.27	0.701	0.294	0.524	0.984
Plant density	2	86.67**	0.027	0.067	0.011	0.089*	329.40**	1.158	0.273	0.192	2.617**
Planting date × plant density	2	6.30	0.087	0.064	0.005	0.065	9.46	0.399	0.058	0.553	0.068
Row distance × plant density	2	29.44	0.151	0.008	0.027	0.012	42.13	0.692	0.500	0.367	0.001
Planting date × row distance × plant density	2	3.03	0.263	0.042	0.020	0.009	8.48	0.824	0.075	0.364	0.672
Error (c)	24	9.04	0.323	0.051	0.028	0.025	19.35	0.575	0.161	0.973	0.288

*significant at 0.05 significance in F-tests;
**significant at 0.001 significance in F-tests;
ns non significant.

In 2008, the maximum root yield, significantly different from 10th June, was recorded from 5th May planting. The maximum sugar content (SC) and potassium content in 2008 was obtained from 10th June and 5th May plantings, respectively. There were no significant differences among treatments in these two experimental characteristics. 10th June planting produced the maximum sodium content and Amino-N content of root in 2008, significantly different from 5th May. In both these two experimental characteristics, significant differences were found between treatments. The maximum root yield was obtained with 5th May planting in 2009, but not significantly different from that obtained with 10th June planting. The maximum sugar content (SC), which had no significant difference with 10th June, was related to 5th May (Table 2). Planting on 10th June produced the highest potassium content in 2009, and its difference with 5th May was significant. Although, the maximum sodium content and Amino-N content of root in 2009 was recorded with planting on 10th June, there were no significant differences between them. Na is considered one of the most important impurities of sugar beet roots, and it was stated that its content in root has a negative correlation with white sugar percentage (Cooke and Scott, 1993). The maximum root yield was obtained by planting at 50 cm distance between rows. The highest sugar content (SC), potassium content, sodium content and Amino-N content of root in 2008 were recorded at 50 cm distance between rows, but no significant differences were found between treatments in these four experimental characteristics. The maximum root yield in 2009 was obtained with 50 cm distance between rows, which had significant difference as compared with 60 cm distance. Campel (2002) concluded that the effect of the increase in root weight on sugar yield was greater than that of the increase in sugar content alone. Schneider et al (2002) showed that sugar yield was strongly correlated with root yield and less strongly with sugar concentration. The highest sugar content (SC) and potassium in 2009 was obtained by planting at 50 cm distance between rows, but the differences with other treatment were not significant. The maximum sodium content and Amino-N content of root in 2009 was related to 60 cm, and 50 cm distance between rows, respectively; but all differences for these experimental characters between 50 cm and 60 cm distance between rows were not significant (Table 2). The highest root yield in 2008 was obtained with 12 plants per m^2, but the differences with all treatments were not significant. However, Harris (1972) reported that the effects of variation in plant density on yields of roots were generally slight, and the yield response tended to be highest at the lowest plant densities and least with the normal optimum density of about 80000 plants ha^{-1}. The maximum sugar content (SC) and potassium content in 2008 was associated with 10 plants per m^2 and 8 plants per m^2, respectively, significantly different with each other. On the one hand, the maximum sodium content in 2008 was related to 10 plants per m^2, but this treatment had no significant differences from other treatments. The highest and the lowest Amino-N content of root in 2008 were related to 8 plants per m^2 and 10 plants per m^2, respectively. No significant difference was found between 10 and 12 plants per m^2 (Table 2).

Table 2. Mean comparison for root yield (t ha^{-1}), sugar content (SC) (%), potassium (meq/100 g), sodium (meq/100 g) and amino-N content of root (meq/100 g) for two years

Treatment	2008					2009				
	Root yield	Sugar content (SC)	Potassium	Sodium	Amino-N content of root	Root yield	Sugar content (SC)	Potassium	Sodium	Amino-N content of root
Planting date										
5th May	52.79a	20.51a	3.96a	0.58b	0.70b	84.94a	16.08a	6.28b	4.32a	4.31a
10th June	40.60b	20.56a	3.85a	0.84a	0.98a	47.78b	15.87a	7.11a	4.37a	4.50a
The distance between rows (cm)										
50	50.91a	20.55a	3.91a	0.76a	0.89a	70.77a	16.19a	6.72a	4.10a	4.66a
60	42.48b	20.52a	3.89a	0.66a	0.79a	61.59b	15.77a	6.67a	4.59a	4.15a
Plant density (plants per m^2)										
8	44.03b	20.53a	3.97a	0.71a	0.93a	61.29b	15.99a	6.62a	4.23a	4.85a
10	47.74a	20.58a	3.90a	0.73a	0.79b	67.74a	16.24a	6.62a	4.36a	4.31b
12	48.32a	20.50a	3.84a	0.68a	0.81b	70.05a	15.70a	6.85a	4.45a	4.05b

Values followed by common letters within each column do not differ significantly.

The highest root yield in 2009 was obtained with 12 plants per m^2, and its difference was just significant as compared with 10 plants per m^2. The highest and the lowest sugar content (SC) in 2009 were related to 10 plants per m^2 and 12 plants per m^2, respectively, but all differences among treatments were not significant. Sugar content increases potentially with total and root dry matter during most of crop growth cycle (Parsa et al., 2007). Puscas et al. (2008) concluded that the highest production for beet sugar was obtained with the density of 80000 plants per ha. The maximum potassium and sodium content in 2009 was obtained with 12 plants per m^2, but all differences among treatments in these two experimental characteristics were not significant. Cooke and Scott (1993) stated that the impurities of juice extract had mostly positive correlation with each other and a negative correlation with white sugar percentage. Jadidi et al. (2010) in their experiment reported that the maximum potassium and sodium content were 5.86 and 2.57, respectively. The maximum and the minimum Amino-N content of root in 2009 were found at 8 plants per m^2 and 12 plants per m^2, respectively. The difference between 8 plants per m^2 and both 10 and 12 plants per m^2 was significant. However, there was no significant difference in this trait between 10 and 12 plants per m^2 (Table 2). Determination of optimal plant densities and their effects on yield and quality must play an important role in cases of poor crop establishment of sugar beet (Smit et al., 1996; Baghdadi et al., 2012), and also for designing a suitable management system (Shayanfar et al., 2011).

In 2008, the influence of planting date on the maximum solar radiation absorption at the time of maximum light interception was not significant; although, its value was higher for plantation on 5th May, no significant difference was found between treatments (Table 3).

Table 3. Mean comparison for solar radiation absorption in the time of maximum solar radiation absorption and final harvesting

Treatment	2008			2009	
	Time of sampling (days after germination)	The time of maximum light interception	The time of final harvesting	The time of maximum light interception	The time of final harvesting
	First planting date	110	180	115	190
	Second planting date	74	144	79	154
Planting date:					
5th May		92.39a	72.92a	96.00a	69.31a
10th June		76.59a	63.84b	89.60b	67.80a
The distance between rows (cm):					
50		87.90a	71.71a	95.02a	73.20a
60		81.07b	65.05b	90.58b	63.91b
Plant density (plants per m^2):					
8		78.16b	61.76b	88.21b	58.61c
10		86.56a	70.60a	94.52a	69.46b
12		88.74a	72.78a	95.67a	77.59a

Common letters within each column do not differ significantly.

In contrast, in 2009, the differences between treatments were significant, and the highest solar radiation absorption at the time of maximum light interception was obtained for 5th May planting. Crop yield is highly correlated with the amount of solar radiation intercepted by the canopy during crop growth cycle (Shayanfar et al., 2011). The difference in maximum solar radiation absorption between 5th May and 10th June was significant. In contrast, in 2009, there was no significant difference between treatments, in spite the fact that, plantation of 5th May obtained the maximum solar radiation absorption value for time of final harvesting. Sowing times affect plant canopy development (growth, number, size and age of green leaves) in relation to global and intercepted solar radiation throughout the crop season (Rinaldi and Vonella, 2006). In both 2008 and 2009, the values for the highest solar radiation absorption at the time of maximum light interception were significantly higher for 50 cm distance between rows in comparison with 60 cm. Like the previous experimental characteristic, the value for the maximum solar radiation absorption at the time of final harvesting for 50 cm distance was markedly higher than for 60 cm, not only in 2008, but also 2009. The influence of plant density on the maximum solar radiation absorption at the time of maximum light interception in both 2008 and 2009 was significant. Moreover, in both years, higher values of it were obtained with 12 plants per m^2. On the one side, there were significant differences between 8 and 12 plants per m^2. On the other side, no significant difference was found between 10 and 12 plants per m^2, in both years. Pidgeon et al. (2001) noted that major advances in crop breeding, agronomy, physiology and mechanization have maximized early canopy expansion rates and hence radiation interception. The maximum solar radiation absorption at the time of final harvesting time was significantly influenced by plant density in both 2008 and 2009. In both years, the highest one was obtained with 12 plants per m^2, followed by 8 and 10 plants per m^2. In 2008, the difference between 10 and 12 plants per m^2 was not significant, however, in 2009 the difference was significant between 10 and 12 plants per m^2 (Table 3).

With 50 cm distance between rows, the highest shading percentage was obtained for 12 plants per m^2 with planting on 5th May, in 2008 and 2009. In contrast, the minimum one was obtained for 8 plants per m^2 planted on 5th May. In 2008, with 60 cm distance between rows, the maximum and the minimum shading percentage was achieved in 12 and 10 plants per m^2 planted on 5th May, respectively. However, in 2009, higher value was obtained with 10 plants per m^2 planted on 5th May than those of other treatments. On 10th May, the highest shading percentage was related to 10 plants per m^2 with 60 cm distance between rows, in 2008. Radiation can significantly limit the productivity of beet (Scott and Jaggard, 1978), which means that a high correlation exists between crop growth and the rate of radiation (Rinaldi and Vonella, 2006). In 2009, with 60 cm distance between rows, the highest value of shading percentage was obtained with 12 plants per m^2 planted on 10th May in comparison with those of other treatments (Table 4).

Table 4. Mean of shading percentage in the time of maximum solar radiation absorption

Planting date	Rows distance (cm)	Plant density (plants per m^2)	2008	2009
			Shading percentage	Shading percentage
5th May	50	8	89.22	92.66
5th May	50	10	93.98	95.28
5th May	50	12	95.73	96.07
5th May	60	8	79.20	80.03
5th May	60	10	81.33	91.94
5th May	60	12	83.05	91.37
10th June	50	8	73.18	73.50
10th June	50	10	74.18	77.60
10th June	50	12	70.57	80.97
10th June	60	8	66.41	63.04
10th June	60	10	69.86	70.23
10th June	60	12	69.41	71.75

Planting date had significant effect on maximum LAI in both 2008 and 2009. In both years, the highest values were obtained for plantation on 5th May, which had significant differences with plantation on 10th May (Table 5). Total dry matter was also significantly influenced by planting date in both 2008 and 2009. Planting on 5th May produced the highest value in both years. The sustainability of cropping systems can be achieved through the choice of certain field crops and new agronomic methods, which are better able than others to exploit natural resources, like solar radiation (Rinaldi and Vonella, 2006). The distance between rows had significant influence on maximum LAI in both 2008 and 2009, when highest value was obtained for 50 cm distance between rows. Both maximum LAI and total dry matter not only in 2008, but also in 2009 were significantly affected by distance between rows. Indeed, the highest value for both maximum LAI and total dry matter in both years were obtained for 50 cm, which had significant differences from 60 cm distance between rows. The efficiency of radiation interception and absorption is dependent on leaf area index (Rinaldi and Vonella, 2006). Plant density effects on maximum LAI and total dry matter were significant in both 2008 and 2009. In 2008, the highest and the lowest maximum LAI were related to 12 and 8 plants per m^2, respectively, which had significant difference with each other, however, no significant difference was found between 10 and 12 plants per m^2. The increase in LAI with plant density could also explain increasing yield with plant density (Bavec and Bavec, 2002). In 2009, higher value of maximum LAI was obtained for 12 plants per m^2, as compared to those of other treatments. Furthermore, all differences among treatments were significant. Plant density governs the components of yield, and also is one of the major factors that determine the ability of crops to capture resources (Lloveras et al., 2004). In 2008 and 2009, higher total dry matter was obtained for 12 plants per m^2 than the one obtained in other treatments. Although, in both years, significant differences were found between 8 plants per m^2 and other treatments, the differences between 10 and 12 plants per m^2 were not significant (Table 5). In suitable plant density, plants are completely adapted in environmental conditions such as water, air, light, soil, and inter- or intra specific condition (Draycott and Durrant, 1974; Soleymani et al., 2011).

Table 5. Mean comparison for maximum LAI and final dry matter yield

Treatment	2008		2009	
	Maximum LAI (m^2/m^2)	Total dry matter (g/m^2)	Maximum LAI (m^2/m^2)	Total dry matter (g/m^2)
Planting date:				
5th May	3.80a	1817.3a	4.43a	2414.4a
10th June	2.32b	1467.2b	3.41b	1621.2b
The distance between rows (cm):				
50	3.33a	1803.2a	4.32a	2149.9a
60	2.78b	1481.2b	3.52b	1885.6b
Plant density (plants per m^2):				
8	2.51b	1465.4b	3.27c	1859.3b
10	3.22a	1724.4a	4.05b	2071.7a
12	3.44a	1737.1a	4.44a	2122.3a

Common letters within each column do not differ significantly.

CONCLUSIONS

A basic goal of agriculture is to enhance agricultural production and ensure a sufficient supply of food, through the intensification of farming activities (Kalaitzidis et al., 2011). Sugar beet is the second important sugar crop after sugar cane; it produces about 30% of total world production and is readily adaptable to different environmental factors including climate (Jafari et al., 2006; Sohrabi and Heidari, 2008; Abbassi and Rashidi, 2010; Sadre et al., 2012; Soleymani et al., 2012). In both 2008 and 2009, the highest values of root yield were obtained by planting on 5th May. There were not significant differences in sugar content between two planting dates in 2008 and 2009. The value of potassium, sodium and amino-N content of root were lower with planting on 5th May than those of 10th June planting, in 2008 and 2009. The maximum root yield and sugar content were obtained at 50 cm distance between rows. The highest sugar content and appropriate root yield were achieved with 10 plants per m^2 in both 2008 and 2009. Plant density must be chosen related to its influence on the productivity attributes and finally on production (Hills, 1973; Smit et al., 1996; Puscas et al., 2008; Baghdadi et al., 2012). Higher values for solar radiation absorption, at the time of maximum light interception and the time of final harvesting, both in 2008 and 2009, were found with planting on 5th May at 50 cm distance between rows. Although, 12 plants per m^2 obtained the highest maximum solar radiation absorption at time of maximum light interception and the highest solar radiation absorption at time of final harvesting in both 2008 and 2009, the differences from 10 plants per m^2 were not significant. The sustainability of cropping systems can be achieved through the choice of new agronomic methods, which are better able than others to exploit natural resources, like solar radiation. Planting on 5th May at 50 cm distance between rows produced the highest value for maximum LAI and total dry matter not only in 2008, but also in 2009. Appropriate LAI and total dry matter in these two years were also related to 10 plants per m^2. It is necessary to perform more experiments in different years and locations with various treatments to obtain the exact yield and yield components of sugar beet. Planting at 50 cm distance between rows with 10 plants per m^2 is suggested for farmer fields under the condition similar to the present study.

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