Agricultural Reviews, 36 (3) 2015 : 184-197
Print ISSN:0253-1496 / Online ISSN:0976-0539

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
www.arccjournals.com

Agronomy of sugarbeet cultivation-A review

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Recieved: 17-01-2015 Accepted: 13-07-2015 DOI: 10.5958/0976-0741.2015.00022.7

ABSTRACT

Sugarbeet (*Beta vulgaris* L.), generally considered as a crop of temperate region, is spreading to subtropical countries where it can be grown successfully during winter season. It is having growth period of about half of sugarcane but productivity per unit time is higher and requires less water than sugarcane. Many environmental and agronomic factors influence sugar beet yield and quality. Thus to harness maximum benefits from sugarbeet, there is need to select the most appropriate varieties, planting time, planting methods, planting density, sowing depth, providing adequate crop nutrition and irrigation schedule. For successful production of sugarbeet under subtropical environmental conditions there is need to evaluate the performance of different varieties under subtropical Indian conditions. Planting dates has a vital role for germination, growth, yield and root quality of sugarbeet plants. Sugarbeet emerge faster when air and soil temperature ranges between 15-25°C, thus sowing date should be adjusted accordingly to coincide with given range of temperature. Performance of the crop is likely to be greatly influenced by method of sowing, plant density and depth of sowing. Better growth and higher yields can be achieved by two-rows-bed planting technique, plant density of 12 plants m^{-2} and at the 1.25 and 2.5 cm planting depths. Proper combinations of farm yard manure and inorganic fertilizers should be worked out to derive the best possible advantage of inputs. Under Punjab conditions sugarbeet responded up to 120 kg/ha of nitrogen on high organic carbon loam soil testing high in available N. Potassium fertilizers increase both leaf number and length as well as chlorophyll content. Both sources of potassium i.e. KCl and K_2SO_4 had a positive effect on sugarbeet growth and development. Crop yields can suffer from either under or over irrigation. Irrigation scheduled at 75 and 50 mm evaporation produced the highest yield of sugarbeet.

Key words: Plant density, Root yield, Sucrose, Varieties.

Sugarbeet (*Beta vulgaris* L.) belongs to the family *Chenopodiaceae*, is considered as the second important sugar crop all over the world after sugar cane (*Sacchurum officinarum* L.). It is grown in 57 countries. Top fifteen sugarbeet producing countries are Russian Federation, Ukraine, United States of America, Germany, France, Turkey, China, Poland, Egypt, United Kingdom, Iran (Islamic Republic of), Belarus, Netherlands, Italy and Belgium. Sugarbeet is mainly produced in Europe and, to a lesser extent, in Asia and North America (Kumar and Pathak, 2013).

It contributes about 21.8 % of world sugar (Anonymous 2013). It is a biennial halophytic as well as Na- salts scavenger C_3 plant containing up to 20 % sugar on fresh weight basis. The storage organ of this plant is usually called the root, of which 90% is actually root derived and the remaining 10% (the crown) is derived from the hypocotyls (Shrivastava *et al*, 2013 b).Composition wise, a freshly harvested sugarbeet root contains 75-76% water, 15-20 % sugars, 2.6% non-sugars and 4-6 % the pulp. Processing one ton of fresh sugarbeet roots yields 121 kg sugar, 38 kg molasses (containing 18.2 kg sugar, 12.1 kg impurities and 7.8 kg water) and 50 kg of pulp.

Leaves of sugarbeet exhibit rates of photosynthesis in the range of 38-52 µmol/m²/second, chlorophyll contents 1.20-1.75 mg/g and carotenoid contents 3.6 to 7.76 mg/g fresh weight of the leaf. Biochemically, sugarbeet is a C_3 plant with RuBP Carboxylase as carboxylating enzyme with phosphoglyceraldehyde(PGAl)/dihydroxyacetone phosphate (DHAP) as primary carboxylation products. The enzyme, Ribulose 5-Phosphate Kinase primarily regulates rates of photosynthesis. Sucrose synthesis in the leaves is primarily achieved by the activity of trans-glucosylases namely Sucrose phosphate synthetase, SPS and Sucrose synthetase. Sucrose translocates in the leaves through a symplastic pathway, however, in young and mature storage roots, it is by the apoplastic pathway. Sucrose is stored in vacuoles by an active uptake process and follows an ion co-transport mechanism.

With respect to its life cycle, sugarbeet is a biennial plant; comprising a period of vegetative growth, cold-induced

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vernalization, production of upright extended flowering stem and seed production. After vernalization, bolting occurs where the stem elongates in to a tall shoot like structure. Axillary buds in the axil of the leaves on the shoots quickly develop into inflorescence (an indeterminate raceme) on which sessile flowers are borne. It is cross pollinated crop and a humidity of 75% is important for effective pollination. Warm and dry period after the pollination (during the seed development and ripening) leads to good seed setting and production of good quality seed.

Some of the physiological criteria used in selection of sugarbeet are: High pulp content for high sugar, maintenance of green foliage cover during drought for drought tolerance, restricted chloride accumulation in shoots for salt tolerance, carbon isotope discrimination for improved water use efficiency, etc. Tropicalised sugarbeet hybrids have been selected for heat tolerance and disease (especially the ones prevalent in tropical regions) resistance from the sugarbeets growing in extreme American and European locations. These may be utilized as a valuable complimentary crop with sugarcane in tropical areas of the world (Shrivastava *et al*, 2013 a).

Sugarbeet is generally considered a crop of temperate region and for its flowering, it requires vernalization. However, its cultivation is spreading to subtropical countries where it can be grown successfully during winter season. Most of the sugarbeet is grown for commercial sugar production, though it is sometimes fed to animals including ruminants as well as pigs. Sugarbeet by-products like sugarbeet pulp and molasses are also fed to animals (Singh *et al*, 2013). Ethanol is produced from impure sugary pulp (molasses) and it also fermented to beers. The tops with 10% digestible crude protein, form low cost substitute (forage/silage) for grain in feed concentrates. The tops contain growth stimulant ‘saponin’. Leaves are rich in carotene (1.4 – 6.2%), vitamin C, E and exhibit estrogenic activity. During its first growing season, it produces a large (1–2 kg) storage root whose dry mass is 15–20% sucrose by weight.

Sugarbeet is a short duration crop, having growth period of about half of sugarcane. So its productivity per unit time is higher than sugarcane. Furthermore, sugar beet requires less water. For the production of one kilogram of sugar from sugarbeet about 1.4 m^3 water is required, whereas, for the production of same quantity of sugar from sugarcane about 4.0 m^3 water is required (Sohier and Ouda, 2001). Beet sugar is known to have demulcent and diuretic properties. Beet pulp accounts for 5 % (on dry weight basis) of total roots, which is a good source of feed (forage/silage) for livestock.

In India, sugarcane is main crop grown for processing of sugar. However, as an alternative crop sugarbeet has an important role in decreasing the production cost, reducing crop period and arresting decline in factor productivity as well as sustaining crop productivity at higher level under abiotic stresses *viz*., water and salt stresses. This is mainly because of its short-duration (6-7 months as compared to 10-12 months of sugarcane), high sugar content (15-17%), high sugar recovery (12-14%), high purity (85-90%), and ability to withstand drought and tolerant to salinity. There are differences in sugar and sugar-products derived from sugarbeet and sugarcane. Sugarbeet sugar/ sugar products are characterized by more negative values of $^{13}C/^{12}C$ ratio and absence of theanderose. A comparison of sugarcane and sugarbeet is given in Table-1

Thus sugarcane and sugarbeet, the two important sugar producing plants differ in their position in plant kingdom, process of photosynthesis, response to salinity, tissues storing sugar, process utilized for extraction of sugar, utilization of energy for their processing for sugar, mode of propagation, etc. Although they have nearly same level of sugar, sugar and sugar products from these as well as composition of their molasses in terms of carbohydrates, minerals, non sugars and presence of vitamins.

As such, sugarbeet has good prospects for bridging the gap between present sugar production and anticipated national sugar requirement. In addition to sugar, sugarbeet provides valuable by products like green beet tops and beet molasses which are of value as cattle feed and in fermentation industry. Because of its high chemical quality, beet molasses is a priced item with potentialities for export. In India, approx. 7 million ha area is under saline and alkali range and productivity of these soils are very low as compared to normal soils. Sugarbeet has potential to bring prosperity in these areas. In areas with shortage of water, sugarbeet has the potential to yield reasonably well with much less irrigation required than sugarcane. Hence, sugarbeet is capable of occupying an important place in the sugar economy of the country.

Tropical sugarbeet is yet to be produced on commercial scale in India and it is still considered to be toddling baby in the ethanol industry. Although, few industries are claiming to be using sugarbeet as feed stock for ethanol production, its growth has not reached the level expected. Systematic research on sugarbeet has established that the crop can be grown successfully in India as a winter crop. The sugarbeet growing was found to be profitable compared to the existing cropping systems in the post rainy season in Rajasthan, Punjab, Haryana, Maharashtra and North Karnataka (Kulkarni *et al*, 2013). Farmers are willing to experiment new crop options looking to the profitability of the crop especially in sugarcane growing areas and saline affected areas. For farmers, sugarbeet is important for three main reasons. First, it is a dependable cash crop; second, it ameliorates salt affected soils with promoting soil fertility through sound farming practices and third, the by-products

TABLE-1: Comparison of sugarcane and sugarbeet

Characteristic	Sugarcane	Sugarbeet
Contribution to world sugar production	78.5%	21.5%
Cotyledonous nature of the plant	A monocotyledonous plant	A dicotyledonous plant
Crop duration	10 - 18 months	6-7 months
Photosynthetic characteristics	A C_4 photosynthesizing plant	A C_3 photosynthesizing plant
Response to salinity	Can grow only on partially reclaimed soil	Grows well/in adapted to saline soils
Organ and tissues storing sugar	Parenchymatous cells in the stalk (in the vacuoles and cytoplasm)	Parenchymatous cells in the concentric rings in the roots
Sucrose content in juice	15-20%	15-20%
Process for extraction of sugar (in juice)	Shredding and application of pressure	Slicing and diffusion
Method of propagation	Vegetative, by planting, cuttings with 1,2 or 3 buds or even the whole cane	By true seed
Uniqueness of sugar and sugar products:		
(a) Ratio of $^{13}C/^{12}C$(in sucrose)	Less negative values	More negative values
(b) Theanderose (in sugar and sugar products)	Present (passes through crystallization process)	Absent
Source of energy for processing (for sugar)	Bagasse, a by-product of milling sugarcane is used as fuel	Has to be provided exogenously (as coal or electricity)
Molasses characteristics		
(a) Carbohydrates	Contains relatively less of sucrose (32%), more of reducing sugars (12-30%) and no raffinose .	Contains relatively more of sucrose (63%), less of reducing sugars (1%) and also 1% raffinose.
(b) Minerals (ash)	Relatively lesser (8.0%)	Relatively higher (11.5%, with 6% K)
(c) Non sugars (including nitrogenous materials)	10.0%; betaine is absent	19.0%; contains betaine- an osmoregulant
(d) Vitamins	Biotin is present	Lacks biotin (vitamin B_7)

(Source: Shrivastava, 2006)

provide nutritious cattle feed during the hot months of the year when green fodder is not readily available.

Yield and quality of any crop is a result of complex set of interactions occurring during growth and development of crop plants as a result of genetic and environmental conditions. Many environmental and agronomic factors influence sugarbeet yield and quality. Environmental conditions namely temperature, solar radiation and sunshine hours etc. influence the plant growth and development. Crop emergence is a function of soil temperature. Sugarbeets emerge the fastest when the air and soil temperature ranges between 15–25°C (Khan, 1992; Copeland *et al.*, 2001). After emergence, the growth and development activities are largely influenced by air temperature and crop nutrition. For proper growth of the plants and sugar accumulation, an average temperature of about 20-22°C is ideal. Temperatures above 30°C retard sugar accumulation. Sugarbeet has no self regulatory mechanisms to promote sucrose accumulation but is dependent upon external stimuli from the climatic factors such as light, temperature, moisture and day length which determine to a great extent, the type of growth and the amount of sugar that gets stored in the root (Ulrich, 1952;

Petkeviciene, 2009). The sugarbeet is particularly well adapted in irrigated agriculture (Follet *et al*, 1964). Thus agronomic practices thought to great influence yield & quality and may need to be adjusted to provide suitable conditions for maximizing yield and quality of sugarbeet.

In North India, due to scarcity of irrigation water, the area under sugarcane remained stagnent year after year. However, sugarbeet requires less water and matures within 6 - 7 months and can be a good substitute of sugarcane crop. It increases the operation period of the sugar mill from four months to six months in a year and will also be the best alternative for crop diversification in North India. Thus to harness maximum benefits from sugarbeet, there is need to select the most appropriate varieties, planting time, planting methods, planting density, sowing depth, adequate crop nutrition and irrigation schedule.

Therefore this article is written to review the research work done in India and abroad w.r.t. agronomic practices for sugarbeet cultivation and to help research scientists to plan research work to standardise/recommend agronomic practices for sugarbeet in Northern India.

The review of literature pertaining to the agronomy of sugarbeet is given below under the relevant headings.

Performance of varieties: Yield, as a major economic category, is a quantitative attribute of a complex type for most cultivated species that is highly dependent on environmental factors and their interactions besides the influence of genotype. A successful production of sugar beet under subtropical environmental conditions is not possible without the use of varieties highly suitable under these conditions.

Wyse and Dexter (1971) reported significant differences among sugarbeet varieties for quality parameters. Amin *et al* (1989) at Mardan, Pakistan evaluated three varieties i.e. Kawe poly, Kawe mira, Kawe terma and reported the superiority of var. Kawe terma for root yield and sugar content. Similarly, Zahoor (2007) also reported that Kawe terma performed better than KWS 1451 variety and produced higher beet yield. Balakrishnan and Selvakumar (2008) repoted that among the sugarbeet hybrids (Cauvery, Indus and Shubhra), Cauvery performed better in terms of yield and Shubhra recorded higher brix.

Bhullar *et al* (2009) at Ludhiana reported the superiority of padosa variety of sugarbeet over H10064 as far as root yield/ha, root top ratio as well as sugar yield/ha is concerned. However, the two varieties did not differ significantly in sucrose percentage (Table 2). Refay (2010) at Saudi Arabia reported that fresh, dry root weight and quality parameters as well as chemical composition of sugarbeet roots were greater for Samo-2 as compared to those other two varieties i.e. Univers and Samo-1(Table 3). The superiority of Samo-2 variety may be attributed to its genetic made up.

Ahmad *et al* (2012) at Islamabad evaluated eleven sugarbeet varieties and the results envisaged that SD-PAK09/07 attained the highest sugar yield (9.35 t/ha) with highest sugar contents (12.60%) and beet root yield (74.2 t/ha) followed by California and Magnolia with sugar yield 7.08 and 6.99 t/ha, respectively. They reported non significant difference among varieties for leaf weight, beet root yield and root size. Similarly, Radivojevic *et al* (2013) in Serbia studied the biological and technological characteristics of 17 commonly grown commercial sugarbeet varieties and reported that the highest yield (106.63 t/ha) was recorded for the variety Marcus and the variety Esprit performed best sugar yielding (16.75%). The best performing variety was Tibor with mean granulated sugar content of 15.717 t/ha.

Planting time: Planting dates means the effect of all environmental conditions on growth and yield of crops, which differ widely from one region to another. It has a vital role for germination, growth, yield and root quality of sugar beet plants. For most plants, phenological development is

TABLE 2: Evaluation of root yield, top yield, root top ratio, sucrose and sugar yield of sugarbeet under different varieties.

Variety	Root yield (t/ha)		Top yield (t/ha)		Root top ratio		Sucrose (%)		Sugar yield (t/ha)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
H10064	61.2	70.2	28.2	42.5	2.17	1.65	14.91	14.00	61.2	70.2
Posada	78.9	90.3	32.7	39.6	2.41	2.28	15.00	13.94	78.9	90.3
CD(P=0.05)	2.5	9.2	3.2	NS	NS	0.25	NS	NS	2.5	9.2

(Bhullar et al, 2009)

TABLE 3: Sugarbeet yield and yield component characters as affected by different varieties

Variety	Actual no. of roots/ha	Escape percentage (%)	Root fresh yield (ton/ha)	Root dry weight (ton/ha)	TSS (%)	Purity (%)	Sucrose (%)	Sugar yield (ton/ha)
Univers	68575	16.88	104.87	18.60	18.13	89.93	16.52	17.04
Samo-1	68791	16.62	109.11	18.76	18.57	86.73	16.37	17.55
Samo-2	72742	11.82	119.63	20.62	19.91	90.00	17.33	19.20
LSD at 0.05 level	—	8.12	NS	—	NS	NS	NS	—

(Refay, 2010)

strongly related to the accumulation of heat or temperature units above a threshold or base temperature below which little growth occur. This lower threshold temperature varies with plant species (Ash, 1995; Bellin *et al*, 2007). Sugarbeet emerge at faster when the soil moisture in the seedbed is 20-23% and air and soil temperature ranges between 15-25°C (Khan, 1992; Copeland *et al*, 2001; Sroller and Svachula, 1990; Spaar *et al*, 2004)

Early planting seems to be provide more time for vegetative growth before onset of winter, which checks the growth in favour of sugar accumulation in roots (Metcalfe and Elkins, 1980). Amin *et al* (1989) at Mardan, Pakistan observed non significant differences between 1st and 15th October sown crop w.r.t. yield and quality parameters. Further delay in sowing of crop resulted in reduced yield and quality of sugarbeet. Campbell and Enz (1991) studied the temperature effects on sugarbeet seedling emergence. The experiments were conducted in the laboratory on a thermogradient plate at temperature between 10 and 25 °C. Percent emergence 14 days after planting reached a maximum and appeared to level off at 22 °C. Similarly, EL-Kassaby and Leilah (1992) also observed that sowing sugar beet during October recorded the highest yield components and root, top as well as sugar yields as compared to the November sown crop under the climatic conditions of Egypt. However, Leilah and Nasr (1992) at Egypt reported that early sowing on 15th September recorded the highest root yield but the highest mean of sugar yield was obtained from sowing sugarbeet on 15th Oct. Ghonema (1998) concluded that planting sugar beet during Oct. produced the maximum leaf area index Index (LAI), root length and diameter, root and foliage fresh weights, sucrose and purity percentages as well as root and sugar yields as compared with planting during September or November under Egyptian conditions. Similarly, Abd EL-Gawad *et al*. (2000) at Egypt also found that early planting dates (October) produced thicker, heaviest sugar beet root/plant and top yield per plant as well as sugar yield. However, planting sugar beet on 1st Nov. was more favorable for emergence per cent and plant stand at harvest. Leilah, *et al* (2005) at Egypt reported that sowing sugar beets on 1st October resulted in significant increases in length, diameter and fresh weight of roots, foliage fresh weight, root/top ratio as well as root, top and sugar yields ha^{-1}. Meanwhile, the highest TSS, sucrose and purity percentages were found with planting sugar beets on 1st September. They attributed the increase in root yield with first October planting to the good weather conditions that promoted photosynthesis and improved growth of sugar beet and hence increase root yield.

Bhullar *et al* (2009) at Ludhiana observed non significant differences between September 25 and October 10 sown crop and recorded significantly higher single root weight and sugar yield/ha as compared to October 25 sown crop. Delay in planting from September 25 to October 10, the average root yield was reduced only by 0.6 per cent, while substantial reduction of 19.4 percent was observed with delaying planting on October 25. They further observed that the three planting dates (September 25 and October 10 and October 25) did not differ significantly in sucrose percentage (Table 4).

However, Refay (2010) at Saudi Arabia reported that in both growing seasons (2005/2006 and 2006/2007), the late planting date on 15 November produced the greater number of roots and gave the highest fresh and dry root yield per hectare as compared to early planting date at 15 September and 15 October. It may be due to restrictive effect by higher mean temperature in the stage of seed emergence and early growth stage which was 31.69°C (2005/2006) & 30.77°C (2006/2007) in month of September, 24.94°C (2005/2006) & 27.80°C (2006/2007) in month of October as compared to 21.79°C (2005/2006) & 20.10°C (2006/2007) in month of November. Sowing sugar beet on 15th November recorded higher sugar content, highest juice purity and greatest sucrose percentage as compared to both early planting.

Planting methods: Performance of the crop is likely to be greatly influenced by method of sowing. The underground part of sugarbeeet is the main economic yield component. Therefore, the soil physical conditions near the plough sole depth affect its root growth. El-Maghraby *et al* (2008) reported that sowing of sugarbeet at a laser leveled soil + deep ploughing gave a significant increase in root length, root diameter in comparison to other treatments.

There are a few investigations with respect to the effect of sowing methods on sugarbeet productivity. In this concern, Flat bed planting is a method of seed bed preparation whereby the top soil is ploughed and leveled. In ridge

TABLE 4: Single root weight, root yield, top yield, root top ratio and sucrose percent age of sugarbeet under different sowing dates

Sowing date	Single root weight (kg)		Root yield (t/ha)		Top yield (t/ha)		Root top ratio		Sucrose (%)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
September 25	0.835	1.141	73.0	88.3	24.4	41.2	2.99	2.14	15.07	14.00
October 10	0.864	1.051	77.2	83.1	36.0	46.9	2.14	1.77	14.97	14.41
October 25	0.631	0.783	59.8	69.4	31.0	35.0	1.93	1.98	14.82	14.51
CD (P=0.05)	0.160	0.250	3.1	11.3	ns	7.6	0.24	ns	ns	ns

Bhullar *et al* (2009)

method, the top soil is scrapped and concentrated in a defined region to deliberately raise the seed bed above the natural terrain, which affect the soil physical and chemical properties as well as biological activities and ultimately the crop yield. Moreover, sugarbeet is sensitive to stagnant water, which may be avoided by ridge planting.

Direct sowing of sugarbeet on ridges was more suitable than transplanting seedlings on flat bed or on ridges. The former technique led to establishment of higher number of plants and greater mean weight of individual roots. The estimated yield of white sugar was also greater from crop grown on ridges by direct seed sowing than that from the crop raised by transplanting of seedlings (Garg and Srivastava, 1985). Narang and Bains (1987) reported that seeding the sugarbeet crop on the northern side of east-west ridges gave higher root yields (45–50 t ha^{-1}) with a sucrose content of 12–14% under Punjab conditions. El-Kassaby and Leilah (1992) stated that maximum diameter and weight of roots were obtained with planting beets on one side of ridges 70 cm width, 30 cm apart. The highest yields of roots and sugar were obtained with planting beets on both sides of ridges 70 cm width, 25 cm apart. Bhullar *et al* (2009) at ludhiana concluded that sowing method (flat and ridge) did not significantly influence the root yield, top yield, root top ratio, sucrose content and sugar yield on loamy soils indicating that both methods are equally effective.

Zahoor *et al* (2007) and Ahmad *et al* (2010) while working on silt clay loam soil reported that planting methods signiûcantly affected the days to emergence, petiole length, leaf weight, number of beets harvested, speciûc leaf area, top to root ratio, top yield and root yield of crop. The experiment was designed to compare the conventional ridge planting method (ridges 50 cm apart) with new bed and flat planting techniques under different row geometries. The two sugar beet varieties, Kawe Terma and KWS 1451, were grown on ridges (40 cm, 50 cm and 60 cm apart, pair of ridges 50 cm apart and strip of three ridges 50 cm apart), beds (with two rows 80 cm apart and with three rows 120 cm apart) and flat (with two rows 50 cm apart and with three rows 50 cm apart). Results of the study showed that beet growth (mean leaf area, root diameter and root weight) and quality (sugar percentage, Brix percentage, purity percentage and sugar yield) was significantly affected by new planting methods. The mean root diameter of beets reached a maximum of 12.7 cm on beds with two rows. The mean root weight of beets increased on pair of ridges (1.54 kg) and on the recommended ridge planting method. Sugar and purity percentage of beets increased by 1.1% and 2.7%, respectively, on beds with two rows as compared to the beets planted on conventional ridge spacing. Sugar yield was equally higher on beds with two rows and the recommended ridge planting method. Meaningful comparisons were also performed among the different planting methods to evaluate the overall performance of ridge, bed and flat planting methods and results have been discussed. It can be inferred from the results that equally better growth and higher yields can be achieved by replacing the current ridge planting method with new two-rows-bed planting technique (Table 5)

Cropping density and geometry: Plant density per unit area of cultivated land is a major factor in determining the quality and quantity of the sugar roots, for instance, optimum plant density provides a larger area of nutrients which allows plant sufficient quantity of water, light and thus raises the efficiency of photosynthesis which contribute to increase the dry matter proportion in the roots and higher roots yield per unit area (Freckleton *et al*, 1999).

TABLE 5: Sugarbeet parameters as affected by different planting methods.

Planting methods	Leaf Area (cm^2)	Rootdiameter (cm)	Root wt. (kg)	Sugar %	Brix %	Purity %	Sugar yield (ton/ ha)
				Mean value			
P1	330	9.9	1.47	16.9	20.1	84.2	21.5
P2	288	12.1	1.51	17.9	20.2	88.7	25.2
P3	296	12.0	1.48	17.8	20.2	88.0	22.9
P4	297	11.9	1.49	17.8	20.2	88.1	23.5
P5	301	10.3	1.37	16.6	20.1	82.5	18.8
P6	278	12.7	1.54	18.1	19.8	91.1	25.6
P7	268	10.6	1.15	15.9	19.6	81.3	14.3
P8	274	9.7	1.02	16.0	19.3	83.0	13.2
P9	280	9.6	1.03	16.0	19.4	82.9	13.2
LSD (0.05	13.8	0.3	0.04	0.15	0.4	1.7	0.7

P1 = Ridges 60 cm apart, P2 = Ridges 50 cm apart, P3 = Ridges 40 cm apart, P4 = Pair of rows 50 cm apart and space between the rows 30 cm on ridges, P5 =Three rows strip 50 cm apart and space between the rows 35 cm on ridges, P6 = Pair of rows 50 cm on beds with bed-to-bed distance of 80 cm, P7 = Three rows strip on beds 35 cm apart with bed-to-bed distance of 120 cm, P8 = Pair of rows 50 cm apart on flat and space between the rows 30 cm, P9 = Three rows strip 50 cm apart on flat and space between the rows 35 cm.

(Ahmad *et al* ,2010)

TABLE 6: Root diameter, root fresh weight, foliage fresh weight, root/top ratio and root yield of sugarbeet under different planting densities.

Plant population	Root diameter (cm)		Root fresh weight (g)		Foliage Fresh weight (b)		Root/top ratio		Root yield (t/ha)	
	1994-95	1995-96	1994-95	1995-96	1994-95	1995-96	1994-95	1995-96	1994-95	1995-96
71400 plants/ha	8.8	9.0	502.1	531.1	291.9	315.6	1.73	1.69	35.476	37.619
142800 planta/ha	7.5	7.6	316.1	328.5	201.7	235.6	1.57	1.40	44.500	47.333
57120 planta/ha	9.3	9.5	611.3	627.4	315.3	325.8	1.95	1.94	34.690	35.619
114240 planta/ha	8.1	8.5	404.8	429.4	242.8	265.2	1.68	1.63	45.762	49.405
LSD (5%)	0.1	0.2	3.4	5.9	5.4	4.5	0.04	0.04	0.429	0.548

(Leilah *et al*, 2005)

Many researchers have been conducted to determine the optimum plant population densities for high root and sugar yield as well as the quality. Theurer and Saunders (1995) reported that smooth root sugarbeet productivity was enhanced when sugarbeets were grown at the higher density of 71,760 plants ha^{-1}(46 row width x 30 cm plant spacing).

Nassar (2001) found that sucrose content and recoverable sugar percentages were linearly decreased with the reduction in plant density. He added that root and sugar yield was maximized with plant density of 42000 plants fed^{-1}. Ramazan, (2002) reported that root yield and sugar content was highest at planting density 103600 plants ha^{-1} (i.e 45 cm × 20 cm spacing) as compared to 555000 (45 cm × 40 cm), 73000 (43 cm × 30 cm) and 88900 (45 cm × 25 cm) plants ha^{-1}. Sogut and Arioglu (2004) reported that with 45 cm inter row spacing, narrow plant spacing either 15, 20 and 25 cm (i.e. 116000, 95000 and 81000 plants ha^{-1}) produced higher root yield than 30 and 35 cm intra row spacing (i.e. 71000 and 58000 plants^{-1}). Leilah *et al*, (2005) stated that plant population markedly affected all studied characters in the two seasons. The highest root and sugar yield ha$^{\dagger 1}$ were obtained with sowing sugarbeet at planting density 114240 plants ha^{-1}(Table 6).

Ismail and Allam (2007) reported that sowing sugarbeet at 70000 and 105000 plants per hectare gave high values of yield and quality traits. Masri (2008) observed a positive effect of increasing plant density from 87500 to 100000 plants ha^{-1} as well as significant increase in sucrose content, purity, extractable sucrose and sugar yield. El-Sarag (2009) studied three plant densities (20, 28 and 46 thousand plants fed^{-1}) and reported that the highest plant density (46 000 plants fed^{-1}) recorded the maximum root fresh weight and sugar yield as compared with the lower densities.

Bhullar *et al* (2010) studied the effect of three planting densities i.e. 83,333 plants (rows spaced at 60 cm and plants at 20 cm), 1, 00,000 plants (50 cm x 20 cm) and 1, 11,111 plants (60 cm x 15 cm) ha$^{\cdot 1}$on root and sugar yield of Beet (*Beta vulgaris* L.). They observed that planting density of 1, 00,000 plants ha$^{\cdot 1}$ (50 cm x 20 cm) produced the highest beet root and sugar yield. Increasing plant density, root yield and white sugar yield increased, and most of them were achieved in 12 plants m^{-2} (Sadre *et al* 2012). Field trials have indicated that a row spacing of 50 cm and intra row spacing of 20 cm gave the highest root yield of sugarbeet. This spacing provided about 1,00,000 plants or roots ha^{-1} (Shukla and Awasthi, 2013). Hozayn *et al* (2013) reported that planting density of 36000 plant/fed (50 cm × 23.50 cm spacing) produced the highest root yield and sugar yield with good quality and less detract components.

Sowing depth: Plant emergence is influenced most by soil temperature, moisture and aeration plus physical impedance from the soil. Physical impedance relates to the distance seedlings move through the soil to emerge and the structure of the soil that the seed- ling has to move through. Therefore it is very essential to sow seeds at optimum depth so as to obtain good percentage of emergence.

Ririe and Hills (1970) reported that emergence decreased as depth of sowing increased, the highest percentage emergence was at a depth of 1 inch.

Sugarbeet emergence for the two planters and four planting depths are given in Table 7. For the Rallye 590, as planting depth increased sugarbeet emergence decreased for each increment in planting depth. Greatest emergence occurred at the 1.25 cm planting depth, 53.4% to a low of 28.5% at the 5.0 em planting depth. For the John Deere 71 planter, sugarbeet emergence was greatest and similar at the 1.25 and 2.5 em plant- ing depths. As planting depth increased to 3.75 and 5.0 cm, sugarbeet emergence decreased by 6.1 and 16.7%, respectively (Yonts *et al*, 1999).

TABLE 7: Sugarbeet emergence for John Deere 71 Flexi-planter and Stanhay Webb Rallye 590 planters at 1.25, 2.5, 3.75 and 5.0 cm depths averaged over ten sites.

Depth of Planting	Sugarbeet Final Emergence %	
	Stanhay Webb Rallye 590	John Deere 71 Flexi-planter
1.25 cm	53.4a	53.7a
2.5 cm	49.0b	53.8a
3.75 cm	41.7c	47.7b
5.0 cm	28.5d	37.1c
LSD at 5%	2.3	2.5

(Yonts *et al*, 1999)

Romaneckas *et al* (2009) studied the effect of sugarbeet sowing depth on sugarbeet seed germination, seedling establishment, yield and quality of roots. In the pot trial sugarbeet seeds were incorporated at the depth of 0-6 cm (D0-D6). The depth of 3 cm was control treatment. In the field trial seeds were sown at 2.1-3.0 cm (shallow) (control treatment), 3.1-4.0 cm (moderate) and 4.1-5.0 cm (deep) depths. According to the results of the pot experiment, there were not observed significant differences of 0-5 cm sown seed final germination and height of seedlings compared with control treatment (D3). However, deeper sown seeds emerged later. The germination of deeply (6 cm) sown seeds was 44.2% and was significantly less than sown in 0-5 cm depths. The increase of the sowing depth up to 4-6 cm had negative significant influence on mass of seedlings. In the field experiment the increase of sowing depth from 2.1 to 5.0 cm had significant negative influence on seed germination, crop density and fanging of root-crop. However, when the weather in spring was dry the highest yield of root-crop was of deeper-sown (4.1-5.0 cm) sugarbeets. The results of root-crop quality showed the influence of sowing depth increase on significantly higher amount of potassium and less amount of alpha amino nitrogen. Plant seeds 1.00 to 1.25 inches deep for maximum germination and emergence (Khan, 2013).

Effect of FYM: Soil organic matter is an important component of soil quality as it determines many soil characteristics, *viz*; natural mineralization, aggregate stability, aeration and favorable water uptake and retention properties. It is the major source of plant nutrients including phosphorus and sulphur and organic matter serves as the additional source of nutrition for most of the plants. Farm Yard Manure is the major source of organic matter in intensive cropping system. It occupies a prominent position among the bulky organic manures available in India with a potential supply of 13.39 million tones of N, P_2O_5 and K_2O per annum. Farm Yard manure plays a key role in transformation, cycling and availability of nutrient to the crop. But, in view of the slow availability of nutrients, it is expected that productivity of sugarbeet may be very low with FYM alone; therefore, proper combinations of farm yard manure and inorganic fertilizers should be worked out to derive the best possible advantage of inputs. Thus conjoint use of organic manures and chemical fertilizers can help in enhancing and maintaining stability in production with least degradation in chemical and physical properties of soil. Supplementing N through organic sources thus play a vital role in increasing the yield of any crop (Oad *et al* 2004).

Dubas *et al* (1970) concluded that the yield of roots and leaves increased with increasing rates of F.Y.M. (0- 40 t/ha) but increasing F.Y.M. levels did not influenced the sugar percentage in the roots. Maidl and Fischbeck (1989) concluded that yield of beet roots increased substantially after slurry application and could not be replaced by higher doses of mineral N fertilizer. It is concluded therefore that "special effects" of farmyard manure are involved. Balakrishnan and Selvakumar (2008) while working on clay loam soil testing low in available N reported that the higher crop biometrics of tropical sugarbeet was recorded with the integrated treatments (as application of 100 per cent, 75 per cent and 50 per cent N through Urea along with FYM and biofertilizer treatment) as compared to alone application of inorganic fertilizers. Bhullar *et al* (2010) concluded that under Punjab conditions on high OC loam soil testing high in available N, the nutritional needs of sugarbeet can be met by application of 120 kg/ha of nitrogen integrated with 20 t FYM. This treatment recoded the root yield statically at par with application of 150 and 180 kg N/ha. Similarly, differences in quality parameter were also non significant among the graded N levels and FYM integrated treatments (Table 8).

TABLE 8: Commercial sugar yield of sugarbeet under different nutrient management practices.

Treatments	Root Top ratio	Sucrose (%)	Sugar yield (t/ha)
Nitrogen 120 Kg/ha	1.80	14.34	9.75
Nitrogen 150 Kg/ha	1.70	14.10	10.19
Nitrogen 180 Kg/ha	1.52	14.25	10.36
Nitrogen 90 Kg/ha + FYM 20 t/ha	1.95	14.54	10.31
Nitrogen 120 Kg/ha + FYM 20 t/ha	1.83	14.34	10.36
CD (P=0.05)	NS	NS	0.42

Bhullar *et al* (2010)

Nitrogen requirement: Nitrogen is the most limiting nutrient in sugar beet crop (*Beta vulgaris* L.), determining white sugar production by affecting both root yield and root quality (sucrose, K, Na, α-amino N concentrations). Nitrogen fertilizer has a pronounced effect on the growth, physiological and chemical characteristics of the crop. Excessive N promotes shoot growth at the expense of root growth and sucrose accumulation (Draycott and Christenson, 2003). Some times excess N results in increase in yields of root and tops with a reduction in sucrose content of beet roots. Hence, an adequate supply of N is essential for optimum quality and yield of sugar beet. Sugarbeet quality is dependent on the sucrose content in the roots and the level of impurities that must be removed during sugar refining. Proper nitrogen fertilizer use increases both root and sugar yield. However, excessive nitrogen increases impurities and decreases sugar content. Sugar beet requires a balanced supply of minerals throughout their life cycle for maximum growth, available minerals especially nitrogen. This effect results in improving the colour and vigour of the leaf canopy, net assimilation rate and dry matter accumulation. Therefore, it is necessary to determine optimum nitrogen dose, which may produce maximum yield and best root quality parameters.

In addition to improving the colour of the leaves, nitrogen fertilizer noticeably increases their size and number. Early in the season, therefore, nitrogen increases dry matter production per unit area, mostly from leaves and petioles. Later in the season, nitrogen maintains this increase in leaf and petiole dry matter and also increases root dry-matter production. This is reflected in greater sugar production per unit area.

Dutton and Bowler (1984) found that, on average, an increase in amino nitrogen concentration in roots of 100 mg N/100g sugar decreased sugar percentage by about 0.8%. For optimum returns for grower and processor they suggested that the aim should be to set an upper limit of 150 mg N/100g sugar for mineral soils. Kemp *et al*. (1994) in New Zealand, found that highest root fresh weight was obtained when fertilized plants with 360 kg N/ha, while highest sugar yield and extractable sucrose yield was resulted by adding 180 kg N/ha. Juice purity ranged from 91 % (without nitrogen fertilizer) to 80 % (adding 360 kg N/ha). Lopez *et al*. (1994) in Spain determined that response of sugar yield to nitrogen fertilizer rates depended on the nitrogen available in the soil. They also found that optimum yield from soil testing low in available N was obtained with the application of 160 kg N/ha. Sohier and Ouda (2001) in Egypt, confirmed that root length, foliage fresh weight/plant and root sucrose content were responded to nitrogen fertilizer level up to 75 kg N/fad. While root diameter, root fresh weight/plant, TSS %, root, top and sugar yields/fad were responded up to 90 kg N/fad. On the other side, purity % was not significantly affected due to nitrogen fertilizer levels. Barik (2003) at Calicut (India) on medium organic carbon soils reported that applying nitrogen fertilizer at the rate of 150 kg N/ha recorded the highest values of the root yield and sugar yield/ha while the higher values of sugar concentration were recorded with the application of 120 kg N/ha.

Seadh (2004) while working on high organic carbon clayey soils concluded that increasing nitrogen fertilizer levels from 20 to 40, 60 and 80 kg N/fad tended to increase all growth attributes, yield and its components but conversely sucrose and purity percentages decrease with each increment in N. Seadh *et al* (2007) while working on sandy soils rated low in available N at Egypt reported that the application of nitrogen fertilizer up to 125 kg N/fed significantly increased all yield characters and its components. The significantly highest values of TSS % were obtained by application of 100 kg N/fad. However, the highest means of sucrose % and apparent purity % were resulted from application of 50 kg N/fad. Leilah, *et al* (2005) at Egypt reported that adding 250 Kg N ha^{-1} produced the highest values of length, diameter and fresh weight of roots, foliage fresh weight as well as root, top and sugar yields /ha in a newly reclaimed sandy soil. Bhullar *et al* (2010) concluded that under Punjab conditions sugarbeet responded up to 120 kg/ha of Nitrogen on high OC loam soil testing high in available N. They further reported that differences in quality parameter were non significant among the graded N levels.

Norton (2011) at USA on Garland series soils (fine-loamy over sandy or sandy-skeletal, mixed, superactive, mesic Typic Haplargids) observed that application of 26, 134 and 220 lbs/acre of N resulted in non significant differences in sugar (%) and sugar yield. However, the application of 220 lbs/acre of N recorded significantly higher root yield over the other two treatments.

Awad *et al* (2012) at Egypt on clay soils observed that root dimensions (length, diameter and volume), root yield, concentration of juice impurities (K, Na and alpha-amino-N) and sugar yield were increased by increasing nitrogen rate from 60 to 100 kg N/feddan . However, the inverse was true in gross sugar % and juice purity %. Similarly, Seadh *et al* (2013) at Egypt also reported that yield of sugarbeet incremented with successive N levels from 60-100 kg/ha through 80 kg/ha. But the quality parameters deteriorated with successive N levels from 60-100 kg/ha on laom soil medium in available N (Table 9).

Role of potassium: Potassium plays an important role in photosynthesis, protein synthesis, translocation of assimilates as well as in oncreasing plant growth and yield. It is important to sugarbeet yield and quality in balance with other essential nutrients. The crop is a heavy K feeder but the importance of K for improving sugarbeet yield and sugar content is still unknown to most of growers.

K fertilizers increase both leaf number and length as well as chlorophyll content compared to NP control. No significant difference between KCl and K_2SO_4 was noted. Both sources had a positive effect on sugarbeet growth and

TABLE 9: Average of TSS (%), sucrose (%), apparent purity (%), root, top and sugar yield as affected by nitrogen fertilizer levels.

Nitrogen fertilizer levels	TSS (%)		Sucrose (%)		Apparent Purity (%)		Root yield (t/fed)		Top yield (t/fed)		Sugar yield (t/fed)	
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
60 kg/fed	22.6	23.4	18.8	18.7	82.9	79.2	24.09	25.84	16.34	16.78	4.522	4.820
80 kg/fed	22.1	22.8	18.2	18.0	81.9	79.4	26.81	27.96	18.09	18.37	4.851	5.038
100 kg/fed	21.4	22.2	17.5	17.5	81.8	78.8	29.47	30.98	19.25	19.84	5.128	5.399
LSD 5%	0.06	0.08	0.07	0.07	0.3	0.3	0.15	0.12	0.35	0.34	1.611	2.721

(Seadh *et al*, 2013)

development. As result of improved top growth with application of K, there was an increase in sugarbeet root yield, sugar content and sugar yield as shown in Table 10 (Yu-ying and Hong, 1997).

TABLE 10: Effect of K rate and source on sugarbeet yield and quality

K Source	K_2O rate (mg/kg soil)	Root yield (g/pot)	Increase over control(%)	Sugar content (%)	Sugar yield (g/pot)	Water content in the roots (%)
KCL	50	425	7	16.0	68.2	73.4
	100	411	4	16.5	67.8	69.6
	150	513	29*	15.7	80.6	72.0
	200	439	11	15.0	65.7	71.6
	500	481	21	12.9	62.1	71.4
K_2SO_4	50	438	10	14.7	64.2	73.9
	100	409	3	13.7	56.0	73.6
	150	471	19	16.1	75.9	73.4
	200	511	29*	14.0	71.3	73.0
	500	451	14	14.9	67.2	71.0
Control	0	397	100	13.7	54.2	70.0

Note: $LSD_{0.05}$=9.7 (g/pot), $LSD_{0.01}$=46.2 (g/pot), * significant at 5% level

(Yu-ying and Hong, 1997).

Barik (2003) reported highest yield of 36.21 t ha^{-1} from K 155 Kg ha^{-1} followed 35.26 t ha^{-1} by K 115 Kg ha^{-1}. Seadh *et al* 2007 reported that all the investigated characters were significantly increased due to using potassium sulphate from 0 to 72 Kg/fed in both seasons. The most effective in this concern was 72 Kg/fed potassium sulphate.

Irrigation management: Crop yields can suffer from either under or over irrigation. Under irrigation limits water flow into the plant, which reduces movement of water, nutrients, and photosynthates within the plant. Over irrigation reduces yield through increased incidence of disease, loss of nutrients from the soil root zone, and reduced oxygen to roots. Over irrigation can also reduce sugarbeet quality by lowering the sugar percentage. Water deficiency during the early growing season is the main cause of potential yield loss in sugarbeet production (Abdollahian–Noghabi, 1999).

Kumar (1993) studied the effect of irrigation on yield, sucrose content and impurity levels of sugar beet crop and observed that eight irrigations were required for optimum root production and sugar per unit area. Further, impurities, i.e. α-amino-N, potassium, sodium and impurity index in sugarbeet juice significantly decreased with frequent irrigations. Maximum value of these impurities was recorded when the crop was grown under high moisture stress.

Applying irrigation just before the available soil water is depleted to 60 per cent and replenishing available soil water near field capacity in appropriate root zones will greatly assist in producing a high quality and high yielding sugarbeet crop. Irrigation every 3 weeks gave the highest root yield followed by every 5 weeks and the lowest root yield was obtained by irrigation every 7 weeks (Besheit *et al*, 1996; Abo-Shady *et al*, 2010 and Hassanli *et al* 2010).

On the other hand, Isoda *et al* (2007) found that the irrigation led to an increase in the net sugar yield due to an increase in the root yield. However, there was a slight reduction in the sugar content in roots.For crop establishment, first irrigation is crucial because of sensitivity of seed to water. Therefore, first irrigation should be given in such a way that water should not flow over the ridges. Depending on the soil type and rainfall, irrigation scheduling is required. Irrigation scheduled at 75 and 50 mm evaporation produced the highest yield of sugarbeet. Under this scheduling, 10-12 irrigations are required to grow a luxuriant crop of sugarbeet (Shukla and Awasthi, 2013). Irrigation requirement of Sugarbeet is fairly low, not more than 4 to 5 irrigations amounting to 37.5 – 60 cm would be required for the purpose (Gupta *et al* 2013).

Conclusion

-As large number of sugarbeet cultivars are available all over the world and most of them are grown under temperate conditions. Hence, there is need to evaluate the performance of these varieties under subtropical Indian conditions for their suitability.

-Optimum temperature for emergence and early growth is between 15°C to 25°C. Therefore, sowing date should be adjusted accordingly to coincide with given range of temperature.

-Yield of sugarbeet is higher on ridge or bed sowing as compared to flat sowing. Moreover, sugarbeet is sensitive to stagnant water, which may be avoided by ridge or bed planting.

TABLE 11: Root dimensions (cm), root yield (t/fed), top yield and root/top ratio as affected by irrigation intervals

Irrigation intervals (I)	Root length 2007-08 **	Root length 2008-09 **	Root diameter 2007-08 **	Root diameter 2008-09 NS	Root yield 2007-08 **	Root yield 2008-09 *	Top yield 2007-08 **	Top yield 2008-09 **	Root/top ratio 2007- 08 **	Root/top ratio 2008-09 **
Every 3 weeks	36.63c	35.33c	16.07a	14.50	27.92a	25.89a	12.05a	10.87a	2.33 c	2.39 c
Every 5 weeks	41.28b	42.16 b	15.75 b	14.33	26.49b	24.89b	10.62b	9.94 b	2.50 b	2.52 b
Every 7 weeks	43.60a	42.50 a	14.61 c	14.27	24.40c	24.25c	8.48 c	8.77 c	2.88 a	2.77 a

*, ** and NS indicate P<0.05, P0.01 and not significant, respectively. Means followed by the same letter are not significantly different at 5% level of significancy.

(Abo-Shady *et al*, 2010)

-Highest yield was observed at planting density around 1,00,000 plants to 1,20,000 plants/ha and optimum depth for sowing of sugarbeet is 2-3cm

-Application of FYM along with chemical fertilizers has positive effect on sugarbeet yield.

-Application of nitrogen @ 150-200 kg/ha, depending upon soil type, helps in increasing yield.

-Application of potassium approximately 150 kg/ha either through KCl or K_2SO_4 is essential to obtain good yield.

-Excess or deficit irrigation effects the crop growth negatively. The irrigations should be scheduled in such away to supply optimum amount of water throughout growing period depending upon soil type and climatic conditions

Rerference

Abdollahian-Noghabi, M. (1999). Ecophysiology of sugar beet cultivars and weed species subjected to water deficiency stress. Ph.D. Dissertation, pp: 227. University of Reading, U.K..

Abo-Shady Kh, A., Hilal, S. M. M., El-Sheref, E. El. M. and Ibrahim, M. F. M. (2010). Yield and quality of subarbeet crop as affected by irrigation interval, cultivars and potassium fertilization in north delta. *J. Agric. Res. Kafer. El-Sheikh. Univ.* **36**: 361-76.

Ahmad, S., Zubair, M., Iqbal, N., Cheema, N. M. and Mahmood, K. (2012). Evaluation of sugar beet hybrid varieties under Thal-Kumbi soil series of Pakistan. *Int. J. Agric. Biol.* **14**: 605–608.

Ahmad, Z., Shah, P, Kakar. K. M., El-Sharkawi, H., Gama, P. B. S., Khan, E. A., Honna, T. and Yamamoto, S. (2010). Sugar beet (*Beta vulgaris* L.) response to different planting methods and row geometries II: Effect on plant growth and quality. *J. Food Agric. & Environ.* **8**: 785-91.

Amin, M., Khan, A. and Khan, D. (1989). Effect of date of sowing on yield and quality of sugarbeets. *Pakistan J. Agric. Res.* **10** (1): 30-33.

Anonymous (2013). Hand Book of Agriculture (Published by Indian Council of Agricultural Research, New Delhi – 110 012).

Ash, G. H. B., Blatta, D. A., Mitchell, B. A., Davies. B., Shaykewich, C. F., Wilson, J. L. and Raddatz, R. L. (1999). Agricultural climate of Manitoba. http://www.gov.mb.ca/agriculture/climate/waa50s00.html

Awad, N. M. M., Sahar, F., Tawfik and Sahar, M. I. (2012). Effect of plowing depth, sowing method and nitrogen fertilization on yield and quality of sugar beet. *J. Agric. Res. Kafr. El-Sheikh Univ.* **38** (4): 458-70.

Balakrishnan, A. and Selvakumar, T. (2008). Integrated nitrogen management for tropical sugarbeet hybrids. *Sugar Tech.* **10** (2): 177-180.

Barik, S. (2003). Role of Potassium and nitrogen on sugar concentration of sugarbeet. *African crop sci. journal.* **11**(4) 259-68.

Bellin, D., Schutz, B., Soerensen, T. R., Salamini, F. and Schneider, K. (2007). Transcript profiles at different stages and tap-root zone identity correlated developmental and metabolic pathway of sugar beet. *Journal of experimental botany.* **58** (3): 699-715.

Besheit, S. Y., Mekki, B. B. and Beshay, M. G. (1996). Effect of different levels of water supply on sugar beet yield and quality in calcareous soils. *J. Agric. Sci. Mansoura Univ.* **21**: 3429-36.

Bhullar, M. S., Uppal, S. K. and Kapur, M. L. (2009). Effect of agronomic practices and varieties on productivity of sugarbeet (*Beta vulgaris* L.) in semi-arid region of Punjab. *J. Res. Punjab agric. Univ.* **46**: 6-8.

Bhullar, M. S., Uppal, S. K. and Kapur, M. L. (2010). Influence of planting density and nitrogen dose on root and sugar yield of beet (*Beta vulgaris* L.) under sub-tropical semi-arid conditions of Punjab. *J. Res. Punjab agric. Univ.* **47**:14-7.

Campbell, L. G. and Enz, J. W. (1991). Temperature effects on sugarbeet seedling emergence. *Journal of Sugar Beet Research* .**28** (3 & 4): 129-140.

Copeland, L. O. and McDonald, M. B. (2001). Seed Science and Technology. Norwell, Massachusetts: Kluwer Academic Publishers, Boston, pp.72–124

Draycott, A. P. and Christenson, D. R. (2003). Nutrients for Sugar Beet Production: Soil-Plant Relationships. *CABI Publishing*, Wallingford, UK.

Dubas, A., Pudelko, J. and Luczkiewicz, T. (1970). Nitrogen fertilizing of sugar beets at different doses of farmyard manure. *Rocznik nauk rolniczych. Seria A Roslinne*. **96** (2): 225-45.

Dutton, J. and Bowler, G. (1984). Money is still being wasted on nitrogen fertilizer. *British Sugar Beet Review.* **52** (4): 75-77.

El-Kassaby, A. T. and Leilah, A. A. (1992). Influence of plant density and nitrogen fertilizer levels on sugar beet productivity. Proc 5thConf. Agron., Zagazig, 13-15 Sept., Vol. (2): 954 - 62.

El-Maghraby, S. S., Gomaa, M. A., Rehab, I. F. and Hassan, H. M. (2008). Response of sugar beet to some mechanical management practices, irrigation and plant densities. *Sugar Tech.* **10**: 219-26.

El-Sarag, E. I. (2009). Maximizing sugar beet yield, quality and water use efficiency using some agriculture practice under North Sinai conditions. *Bull. Fac. Agric. Cairo. Univ.* **60**: 2-13.

Follet, R. H., Schmehl, E. R., Powers, L. and Payne, M. G. (1964). Effect of genetic population and soil fertility level on the chemical composition of sugar beet tops. *Tech. Bull. Colombia Agric. Expt. Stat.* **28**: 32.

Freckleton, R. P., Watkinson, A. R., Webb, D. J. and Thomas, T. H. (1999). Yield of sugar beet in relation to weather and nutrients. *Agric. Forest Meteorology.* **93**: 39-51.

Garg, V. K. and Srivastava, S. C. (1985). Evaluation of techniques suitable for growing sugar beet on sodic soils. *J. Indian Soc. of Soil Sci.* **33**: 884-87.

Ghonema, M. H. (1998). Effect of plating dates and harvesting time on yield, yield components and quality of sugar beet (*Beta vulgaris*, L.). *J. Agric. Sci. Mansoura Univ.* **23**(7): 2971- 2979.

Gupta, R., Singh, P. R. and Singh, A. K. (2013). Optimizing irrigation water and land need for sugar production through intercropping sugarbeet in autumn planted sugarcane. Souvenir- IISR-Industry Interface on Research and Development Initiatives for Sugarbeet in India, 28-29 May, Sugarbeet Breeding Outpost of IISR IVRI Campus, Mukteswar-263138, Nainital,. Organised by Indian Institute of Sugarcane Research (ICAR) and Association of Sugarcane Technologists of India. pp 51-52.

Hassanli, A. M., Ahmadirad, S. and Beecham, S. (2010). Evaluation of the influence of irrigation methods and water quality on sugar beet yield and water use efficiency. *Agri. Water Manage.* **97**: 357-62.

Hozayn, M., Tawfik, M. M., Abd El-Ghany, H. M. and Korayem, A. M. (2013). Effect of plant density on yield and sugar quality characteristics of sugar beet. *J. Appl. Sci. Res.* **9**: 1004-09.

Ismail, A. M. A. and Allam, S. M. (2007). Yield and technological traits of sugar beet as affected by planting density, phosphorus and potassium fertilization. Proc. The 3rd Conf. of Sustain. Agric. Develop. Fac. Agric. Fayoum. Univ., pp: 15-28.

Isoda, A., Konishi, H. and Wang, P. (2007). Effect of different irrigation methods on yield and water use efficiency of sugar beet (*Beta vulgaris*) in the arid area of China. *Hort, Research Chiba University (Japan).* **61**: 7-10.

Kemp, P. D., Khani, A. M. and Millner, J. P. (1994). The effect of plant population and nitrogen level on sugar yield and juice purity of sugar beet (*Beta vulgaris*, L.). *Proc. Annual Conf. Agron. Soci. of New Zealand.* **24**: 131-134.

Khan, A. A. (1992). Pre-plant physiological seed conditioning. *Horticultural Reviews.* **13:** 131–166.

Khan, M. (2013). Sugarbeet production guide. NDSU Extension Service, North Dakota State University of Agriculture and Applied Science, and U.S. Department of Agriculture cooperating. Duane Hauck, Director, Fargo, North Dakota pp: 9.

Kulkarni, V. N., Rana, D. K. and Wielandt, N. (2013). Sugar beet a potential new crop for sugar and ethanol production in India. Souvenir- IISR-Industry Interface on Research and Development Initiatives for Sugarbeet in India, 28-29 May, Sugarbeet Breeding Outpost of IISR IVRI Campus, Mukteswar-263138, Nainital. Organised by Indian Institute of Sugarcane Research (ICAR) and Association of Sugarcane Technologists of India. pp 58-62.

Kumar, R. and Pathak, A. D. (2013). Recent trend of sugarbeet in world. Souvenir- IISR-Industry Interface on Research and Development Initiatives for Sugarbeet in India, 28-29 May, Sugarbeet Breeding Outpost of IISR IVRI Campus, Mukteswar-263138, Nainital. Organised by Indian Institute of Sugarcane Research (ICAR) and Association of Sugarcane Technologists of India. pp 46-47.

Kumar, V. (1993). Effect of irrigation on yield, sucrose content and impurity levels of sugarbeet crop. *J. Indian Soc. of Soil Sci.* **41**: 26- 8.

Leilah, A. A. and Nasr, S. M. (1992).: The contribution of sowing and harvesting dates on yield and quality of some sugar beet cultivars. Proc. 5th Conf. Agron. Zagazig, 13 - 15 Sept., Vol (2): 970 - 979.

Leilah, A. A., Badawi, M. A., Said, E. M., Ghonema, M. H. and Abdou, M. A. E. (2005). Effect of planting dates, plant population and nitrogen fertilization on sugar beet productivity under the newly reclaimed sandy soil in Egypt. *Scientific Journal of King Faisal University (Basic and Applied Sciences).* **6**: 85-110.

Lopez, B. L., Castillo, J. E. and Fuentes, M. (1994). Nitrogen uptake by autumn sown sugar beet. *Fertilizer Res.* **38** (2): 101-109.

Maidl, F. X., and Fischbeck, G. (1989). Effect of Long-term Application of Farmyard Manure on Growth and Quality of Sugar Beet. *Journal of Agronomy and Crop Science*. **162** (4): 248–255.

Masri, M. I. (2008). Effect of nitrogen level and planting density on sugar beet yield and its attributes. *Egypt J. Agron.* **30**: 119-36.

Metcalfe, D. S. and Elkins, D. M. (1980). Sugar crops: In "*Crop production: Principle and PracticesI*". Mac Milan Company, New York, pp 511-27.

Narang, R. S. and Bains, B. S. (1987). Techniques for planting sugarbeet to advance the harvest date in North Indian Conditions. *Exp. Agri*. **23**: 99-103.

Nassar, A. M. (2001). Effect of plant density on the productivity of some sugar beet varieties. *J. Agric. Sci. Mansoura Univ.* **26**: 7533-46.

Norton, J. B. (2011). Nitrogen source, timing, and rate alternatives for furrow-irrigated sugarbeet. *Online. Crop Management* doi:10.1094/CM-2011-0829-01-RS.

Oad, F. C., Burrio, U. A. and Agha, S. K. (2004). Effect of organic and inorganic fertilizer application on maize fodder production. *Asian J. Pl. Sci*. **3**: 375-77.

Petkeviciene, B. (2009). The effects of climate factors on sugar beet early sowing timing. *Agron. Res.* **7**: 436–43.

Radivojevic, S., Kabic, D., Filipovic, V., Jacimovic, G. (2013). Yield And Technological Quality Of Modern Sugar Beet Varieties in the Republic of Serbia. *Food and Feed Research.* **40**: 53-58.

Ramazan, C. (2002). Root yield and quality of sugarbeet in relation to sowing date, plant population and harvesting date interactions. *Turk. J. Agric*. **26**: 133-39.

Refay, Y. A. (2010). Root Yield and Quality Traits of Three Sugar Beet (*Beta vulgaris* L.) Varieties in Relation to Sowing Date and Stand Densities. *World Journal of Agricultural Sciences.* **6** (5): 589-594.

Ririe, D. and Hills, F. J. (1970). Effects of row covering materials and depth of planting on sugarbeet emergence. *Journal of the American Society of Sugar Beet Technologists*. **16**: 168-71.

Romaneckas, K., Pilipavicius, V., Sarauskis, E. and Sakalauskas, A. (2009). Effect of sowing depth on emergence and crop establishment of sugar beet (*Beta vulgaris* L.). *Food Agriculture and Environment (JFAE).* **7**: 571-75.

Sadre, P., Soleymani, A. and Javanmard, H. R. (2012). Root yield and quality traits of sugar beet (*Beta vulgaris* L.) in relation to nitrogen fertilizer and plant density in isfahan region. *Intl. J. Agri. Crop Sci.* **4**: 1504-07.

Seadh, S. E., Attia, A. N., Said, E. M., EL-Maghrabby, S. S. and Ibrahim, M. E. M. (2013). Productivity and quality of sugarbeet as affected by sowing methods, weed control treatments and N fertilizer levels. *Pakistan J. of Biological Sciences.* **16**:711-19.

Seadh, S. E. (2004). Effect of planting dates, biofertilization treatments, nitrogen and potassium fertilizer levels as well as their interactions on growth, yield and yield components as well as quality of sugar beet (*Beta vulgaris* var. altissima, L.) cv. Beta Poly 4. *Ph. D. Thesis, in Agron*., Fac. of Agric., Mansoura Univ.

Seadh, S. E., Farouk, S. & EL-abady, M. I. (2007). Response of sugar beet to potassium sulfate under nitrogen fertilizer levels in newly reclaimed soils conditions. *African Crop Science Conference Proceedings*. **8**: 147-153 Printed in El-Minia, Egypt ISSN 1023-070X/2007$ 4.00 © 2007, African Crop Science Society.

Shrivastava, A. K. (2006). Sugarcane at a Glance, IBDC, Lucknow, Pp. 246.

Shrivastava, A. K., Sawnani, A., Shukla, S. P. and Solomon, S. (2013). Unique features of sugarbeet and its comparison with sugarcane. Souvenir- IISR-Industry Interface on Research and Development Initiatives for Sugarbeet in India, 28-29 May, Sugarbeet Breeding Outpost of IISR IVRI Campus, Mukteswar-263138, Nainital. Organised by Indian Institute of Sugarcane Research (ICAR) and Association of Sugarcane Technologists of India. pp 36-39.

Shrivastava, A. K., Shukla, S. P. and Sawnani, A. (2013). Useful products from sugarbeet. Souvenir- IISR-Industry Interface on Research and Development Initiatives for Sugarbeet in India, 28-29 May, Sugarbeet Breeding Outpost of IISR IVRI Campus, Mukteswar-263138, Nainital. Organised by Indian Institute of Sugarcane Research (ICAR) and Association of Sugarcane Technologists of India. pp 43-45.

Shukla, S. K. and Awasthi, S. K. (2013). Sugarbeet: A supplement to sugarcane in non-traditional areas to meet future sugar demand. Souvenir- IISR-Industry Interface on Research and Development Initiatives for Sugarbeet in India, 28-29 May, Sugarbeet Breeding Outpost of IISR IVRI Campus, Mukteswar-263138, Nainital. Organised by Indian Institute of Sugarcane Research (ICAR) and Association of Sugarcane Technologists of India. pp 55-57.

Singh, R. K., Sharma, A. K., Singh, R. K. and Prakash, B. (2013). Problems and prospects of sugarbeet cultivation as fodder crop in subtropical India. Souvenir- IISR-Industry Interface on Research and Development Initiatives for Sugarbeet in India, 28-29 May, Sugarbeet Breeding Outpost of IISR IVRI Campus, Mukteswar-263138, Nainital. Organised by Indian Institute of Sugarcane Research (ICAR) and Association of Sugarcane Technologists of India. pp 53-54.

Sogut, T. and Arioglu, H. (2004). Plant density and sowing date effects on Sugarbeet yield and quality. *J.Agron.* **3**: 215-18.

Sohier, M. M. and Ouda. (2001). Response of sugar beet to N and K fertilizers levels under sandy soil conditions. *Zagazig J. Agric. Res*. **28**(2): 275-297.

Spaar, D., Dreger, D. and Zacharenko, A. (2004). Sugar beet. CUP „Orech", Minsk, pp. 133– 135 (in Russian).

Sroller, I. and Svachula, V. (1990). Influence of weather on the production and quality of sugar beets. In Baier, J., Bures, R., Coufal, V. I. *et.al.*: Weather and production. Agropromizdat, Maskva, pp. 247–269 (in Russian).

Theurer, J. C. and Saunders, J. W. (1995). Row spacing and plant density Effects on smooth root sugarbeets. *J. Sugar Beet Res.* **32**: 69-78.

Ulrich, A. (1952). The influence of temperature and light factors on the growth and development of sugar beets in controlled conditions. *Agro. J*. **44**: 66–73.

Wyse, R. E. and. Dexter, S. T. (1971). Effect of agronomic and storage practices on raffinose, reducing sugar, and amino acid content of sugarbeet varieties. *J. of the A.S.S.B.T.* J. **6** : 369-83.

Yonts, C. D., Smith, J. A. and. Wilson, R. G. (1999). Effect of seed type, planter type and depth of planting on sugarbeet emergence. *Journal of Sugar Beet Research.* **36**: 1-9.

Yu-ying, L. and Hong, L. (1997). Effects of potassium fertilizers on sugar beet yield and quality. *Better Crops International.* **11**: 24-25.

Zahoor, A., Faridullah, Paigham, S., Sanaullah, B., Kakar, K. M., Haytham El-Sharkawi, Honna, T. and Yamamoto, Y. (2007). Sugar beet (*Beta vulgaris* L.) response to different planting methods and row geometries I: Effect on plant growth and yield. *Arch.. Agron.. Soil Sci.s* **53**:49-61.