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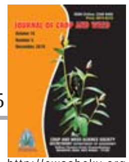

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Effect of planting techniques, plant densities and different depths of sowing on production economics, water and sugar productivity of sugarbeet

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ABSTRACT

An experiment was conducted in Factorial RBD with three replications during rabi season, 2013-14 and 2014-15 at the Punjab Agricultural University, Ludhiana to evaluate the effect of planting techniques, plant densities and depths of sowing on production economics, water productivity and sugar productivity of sugarbeet under subtropical conditions. Nine planting techniques corresponding to plant population and two sowing depths were evaluated. A monogerm SZ-35 cultivar of sugarbeet was used in the study. In flat sown treatments, row to row spacing was 50 cm, whereas it was 60 cm under ridge sowing. Under bed planting, the beds are 67.5 cm wide with 37.5 cm top of bed. Two depths of sowing i.e 2-3 cm and 4-5 cm were evaluated in the study. The depths of post sowing irrigations were kept 7.5 cm under flat sown, 6 cm under ridge sown and 5 cm under bed sown crop. All other agronomic practices were kept uniform in all treatments. Planting two rows on bed with planting density of 1.23 lakh plants ha^{-1} recorded maximum production efficiency (2.98 q ha^{-1}day^{-1}and 2.58 q ha^{-1} day^{-1}), monetary efficiency (Rs 314 ha^{-1}day^{-1} and Rs 208 ha^{-1}day^{-1}) and sugar productivity (9.65 t ha^{-1} and 8.62 t ha^{-1}), which was at par with planting two rows on both side of ridge with planting density of 1.23 lakh plants ha^{-1} and significantly higher than rest of the treatment. Significantly higher water productivity (11.03 kg m^{-3}and 10.63 kg m^{-3}) was also recorded under same treatment. Sowing depth of 2-3 cm recorded higher production efficiency, monetary efficiency, water and sugar productivity than sowing depth of 4-5 cm in both the years, however, no significant difference was recorded between the depths of sowing. So, to realize maximum production efficiency, monetary efficiency, water productivity and sugar productivity from sugarbeet cultivation under subtropical conditions, planting sugarbeet as two rows on beds with planting density 1.23 lakh plants ha^{-1} and planting depth 2-3 cm is most viable option.

Keywords: Planting techniques, sugarbeet, sugar productivity and water productivity

Sugarbeet (*Beta vulgaris* L.) is second most important sugar crop in the world after sugarcane. It is a crop of temperate region but now its cultivation is also started successfully in subtropical countries during winter season (Brar *et al.*, 2015). In Northern India, it can be grown in plains during *rabi* season (Pathak *et al.*, 2014). It is a short duration crop as compare to sugarcane. It is having growth period of about half of sugarcane, which leads to its higher sugar and water productivity per unit time than sugarcane. In Northern India, scarcity of irrigation water resulting in decrease in area under sugarcane year after year. However, sugarbeet requires less water as compare to sugarcane and it can be good substitute for sugarcane crop. To produce of one kilogram of sugar from sugarbeet 1.4 m^3 of water is required as compare to 4.0 m^3 water required for the production of same quantity of sugar from sugarcane (Sohier and Ouda, 2001). As an alternate crop of sugarcane, sugarbeet has the potential to play important role in decreasing cost of production. Sugarbeet has the ability to sustain higher crop productivity under water stress and saline condition because of its short-duration, higher sugar content, sugar recovery, high purity, ability to tolerate drought and salinity (Shrivastava, 2006). Being a halophyte crop, it has the potential to bring large area under cultivation, which is affected by salinity (Pathak *et al*., 2014). Increase in area under sugarbeet cultivation also results in increasing the operation period of the sugar mill from four months to six months in a year.

Sugarbeet yield and quality are affected by environmental and agronomic factors. To accumulate sucrose, it also depends upon environmental factors such as light, temperature, moisture and day length, which determine the type of growth and the amount of sugar stored in the root (Petkeviciene, 2009). It requires less water than sugarcane, (Lukovic *et al.*, 2016).In order to get maximum returns from sugarbeet in sub-tropical conditions of Northern India, there is need to adjust agronomic practices to provide optimum environment for growth and development of the crop.

Planting method, density and sowing depth are the main factors, which influenced the water requirement and performance of the crop. Ahmad *et al*. (2007)

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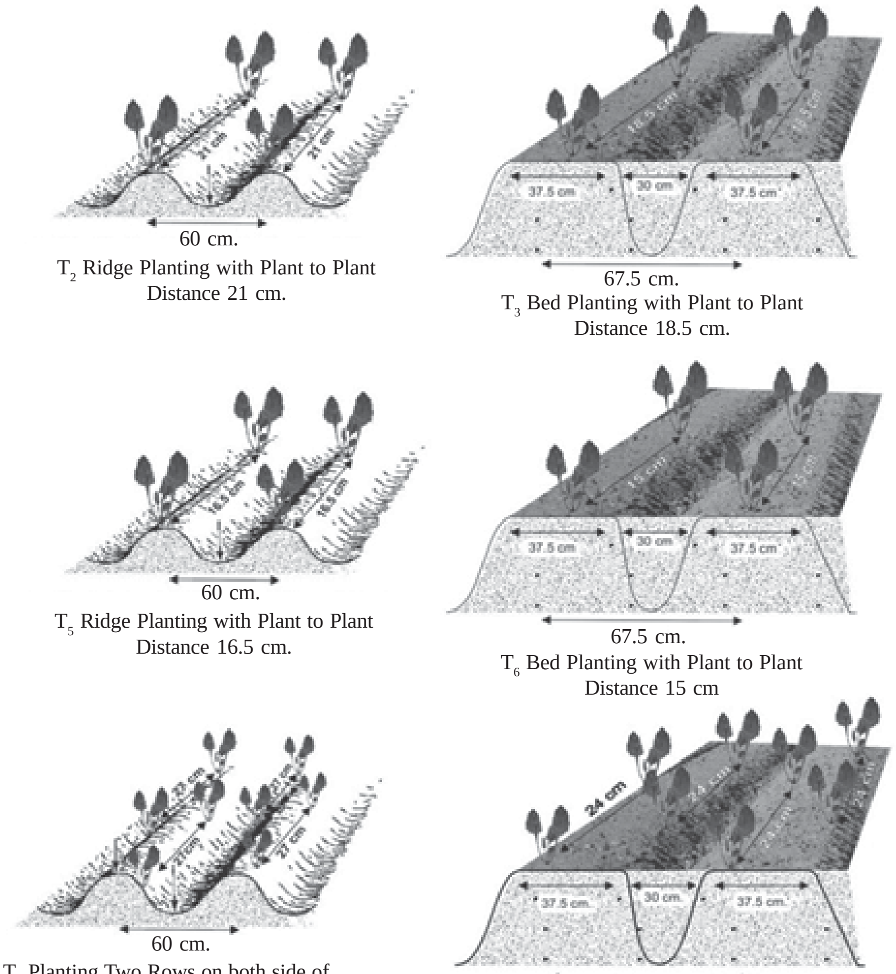

T_2 Ridge Planting with Plant to Plant Distance 21 cm.

T_3 Bed Planting with Plant to Plant Distance 18.5 cm.

T_5 Ridge Planting with Plant to Plant Distance 16.5 cm.

T_6 Bed Planting with Plant to Plant Distance 15 cm

T_8 Planting Two Rows on both side of Ridge with Plant to Plant Distance 27 cm.

T_9 Planting two rows on Bed with Plant to Plant Distance 24 cm.

Fig. 1 : Planting methods

reported significant effect of planting methods on the root and foliage weights, root/top ratio, root and top yields ha^{-1} of sugarbeet. Planting density is one of the major factors, which determining the total yield of roots in terms of quality and quantity per unit area. Crop sown at optimum plant density can utilise sufficient quantity of water and light, which results in increase in efficiency of photosynthesis, increase in dry matter accumulation in the roots and higher productivity (Freckleton *et al.*, 1999).Crop emergence is also an important factor for determining the yield of sugarbeet as emergence is mostly affected by physical impedance from the soil. Thus, proper depth of sowing facilitates speedy emergence of seedlings.

So far limited research work has been conducted to assess the effect of planting methods, plant density and depth of sowing on yield performance per unit area and time, economic returns, water and sugar productivity of sugarbeet under subtropical conditions. For harnessing maximum benefit from sugarbeet, agronomic practices which have greater influence on yield and quality, need to be adjusted to create favourable condition for growth and development of sugarbeet. While considering the above objective, the present investigation was undertaken to optimise planting technique, plant density and depth of sowing for sugarbeet cultivation under subtropical conditions.

MATERIALS AND METHODS

The research work was conducted at the research farm of the Department of Agronomy, Punjab Agricultural University, Ludhiana during *rabi* season of 2013-14 and 2014-15. The soil of experimental site was loamy sand in texture with soil pH 7.4, EC 0.15 m mhos/ cm, low in organic carbon (0.33 %), low in available nitrogen (216 kg ha^{-1}), high in available phosphorus (24.25 kg ha^{-1}) and available potash (202.5 kg ha^{-1}).

The experiment was laid out in factorial RBD with three replications. It consisted ofnine treatment combinations of planting techniques corresponding to plant densities (Fig. 1) *i.e.* T_1- Flat sowing with planting density 0.80 lakh plants ha^{-1}, T_2- Planting on the ridge with planting density 0.80 lakh plants ha^{-1}, T_3- Planting on the bed with planting density 0.80 lakh plants ha^{-1}, T_4- Flat sowing with planting density 1.0 lakh plants ha^{-1}, T_5- Planting on the ridge with planting density 1.0 lakh plants ha^{-1}, T_6- Planting on the bed with planting density 1.0 lakh plants ha^{-1}, T_7- Flat sowing with planting density 1.23 lakh plants ha^{-1}, T_8- Planting two rows on both side of ridge with planting density 1.23 lakh plants ha^{-1}, T_9- Planting two rows on bed with planting density 1.23 lakh plants ha^{-1} and two depth of sowingi.e D_1-2-3 cm, D_2- 3-4 cm,altogether comprising eighteen treatment combinations.

A monogerm cultivar of sugarbeet SZ-35 was used in this study and seed was sown by dibbling one seed hill^{-1}. Crop was sown on20th November, 2013 and on 15thNovember, 2014. Row to row spacing was maintained 50 cm under flat and 60 cm under ridge sowing. In bed planting, the beds were laid out 67.5 cm wide with 37.5 cm top of bed. In planting two rows on both sides of ridge and planting two rows on bed techniques, the seeds were sown in diagonal fashion in two rows on the both side of the ridges and on the beds. In the experiment, nitrogen was applied at the rate of 125 kg ha^{-1} in three splits *i.e.* 62 as basal followed by 31.5 kg at 60 and 75 days after sowing (DAS) in the form of urea. 62.5 kg $P_2O_5$and 30 kg K_2O per hectare were applied as basal in the in the form of single super phosphate (16% P_2O_5) and muriate of potash (60 % K_2O), respectively. The weeds in experiment field were controlled by hand-hoeing, implemented at 55DAS and 110 DAS. The post sowing irrigations were applied with the depth of irrigation of 7.5 , 6 and 5 cm for flat, ridge and bed planting techniques, respectively. These depths of irrigation were measured with the help of Parshall flume. Total ten irrigations were applied during first year and nine irrigations were applied during second year of experimentation. Total depth of irrigation water applied under flat was 75 cm and 67.5 cm, ridge planting was 60 cm and 54 cm and bed planting was 50 cm and 45 cm during 2013-014 and 2014-15, respectively. All other agronomic practices were kept uniform in all the treatments. The crop was harvested at185 DAS during the month of May2014 and 2015.

Harvesting was done manually.Weight of roots and tops in each plot were taken in kg and the data were converted to t ha^{-1}.

Production efficiency (PE) of sugarbeet (q ha^{-1} day^{-1}) was computed by the following formula (Bai *et al.*, 2016):

$$PE = \frac{\text{Total economic yield of sugarbeet(q ha}^{-1}\text{)}}{\text{No. of days taken by crop from sowing to harvesting}}$$

Harvest index of the crop was calculated using following expression (Donald, 1962):

$$\text{Harvest Index} = \frac{\text{Root yield(t ha}^{-1}\text{)}}{\text{Biological yield(t ha}^{-1}\text{)}}$$

For economic analysis of the experiment,prevailing prices of inputs used and selling price of sugarbeet at that time were taken into consideration. Selling price of sugarbeet was Rs 195 q^{-1} during 2013-14 and Rs 190 q^{-1} during 2014-15. The various overhead costs, such as that on seedbed preparation, input costs, plant protection, harvesting, transportation cost have been taken into account. The production cost (Rs. ha^{-1}) for raising sugarbeet during 2013-14 and 2014-15, assuming owned land, was Rs.49164/- and Rs.52447/-respectively.

Monetary efficiency (Rs ha^{-1} day^{-1}) was calculated by using following formula (Bai e*t al.*, 2016):

$$ME = \frac{\text{Total net returns of sugarbeet(Rs ha}^{-1}\text{)}}{\text{No. of days taken by crop from sowing to harvesting}}$$

Water productivitywas calculated by the following (Saini and Brar, 2018) :

$$\text{Water productivity(kg m}^{-3}\text{)} = \frac{\text{Root yield(kg ha}^{-1}\text{)}}{\text{Irrigation water applied(m}^3\text{ha}^{-1}\text{)}}$$

Sucrose content (%): It was calculated polarimetrically on lead acetate extract of fresh macerated root.

Sugar productivity (t ha^{-1})**:** Root yield (t ha^{-1}) × Sucrose (%)/100

The data were statistically analyzed by STAR 2.0.1 (IRRI) software according to technique of analysis of variance (ANOVA) for RBD factorial experiment and multiple comparison within treatments were done through least significance difference (LSD <0.05).

RESULTS AND DISCUSSION

The perusal of data in the table 1 shows that Planting two rows on bed with planting density 1.23 lakh plants ha^{-1} (T_9) gave highest production efficiency *i.e.* 2.98 and 2.58 q ha^{-1}day^{-1}during 2013-14 and 2014-15 respectively, which was at par with T_8 (Planting two rows on both side of ridge with planting density 1.23 lakh plants ha^{-1}) and significantly higher than rest of treatments. Decrease in yield at higher plant population due to increase in interplant competition was recorded by Khaiti (2012). But in this study, it was observed that at higher planting density *i.e.* 1.23 lakh plants ha^{-1}, by planting two rows

Table 1: Yield attributes and root yield of sugarbeet under different treatments

Treatments	Root yield (t ha^{-1})		Biological yield (t ha^{-1})		Production efficiency (q ha^{-1}day^{-1})		Harvest index	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Planting methods × density								
T_1	36.42	32.70	53.59	48.55	1.98	1.77	0.68	0.68
T_2	32.56	28.65	48.35	42.36	1.75	1.55	0.68	0.68
T_3	37.55	32.67	53.28	47.59	2.02	1.77	0.70	0.68
T_4	37.00	33.38	53.66	48.74	2.00	1.78	0.69	0.69
T_5	39.43	35.09	57.36	51.91	2.15	1.90	0.69	0.67
T_6	40.18	34.96	57.78	51.34	2.18	1.88	0.69	0.68
T_7	40.25	36.22	58.69	53.83	2.17	1.95	0.68	0.67
T_8	50.22	44.19	70.96	64.69	2.72	2.37	0.70	0.68
T_9	55.00	47.85	77.69	69.70	2.98	2.58	0.71	0.69
SEm (±)	**2.21**	**1.70**	**3.73**	**1.84**	**0.16**	**0.09**	**0.01**	**0.01**
LSD (0.05)	**8.29**	**6.32**	**10.77**	**5.32**	**0.45**	**0.26**	**NA**	**NA**
Depth of Sowing								
D_1	41.43	36.71	59.50	53.89	2.24	1.98	0.69	0.68
D_2	40.48	35.67	58.58	52.59	2.19	1.92	0.69	0.68
SEm (±)	1.04	0.80	1.76	0.87	0.07	0.04	0.01	0.01
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Interaction								
SEm (±)	**3.12**	**2.40**	**5.28**	**2.61**	**0.22**	**0.13**	**0.01**	**0.02**
LSD (0.05) (PM × D × Depth)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

on bed or planting two rows on both sides of ridge, the plant to plant distance was remained 27 cm in ridge and 24 cm in bed planted crop (Fig. 1) due to sowing of seed alternately *i.e*. in between the gap of two plants sown in opposite row. Whereas, under flat sowing at planting density 1.23 lakh plants ha^{-1}, plant to plant distance was16 cm. So by planting two rows on bed or planting two rows on both sides of ridge , we were able to accommodate more number of plants per unit area as compare to planting single row on ridge or bed, without or with little increase in interplant competition for water, solar radiations and nutrients. This intensification to the optimum density resulted in mature plants that are sufficiently crowded to efficiently use resources such as water, nutrients and maximum leaf light interception, which leads to higher photosynthesis and in turn higher root yield per ha in these treatments. As the value of root parameters at higher planting density was lower, but increase in number of plants per unit are acompensate the loss and leads to higher root and top yield per unit area (Saini and Brar, 2017).

Effect of planting methods × density on harvest index was reported non-significant (Table 1). The harvest index varied from 0.68 to 0.71 during 2013-14 and 0.67 to 0.69 during 2014-15 in different treatments.

Under depth of sowing, higher production efficiency was recorded under treatment D1 (sowing depth 2-3 cm) as compare to D2 (sowing depth 4-5 cm) during both the years of study (Table 1), but the difference was statistically non-significant. Khan (2013) also recommended 1.00 to 1.25 inch as optimum depth for sowing sugarbeet. Significantly higher emergence was recorded at sowing depth 2-3 cm as compare to depth of 4-5 cm (Saini and Brar, 2017). The interaction effect of planting methods × density and sowing depth on production efficiency and harvest index was also non significant.

Observations on economics of sugarbeet cultivation is given in the table- 2 shows that, Planting two rows on bed with planting density 1.23 lakh plants ha^{-1} (T_9) shows maximum gross return (Rs. 107248 ha^{-1}and Rs. 90921 ha^{-1}), net return (Rs. 58084 ha^{-1}and Rs 38474 ha^{-1}), monetary efficiency (Rs. 314 ha^{-1} day^{-1}and Rs 208 ha^{-1} day^{-1}) and BC ratio (2.18 and 1.73) during 2013-14 and 2014-15, which was statistically similar with T_8 and significantly higher than rest of the treatments. As the root yield was highest under treatment T_9 (Table 3), which results in higher economic return and BC ratio. Brar and Kumar (2019) also reported good economic

Table 2: Economics of sugarbeet cultivation

Treatments	Gross return (Rs ha^{-1})		Net return (Rs ha^{-1})		Monetary efficiency (Rs ha^{-1}day^{-1})		B:C	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Planting methods × density								
T_1	71013	62124	21849	9677	118	52	1.45	1.18
T_2	63490	54429	14326	1982	77	11	1.29	1.04
T_3	73211	62064	24047	9617	130	52	1.49	1.18
T_4	72150	63428	22986	10981	124	59	1.47	1.21
T_5	76886	66662	27722	14215	150	77	1.56	1.27
T_6	78349	66418	29185	13971	158	75	1.59	1.27
T_7	78488	68812	29324	16365	159	89	1.60	1.31
T_8	97925	83955	48761	31508	264	170	1.99	1.60
T_9	107248	90921	58084	38474	314	208	2.18	1.73
SEm (±)	**5626**	**3228**	**5626**	**3228**	**30**	**18**	**0.11**	**0.06**
LSD (0.05)	**16241**	**9317**	**16241**	**9317**	**88**	**50**	**0.33**	**0.18**
Depth of Sowing								
D_1	80793	69750	31629	17303	171	94	1.64	1.33
D_2	78931	67764	29767	15317	161	83	1.61	1.29
SEm (±)	**2652**	**1522**	**2652**	**1522**	**14**	**8**	**0.05**	**0.03**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction								
SEm (±)	**7957**	**4565**	**7957**	**4565**	**43**	**25**	**0.16**	**0.09**
LSD (0.05) (PM × D × Depth)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Notes: Cost of input factors (Rs ha^{-1} for year 2013-14 and 2014-15, respectively): Seed- 2000 and 2000; fertilizer-5637 and 5665; fungicide- 940 and 630; insecticides- 675 and 750; human labour cost- 13500 and 15400; harvesting and loading- 10000 and 10000; tractor hours- 7480 and 8470; irrigation- 850 and 878; transportation and marketing- 7000 and 7500, quarterly interest on variable cost @ 9%- 1082 and 1154.

returns from sugarbeet plant on beds at farmer's field. Economic returns were recorded numerically higher under treatment D1 (sowing depth 2-3 cm) as compare to D2 (sowing depth 4-5 cm) during both the years of study (Table 2), but the difference was statistically non-significant.

Water productivity of sugarbeet is significantly influenced by planting methods × density (Table 3). Planting two rows on bed with planting density 1.23 lakh plants ha^{-1} (T_9) reported maximum water productivity during both years of study *i.e.* 11.03 kg m^{-3} during 2013-14and 10.63 kg m^{-3} during 2014-15, which was significantly higher than all other treatments. The total amount of irrigation water applied was minimum in bed planted treatments and the root yield was maximum under treatment T_9 (planting two rows per bed with planting density 1.23 lakh plants ha^{-1}) (Table 1), which results in maximum water productivity under this treatment. Treatment T_9 showed an increase in water productivity by 32.09 % and 29.63 % as compared to T_8, 105.01 % and 96.85 % as compare to T_7, 37.36 % and 36.63 % as compare to T_6, 67.88 % and 63.04 % as compare to T_5, 123.73 % and 114.74 % as compare to T_4, 47.07 % and 46.62 % as compare to T_3, 103.13 % and 99.87 % as compare to T_2 and 126.49 % and 120.08 % as compare to T_1 during year 2013-14 and 2014-15, respectively. Saini and Brar (2018) recorded highest root yield and water productivity under planting method two rows per bed. Maximum root irrigation water use efficiency under furrow irrigated medium raised bed with two crop rows on each side of the bed was also recorded by Malik *et al*. (2018). Under depth of sowing, higher water productivity was recorded under treatment D1 (sowing depth 2-3 cm) which is at par with D2 (sowing depth 4-5 cm) during both the years of study (Table 3).

Planting methods × density however, did not influence sucrose content (Table 3), while affect sugar productivity significantly. Sugar productivity was recorded highest under treatment T_9 (Planting two rows

Table 3: Water and sugar productivity of sugarbeet under different planting methods, densities and depth of sowing

Treatments	Water productivity (kg m^{-3})		Sucrose (%)		Sugar productivity (t ha^{-1})	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
Planting methods × density						
T_1	4.87	4.83	16.95	17.383	6.17	5.68
T_2	5.43	5.32	17.25	18.050	5.62	5.19
T_3	7.50	7.25	17.42	17.750	6.51	5.79
T_4	4.93	4.95	17.55	17.983	6.47	6.00
T_5	6.57	6.52	17.28	17.717	6.82	6.23
T_6	8.03	7.78	17.90	18.333	7.17	6.42
T_7	5.38	5.40	17.00	17.333	6.83	6.28
T_8	8.35	8.20	17.05	17.717	8.52	7.85
T_9	11.03	10.63	17.55	18.017	9.65	8.62
SEm (±)	**0.47**	**0.33**	**0.35**	**0.29**	**4.6**	**3.3**
LSD (0.05)	**1.34**	**0.97**	**NS**	**NS**	**1.33**	**0.94**
Depth of sowing						
D_1	6.94	6.89	17.27	17.83	7.14	6.55
D_2	6.86	6.64	17.39	17.79	7.03	6.35
SEm (±)	**0.22**	**0.16**	**0.17**	**0.14**	**2.2**	**1.5**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Interaction						
SEm (±)	**0.66**	**0.47**	**0.50**	**0.41**	**6.5**	**4.6**
LSD (0.05) (PM × D × Depth)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

per bed with planting density 1.23 lakh plants ha^{-1})i.e. 9.65 t ha^{-1} during 2013-14 and 8.62 t ha^{-1} during 2014-15, which was statistically at par with T_8 and significantly higher than rest of treatments. As the root yield was significantly higher in these treatments (Table 1), thus results in higher sugar productivity. Treatment T_9 recorded an increase in sugar productivity by 13.26 % and 9.80 % as compare to T_8, 41.29 % and 37.26 % as compare to T_7, 34.59 % and 34.27 % as compare to T_6, 41.50 % and 38.36 % as compare to T_5, 49.15 % and 43.67 % as compare to T_4, 48.23 % and 48.88 % as compare to T_3, 71.71 % and 66.09 % as compare to T_2 and 56.40 % and 51.76 % as compare to T_1 during year 2013-14 and 2014-15 respectively. Leilah *et al*. (2005) also reported highest root and sugar yield ha^{-1} by sowing sugarbeet on both side of ridge (1.14 lakh plants ha^{-1}). Abd El-Kader (2005) reported highest root and sugar yield at planting density 56000 plants fed^{-1} as compare to 33600 plants fed^{-1}. Higher sugar yield by planting two rows on bed was also reported by Ahmad *et al*. (2010). Numerically higher sugar productivity was recorded under treatment D1 (sowing depth 2-3 cm) as compare to D2 (sowing depth 4-5 cm) during both the years of study (Table 3), but the difference was statistically non-significant.

Based on findings of present study, it is concluded that in order to get maximum production efficiency and monetary returns per unit area per unit time, water productivity and sugar productivity, planting sugarbeet as two rows on beds with planting density 1.23 lakh plants ha^{-1} and planting depth 2-3 cm, could be recommended for cultivation of sugarbeet under sub-tropical conditions.

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