9 Scope of Cultivation of Sugar Beet Under Indian Subtropical Conditions

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Abstract

In India, sugar cane is a main crop grown for processing of sugar. As an alternative to sugar crop, sugar beet is a short duration crop, having growth period of 6–7 months as compared to 10–12 months of sugar cane, which results in higher productivity per unit time than sugar cane. Sugar yield of sugar beet is equivalent to that of sugar cane, having more sugar content, recovery and purity and can tolerate adverse conditions like salt and water stress. Sugar beet cultivation results in considerably good yield with use of less irrigation water than sugar cane. Sugar beet crop matures in April–May, when the cane-crushing season is nearly over, thus helps in increasing the operation period of the sugar mills from four to six months in a year. Hence, sugar beet has a potential in sugar industry of the subtropical regions, especially India. For widening the scope of cultivation of sugar beet under subtropical Indian conditions, there is need to select the most appropriate varieties, planting time, planting methods, planting density, sowing depth, adequate crop nutrition, pest management and irrigation scheduling. Further, intensive studies are needed to estimate the economics of its cultivation in comparison to winter crops under cultivation and sugar cane in the region. Also sugar industries need to be upgraded for processing of sugar beet to ensure its marketing at good price for more profit than existing crops.

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Abbreviation

CPE Cumulative pan evaporation
IW Irrigation water

9.1 Introduction

Sugar beet (*Beta vulgaris* L.) is a member of *Chenopodiaceae* family. It has economic importance as a sugar crop is next to sugar cane (*Saccharum officinarum* L.). About 30% of world sugar comes from sugar beet, with Europe at top with regard to sugar beet cultivation. European countries account for 70% of the world's sugar beet production and France is on top in terms of per hectare yield (about 90 t/ha) of sugar beet (Iqbal and Saleem 2015). It is a crop of temperate climate; however, its cultivation is extending to subtropical conditions of India, Pakistan, Bangladesh, etc. In these subtropical countries, it is mainly cultivated in the winter season spanning from October to May months (Brar et al. 2015).

In India, sugar cane is the main crop grown for processing of sugar with an area hovering around five million hectare and the sugar industry encompasses 597 operating sugar mills, 309 distilleries, 213 cogeneration plants and numerous pulp, paper and chemical making units (Solomon et al. 2020). During 2018–2019, sugar production was 33.18 million tonnes in India (Online database 2020). Sugar demand in country is increasing continuously due to stress imposed by population explosion (Singh et al. 2018). This demand cannot be entirely fulfilled from sugar cane crop. Given the physical water scarcity on a global level, especially in subtropical countries, sugar cane being a water guzzling crop cannot be grown on a large area. However, sugar cane by-products such as ethanol are in great demand. Sugar beet can serve as an alternative sugar crop in place of sugar cane for sugar and its by-products. Sugar beet takes 6–7 months for completing its life cycle, whereas sugar cane takes a double time period 10–12 months for completing its life cycle (Mall et al. 2021). Sugar beet, being a short duration crop results in higher yield than sugar cane on unit time basis. Sugar beet has many advantages such as higher yield, short life cycle of 6–7 months, low water use, less fertilizer requirement and withstand abiotic stresses (Rozman et al. 2015).

In subtropical Indian conditions, sugar beet is a short season *Rabi* (Winter) crop (which is planted in October–November and harvested in April–May) and its yields at par to sugar cane with higher sugar content (15–17%), recovery (12–14%) and purity (85–90%) (Sanghera et al. 2016). Further, sugar beet can withstand drought (low water stress) and salinity (high salt stress). In comparison to sugar cane, sugar beet required less water. To produce one kilogram of sugar from sugar beet, about 1.4 cubic metre water is required, whereas 4.0 cubic metre of water is required to produce same quantity of sugar from sugar cane (Sohier and Ouda 2001). Moreover, sugar cane consumes 35–40% more water and fertilizer than sugar beet (Balat and Balat 2009). Thus, sugar beet can play a significant part in lowering production cost without decreasing factor productivity in varied environment conditions (irrigated, drought, saline soils). Sugar beet can assist in sustaining crop productivity in a short time period in comparison to sugar cane.

9.2 Uses of Sugar Beet

Sugar beet is grown for commercial sugar production. It is a biennial crop, and it stores food in underground plant part (root) during first year. For commercial purpose, sugar beet is harvested for its root after first year of its growth cycle, which weighs around 1–2 kg with 15–20% sucrose on dry weight basis. Sugar beet also provides valuable by-products such as green leaves after harvesting, which can be used as green fodder and/or ensilaged for animal feed for cattle. Green beet tops (leaves) may be used as mulch material. After sugar beet processing, along with sugar, molasses are produced as by-product, which can be used in cattle feed and in fermentation industries (Singh et al. 2013). Finkenstadt (2013) reported that sugar beet leaves have almost double crude protein content (15%) on dry weight basis than sugar cane leaves (6–8%) while D-value (Digestibility) is almost similar (55–57). Thus sugar beet can also be used as an alternative for grain in animal feed concentrates/green fodder/silage. Apart from this, ethanol, beer upon fermentation can be produced from impure sugary pulp (molasses).

9.3 Sustainability Through Sugar Beet Cultivation

In India, salt affected soils found in approximate seven million ha area, which have low crop productivity. Sugar beet can be successfully grown in such areas. Sugar beet can yield reasonably well with much less irrigation water than sugar cane. Therefore sugar beet can be successfully grown under water stress conditions. Hence, sugar beet can be explored and exploited for increasing profits and working time span of sugar industries.

Tropical sugar beet is not yet cultivated on large scale in India. In ethanol industry, use of sugar beet as feed stock is in nascent stage (Kulkarni et al. 2013). Research work done so far under Indian subtropical conditions reported that the crop can be grown successfully during winter months in plains of north India for its roots which contains 13–15% sugar (Pathak et al. 2014). Sugar beet cultivation is profitable enterprise amongst various cropping systems of winter season in subtropical conditions. Sugar beet, a new option for farmers, helps to increase profitability as compared to sugar cane especially in saline affected areas. Singh et al. (2018) from

PAU, Ludhiana reported that sugar beet not only helps in diversification of agriculture and but is a viable alternative for paddy–wheat cropping system. Sugar beet cultivation will help in increasing farmer's income along with saving of Rs. 10,000 crores foreign exchange per year and serves as a supplementary crop to augment optimal utilization of operating capacity of sugar industry.

Sugar beet cultivation has a bright scope in subtropical conditions (e.g. India) due to the following four main reasons.

1. Sugar beet is a dependable cash/truck crop of winter season.
2. It performs well under saline conditions and results in its reclamation through improved agronomic practices.
3. Sugar beet has excellent potential to yield reasonably well with much less irrigation water than sugar cane.
4. Sugar beet exhibits tolerance to different climatic and soil stresses. It can be grown on marginal land.

The complex set of interactions of genetic and environmental conditions occurring during growth and development phases of any crop plant decide the crop performance, productivity and its quality. Many environmental and agronomic factors influence sugar beet yield and quality. Both areal (temperature, solar radiation, sunshine hours) and soil (temperature, moisture) environment conditions affect the crop emergence, plant growth and development. Sugar beets emerge fast under temperature range between 15 and 25 °C (Khan 1992; Copeland and McDonald 2001). After emergence, crop growth and development activities are largely influenced by air temperature and crop nutrition. For proper plant growth, development and quality of sugar beet, an average temperature of about 20–22 °C is ideal. Temperatures above 30 °C retard sugar accumulation.

In North India, sugar cane area is almost stagnant year after year due to scarcity of irrigation water. However, sugar beet requires less water and matures within 6–-7 months and it is a good substitute of sugar cane (Brar et al. 2015). Working of sugar cane mills is almost over by April to May in northern India. Sugar beet crop cultivation will assist in increasing this operating time of sugar mills by another 4–6 months. This will be an exciting offer for both Indian farmers and sugar industry of northern India (Misra et al. 2017).

However, to widen the scope of cultivation of sugar beet, extensive studies are needed to identify the improved varieties, sowing time, sowing methods, crop geometry, seeding depth, nutrient management, pest management and water management practices suitable for subtropical conditions. Along with this, its economics should be evaluated while comparing it with economics of cultivation of major rabi crops and sugar cane grown in the region. The role of all these crop management practices in successful sugar beet production under subtropical (Indian) conditions is discussed further.

9.4 Scientific Cultivation of Sugar Beet Under Subtropical Conditions

9.4.1 Selection of Varieties

The main aim of plant breeders is to develop varieties which are high yielder and have high sugar recovery, so as to fulfil the deficit in sugar production. Sugar beet can only be possible under subtropical environmental conditions, if varieties to be sown are suitable for these conditions. Although sugar beet is primarily a temperate crop, but some genotypes (called as tropical sugar beet) are suitable for cultivation under subtropical climatic conditions. Under subtropical conditions of Northern India, cultivation of hybrids of tropical sugar beet resulted in average root yield of 60–80 t/ha with 13–15% sucrose content (Anonymous 2020).

Various sugar beet hybrids such as Cauvery, Indus and Shubhra are being grown, however, Cauvery hybrid resulted in maximum root yield (Balakrishnan and Selvakumar 2008). Sugar beet variety Padosa resulted in higher root yield, root/top ratio and sugar recovery than HI 0064. However, two varieties did not differ significantly in sucrose percentage (Bhullar et al. 2009). Ahmad et al. (2012) at Islamabad observed that SD-PAK09/07 resulted in the maximum beet root yield (74.2 t/ha), sugar yield (9.35 t/ha) and highest sugar content (12.60%) among 11 sugar beet hybrids and it was followed by California and Magnolia with sugar yield of 7.08 and 6.99 t/ha, respectively. They reported non-significant difference among varieties for leaf weight, root size and yield.

Bhullar et al. (2014a) at PAU, Ludhiana evaluated four sugar beet genotypes (SV 887 DSO 323, SV 888 DSO324, SV 891 DSO 325, SV 892 DSO 326) and observed that these genotypes performed equally well in terms of root yield and quality under Punjab conditions. In another experiment, Bhullar et al. (2014b) tested six monogerm sugar beet hybrids, *viz.* Cauvery & Shubra (M/s Syngenta India Ltd), Calixta & Magnolia (M/s JK Seeds Ltd) and PAC 60008 & SZ 35 (M/s Sesvanderhave) during 2013–14 (Table 9.1). Sugar beet genotype PAC 60008 resulted in the maximum root yield (87.5 t/ha) and was at par to Cauvery (87.3 t/ha) and Magnolia (80.1 t/ha). When crop was sown on 15 November, PAC 60008 resulted in maximum root yield which was similar to Cauvery but was statistically more than all the other hybrids.

Bhullar et al. (2015) evaluated four hybrids (SV 887, SV 889, SV 891, SV 892) (Table 9.1) from M/s Sesvanderhave in a field study conducted during 2014–15 at Ludhiana, Punjab and observed that at these hybrids recorded root yield varied from 87.9 to 89.0 t/ha with sugar recovery 15.0–15.2% in 150 days. Sanghera et al. (2016) reported that maximum root yield and quality product were obtained from Cauvery genotype, which was seconded by Indus and SV 892 genotypes out of 13 evaluated sugar beet genotypes (Calixta, Cauvery, H10671, H10826, Indus, Magnolia, Shubra, SV 887, SV 889, SV 891, SV 892, SV 893, SV 894).

Table 9.1 Yield and quality of sugar beet genotypes under subtropical Indian conditions

Genotype	Root yield (t/ha)	Sucrose (%) in beet roots	Reference
Cauvery	87.3	14.6	Bhullar et al. (2014b)
Shubra	73.6	14.5	
Calixta	72.9	14.5	
Magnolia	80.1	13.9	
PAC60008	87.5	14.4	
SV 887	88.3	15.1	Bhullar et al. (2015)
SV 889	88.3	15.0	
SV 891	89.0	15.2	
SV 892	87.9	15.0	

9.4.2 Planting Time

The influence of environmental conditions on germination, growth and productivity of any crop mainly depends upon the planting time of crop. Planting time influences the emergence, seedling growth, root yield and sugar recovery of sugar beet. The crop phenology depends upon cumulative growing degree days (sum of heat or temperature units more than threshold or base temperature, below which little growth occur). This threshold or base temperature depends upon season and plant species being grown (Bellin et al. 2007). Seed emergence is function of soil moisture, temperature and aeration. At soil moisture of 20–23% and 15–25 °C soil temperature, emergence of sugar beet seedling is at faster rate (Sroller and Svachula 1990; Khan 1992; Copeland and McDonald 2001; Spaar et al. 2004).

Sowing date of sugar beet in a particular region is fixed to ensure optimum temperature for its faster emergence. Amin et al. (1989) observed non-significant differences in root yield of sugar beet and its quality, when crop was sown on first and 15 October at Mardan, Pakistan. Crop sown later than this period resulted in reduced root yield and sugar recovery. Bhullar et al. (2009) observed non-significant difference for root yield when crop was sown on 25 September and tenth October. Further, sowing on these dates resulted in higher root weight and yield (root and sugar) than crop sown on 25 October. Delay in planting from 10 October to 25 October resulted in substantial reduction (19.4%) in root yield. They further observed that sucrose content is statistically similar in three planting dates.

Bhullar et al. (2014b) at PAU, Ludhiana reported that sowing sugar beet on 15 October resulted in maximum productivity, which was at par to root yield obtained from sowing on 30 October and significantly higher than November sowings. They further reported that Cauvery genotype recorded similar root yield when it was sown between 15 October and 15 November (90.8–98.7 t/ha) but its sowing on 30 November resulted in less yield (61.2 t/ha). Calixta and Magnolia genotypes recorded similar root yield when sowing was done between 15 October and 30 October (82.8–96.3 t/ha) and there was decrease in yield when sowing was done between 15 November and 30th November (54.3–75.1 t/ha, respectively). Shubra and SZ 35 genotypes recorded significantly lower root yield when sowing was done beyond 15 October. PAC 60008 genotype resulted in increased root yield when sowing was delayed from mid-October to mid-November (81.0–115.9 t/ha).

9.4.3 Planting Methods, Density and Depth of Sowing

Method of sowing decides the crop performance and yield. In sugar beet, the economical part is underground root. The soil physical conditions of upper 0–15 cm soil depth decide the growth behaviour of sugar beet roots. Planting method affects the soil physico-chemical properties and microbial activities, which ultimately affect the crop yield. In flat planting method, seed bed is prepared by ploughing and levelling top soil, whereas in ridge or bed planting, top fertile soil is accumulated in a particular shape of raised seed bed above the natural terrain. In ridge and bed sowing, water drains very quickly and sugar beet crop escapes from negative effects of water stagnation.

Sugar beet can be successfully grown on ridges with direct seeding in comparison to its transplanting. The former technique led to establishment of higher number of plants and greater mean weight of individual roots. Sugar yield of crop sown on ridges with direct seeding method is higher than transplanting of seedling on ridges (Garg and Srivastava 1985). Narang and Bains (1987) reported that direct seeding of sugar beet on the southern slope of east-west ridges resulted in higher root yield. Whereas, Bhullar et al. (2009) observed no significant difference for root, forage and sugar yield when sowing was done on flat or ridges on loamy soils.

The quality and quantity of any crop depend upon its plant density. Optimum plant population helps in optimum use of natural resources like water, light and space and therefore increasing the photosynthesis and assimilation of sugars. Optimum plant density is a principal component for achieving higher sugar beet productivity and returns (Freckleton et al. 1999). Bhullar et al. (2010) observed that plant population of 100,000 plants/ha (50 cm × 20 cm) resulted in the highest sugar beet root yield as compared to 83,333 plants/ha (60 cm × 20 cm) and 111,111 plants/ha (60 cm × 15 cm).

Saini and Brar (2017) observed that planting two rows on a bed resulted in maximum sugar beet root yield which was statistically similar to planting two rows per ridge with plant population of 1.23 lakh/ha. Saini and Brar (2018) reported that planting two rows on a bed (2R/Bed) (Fig. 9.1) received maximum interception of the light which resulted in more photosynthesis. This higher photosynthetic efficiency resulted in more dry matter production and more translocation of assimilates to the economic part (roots) ultimately resulted in higher root yield (Table 9.2). Raised bed provided well aerated, friable and well-drained soil conditions conducive for plant growth and root yield of 68.36 t/ha (Behera and Arvadia 2018).

Fig. 9.1 Crop sown on raised bed (two rows/bed) at farmers field in district Tarn Taran (Punjab)

Table 9.2 Root yield, quality and water productivity of sugar beet under different planting methods under subtropical Indian conditions

Planting methods	Root yield (t/ha)	Sucrose (%)	Water productivity (kg m^{-3})	Reference
Flat	55.82	17.9	12.8	Saini and Brar (2018)
	55.87	15.8	–	Behera and Arvadia (2018)
Ridge	57.26	17.7	14.1	Saini and Brar (2018)
	60.15	16.3	–	Behera and Arvadia (2018)
Bed	61.50	18.4	15.0	Saini and Brar (2018)
	68.36	16.5	–	Behera and Arvadia (2018)
Planting two rows on both sides of ridge	67.09	17.8	16.2	Saini and Brar (2018)
Planting two rows per bed	70.67	18.1	17.6	Saini and Brar (2018)

Seedling emergence is affected by soil physical and chemical properties. Among soil physico-chemical properties, soil moisture, temperature and aeration affect the most. Apart from this soil structure and mechanical friction/impedance also decide the emergence (Brar et al. 2015). Seeding at proper depth is essential for good emergence and optimum plant population in a field. Seed of sugar beet is very small, and its emergence is lowered with deeper sowing. The maximum emergence was observed when sugar beet was sown at 1.00 cm–3.00 cm soil depth than its deeper sowing at 3.75 cm–5.00 cm (Yonts et al. 1999; Khan 2013; Saini and Brar 2017).

9.4.4 Nutrient Management

Balanced fertilization is a major factor for achieving higher root yield of sugar beet. Fertilizer addition, especially nitrogen helps in more plant growth, chlorophyll content and higher photosynthesis rate, thus resulting in more dry matter production (Brar et al. 2015).

However, excessive use of nitrogen fertilizer results in more vegetative growth on the expense of root (economical part) growth and its quality (Draycott and Christenson 2003). Under certain conditions, excessive nitrogen application results in increase in root and forage (leaves) yield and reduces the sugar content. Determination of the optimum rate of application of nitrogen, which may produce maximum yield, improve root quality parameters by improving the chlorophyll content of the leaves and increasing root number and size, is of prime importance. In initial crop growth period, nitrogen application results in more dry matter accumulation per unit area, while nitrogen application in later stages of crop growth increases above ground and below ground dry matter production, thus helps in greater sugar production.

Soil organic matter plays a prominent part in natural mineralization, aggregate stability, aeration, favourable soil moisture conditions and retention properties. Soil organic matter is an indicator of inherent nutrient supplying capacity of a soil and decides the availability and relative proportion of different nutrient elements, both macro- and micro-nutrients. Bulky organic manures such as farmyard manure and green manure add humus/organic matter in the soil, and their application helps in nutrient transformation and their availability to the crops (Brar et al. 2015). The release of nutrients from bulky organic manure is very slow, so the maximum sugar beet productivity cannot be achieved with addition of farmyard manure alone. Therefore, bulky organic manures should be used in integration with chemical fertilizers for maximum availability of nutrients to the plants. This integration of chemical fertilizer with organic manures not only helps in nutrients availability but also helps in improvement of soil physico-chemical and biological properties (Kumar and Lokesh 2018).

Balakrishnan and Selvakumar (2008) reported that integrated use of nitrogen through chemical fertilizer, FYM and bio-fertilizer resulted in higher crop growth and yield of sugar beet under clay loam soil (with low available nitrogen status) than chemical fertilizers when used alone. Bhullar et al. (2010) reported that application of 120 kg/ha of nitrogen integrated with 20 t FYM in loamy soils (with high available nitrogen) results in higher sugar beet yield (Table 9.3). Further, this treatment recoded statistically similar root yield with application of 150–180 kg N/ha. Application of 150 kg/ha of nitrogen fertilizer resulted in maximum sugar beet root and sugar yield per unit area; however, highest values of sugar concentration in roots were recorded with 120 kg N/ha (Barik 2003).

Table 9.3 Sugar yield of sugar beet 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

(Source: Bhullar et al. 2010)

9.4.5 Irrigation Management

Sugar beet has a deep root system, which can effectively extract water from deep soil. Sugar beet yield is lower under both extreme conditions, i.e. water stagnation and drought. Under drought conditions or rainfed farming, water available to the plants is very less which results in poor crop growth and reduced crop yield. If water remains stagnant in field, then it will result in aeration problem and more infestation of disease, which ultimately leads to poor crop growth and reduce yield. Water deficiency in the initial crop growth phase results the maximum reduction in sugar beet yield (Abdollahian-Noghabi 1999). Singh et al. (2018) working in 22 villages of district Amritsar, Gurdaspur and Kapurthala of Punjab reported water productivity 13.98 kg/m^3 in beet crop than 8.17 kg/m^3 in sugar cane. Similarly, Gupta et al. (2013) and Shukla and Awasthi (2013) also reported that sugar beet requires less irrigation than sugar cane. Thus, sugar beet cultivation can be of considerable help in saving precious water.

The intensity and frequency of irrigation affect sugar beet root yield and relative proportion of sugars. Total eight irrigations were given for higher root yield and sugar recovery (Kumar 1993). Further, he observed that sugar beet juice contain less impurity index when irrigated frequently. Irrigation scheduling at IW/CPE of 0.8 resulted in the highest sugar beet root yield, while irrigation scheduling at IW/CPE of 1.0 and 1.2 resulted in lower yield (Saini and Brar 2018). This resulted in significantly higher water productivity under IW/CPE of 0.8 (18.8 kg/m^3) than IW/CPE of 1.0 (14.9 kg/m^3) and 1.2 (11.7 kg/m^3). Sugar beet sowing on beds or ridges (two rows per bed/ridge) resulted in significantly higher water productivity as compared to flat method (Table 9.2) (Saini and Brar 2018; Saini et al. 2020). They further reported that for maximum sugar beet root yield and water productivity, crop should be sown on beds/ridges (with two rows per bed/ridges) keeping plant population of 1.00–1.23 lakh plants/ha and watering should be done at IW/CPE of 0.8.

9.4.6 Pest Management

Sugar beet crop, being short statured is relatively susceptible to the competition of weeds owing to its slow initial growth (Bhadra et al. 2020). Weeds result significant

Fig. 9.2 Crop before and after hand weeding

reduction on yield of sugar beet. Weeds cause maximum damage when these are allowed to grow for initial 60 days (Gerhards et al. 2017). If control measures are not employed during this critical period of crop weed competition, a severe competition occurs which results in full crop damage (Fig. 9.2) (Cioni and Maines 2010; Kropff and Spitters 1991; Salehi et al. 2007). Among 250 weed species infesting sugar beet crop on global level, 60 weed species are detected as major infesting species, out of which approximately 70% are broadleaved and 30% are grass weeds (May and Wilson 2006). Weed competition from dicot weeds is intense as compared to monocot weeds (Roos and Brink 1996; Zoschke and Quadranti 2002). In winter season, *Anagallis arvensis, Chenopodium album, Convolvulus arvensis, Coronopus didymus, Lathyrus aphaca, Malva neglecta, Medicago denticulate, Rumex dentatus* and *Rumex spinosus* are among major broad leaf weeds which infest sugar beet crop under subtropical Indian conditions. Amongst annual grasses, *Avena ludoviciana, Phalaris minor* and *Poa annua* are major ones which infest sugar beet crop.

Weeds result in significant reduction in sugar beet root yield because of intense competition for crop nutrients, water, light and space and may cause complete crop failure if not controlled on time. The most competitive are annual weeds, mostly broadleaved species that emerge with, or shortly after the crop. These weeds attain more height with time and over-shadow the sugar beet plants and develop dense shade (Cioni and Maines 2010).

Mechanical weed management techniques include physical uprooting and mowing of the above ground plant parts is beneficial when weeds are relatively young and annual (Cioni and Maines 2010). In this method, major disadvantage is shifting of dormant weed seeds to the soil's surface, where they may germinate. Use of herbicide for weed management is economical, simple and effective method for keeping the weed population below minimum threshold level. Herbicide use ensures timely control of weeds during critical period of crop weed competition. Bhullar et al. (2013) evaluated different herbicides for weed management at PAU, Ludhiana. Four pre-emergence herbicides, *viz*. pendimethalin at 365 & 562 g, alachlor at 937 & 1250 g, oxadiargyl at 67 & 90 g and oxyfluorfen at 58 & 87 g/ha were evaluated. All herbicides provided effective control of grasses and broadleaves weeds during initial crop growth stage. However, oxyfluorfen 87 g/ha and pendimethalin 562 g/ha were observed phytotoxic for sugar beet crop. All the herbicidal treatments except oxyfluorfen 87 g/ha recorded statistically higher yield as compared weedy check.

Various cutting and feeding insect-pests such as army worm, hairy caterpillar, pod borer, semilooper, cutworms and sucking pests like aphids cause considerable damage to sugar beet. Aphid population decreased with increase in temperature while an infestation of armyworm and pod borer increased with rise in aerial temperature (Sharma et al. 2017).

9.5 Economics of Cultivation

Rice–Wheat is a widely cultivated cropping system in Indo-Gangetic plains and productivity of this system stagnated in the last few years. Farmers are looking for alternative crops which give more returns under existing conditions. Sugar beet crop is a great option to replace wheat crop and results in more returns than rice–wheat cropping system and sugar cane (Brar and Kumar 2019; Iqbal and Saleem 2015). Moreover, the economic viability of sugar industry can be enhanced through increasing the milling period. Sugar beet may provide supplementary/ alternate source of farm produce which can be used as a raw material in sugar industry to increase in its operational time period. Sugar beet cultivation requires significantly less investment than sugar cane and results in more economic returns of Rs. 20–25 thousands on per hectare basis.

Brar and Kumar (2019) did the economic comparison of cultivation of two winter crops, namely wheat and sugar beet (Fig. 9.1) under subtropical region. They reported that sugar beet and wheat resulted in mean yield of 940 q/ha and 47.5 q/ha, respectively. The sale price of sugar beet produce was Rs. 185/quintal (sugar mill situated in district Amritsar) and wheat was sold in local grain market at Rs. 1735/quintal. After making economic comparison, they found that the sugar beet cultivation resulted in more net returns of Rs. 35,945/ha than wheat (Table 9.4). In Punjab, farmers are reaping a harvest of 87.5 tonnes sugar beet per ha and earning gross and net returns of 1.5 lakh and 0.68–0.75 lakh, respectively, from a short

Table 9.4 Comparative yield and economics of sugar beet and wheat

Parameters	Sugar beet	Wheat
Yield (q/ha)	940	47.5
Selling price (Rs/ha)	185	1735
Gross returns (Rs/ha)	173,900	82,413
Cost of cultivation (Rs/ha)	82,612	27,070
Net return (Rs/ha)	91,288	55,343

(Source: Brar and Kumar 2019)

duration sugar crop (Anonymous 2019). Sugar beet crop can replace wheat in the northern India, provided there is assured market for this crop. Saini et al. (2020) observed that sugar beet cultivation is economical if sugar beet is grown on beds with plant population of 1.23 lakh/ha.

9.6 Major Constraints in Cultivation of Sugar Beet in Indo-Gangetic Plains

There are some problems which need to be solved for wider cultivation under Indian subtropical conditions:-

1. Unavailability of processing units for marketing of crop.
2. Huge labour requirement with high wages rate.
3. High cost of cultivation.
4. Market price uncertainty.
5. Poor technical knowledge.

Since it is an industrial crop and additional machinery is required in present-day sugar mills for its processing, which requires huge investment. Sugar cane is principally used to extract white sugar, khandsari and jaggery (Bhatt 2020). Whereas, jaggery cannot be produced from sugar beet, rather it needs additional plant for vacuum-pan sugar production. Sugar beet roots deteriorate faster after harvesting; therefore, it needs immediate transportation from farmer's field to the sugar factories. So its commercial cultivation is possible only around the processing units. Also, there is necessity of incentivization for shifting of area from sugar cane to sugar beet by the farmers and to sugar processor/industries for installing new units required for sugar beet processing (Singh et al. 2018).

The other major limitations in sugar beet cultivation are huge labour requirement with high rate of wages in region, costly seed and absence of label claim of pesticides in sugar beet for controlling different agricultural pests. Presently, production cost of sugar beet is very much high due to costly seed and huge labour demand. Brar and Kumar (2019) reported that sugar beet cultivation requires Rs. 82,612/ha than Rs. 27,070/ha required for wheat cultivation (Table 9.4). Further, there is uncertainty in sale price and sugar beet produce fetches market price of Rs. 190–195/q which is lower than sale price of sugar cane, i.e. Rs. 290–295/q (Saini et al. 2020). Apart from this, the simple farmers could not realize the full yield potential of sugar beet without following complete package of practice.

9.7 Future Prospects

Sugar beet has a vast scope to give more economic returns to farmers and increase economical viability of sugar industry through increasing the milling period. Favourable government policy and/or incentives for upgrading the existing sugar mills can boost the acreage under this crop during October to May months in subtropical region. Further, mechanization solutions must be explored to cut down the labour demand and make it a more viable option for the growers under Indian subtropical conditions.

9.8 Conclusion

Development and identification of suitable sugar beet cultivars for subtropical conditions are of utmost importance for realizing maximum economic returns. Improved cultivars with higher harvest index, higher root and sugar yield should be bred for cultivation and attaining maximum productivity under subtropical conditions. Planting time varies according to genotype selected and yield reduces with delay in sowing from 15 October to 15 November. Sugar beet sowing on ridges/beds with two rows per ridge/bed while maintaining plant population of 100,000 plants per/ha results in maximum yield. On soil test basis, judicious use of chemical fertilizers and organic manures should be followed for higher sugar beet productivity. Water management should be strictly according to climate of the region and field should be well drained to avoid water stagnation. More experimentation is needed to develop different integrated pest management techniques and different pesticide companies should get label claim of their pesticides for this crop.

References

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

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

Amin M, Khan A, Khan D (1989) Effete of date of sowing on yield and quality of sugar beets. Pakistan J Agric Res 10(1):30–33

Anonymous (2019) Annual report 2018–19, ICAR-Indian Institute of Sugarcane Research, Lucknow, (UP) India

Anonymous (2020) Package of practices for crops of Punjab: *Rabi* 2020–21, Punjab Agricultural University, Ludhiana. p 67

Balakrishnan A, Selvakumar T (2008) Integrated nitrogen management for tropical sugar beet hybrids. Sugar Tech 10(2):177–180

Balat M, Balat H (2009) Recent trends in global production and utilization of bio-ethanol fuel. Appl Energy 86(11):2273–2282. https://doi.org/10.1016/j.apenergy.2009.03.015

Barik S (2003) Role of potassium and nitrogen on sugar concentration of sugar beet. African Crop Sci J 11(4):259–268

Behera SD, Arvadia MK (2018) Root yield and quality of tropical sugar beet (*Beta vulgaris* L.) cultivars under land configurations in *vertisol* and impact on soil health. J Crop Weed 14:193–197

Bellin D, Schutz B, Soerensen TR, Salamini F, Schneider K (2007) Transcript profiles at different stages and tap-root zone identity correlated developmental and metabolic pathway of sugar beet. J Exp Bot 58(3):699–715

Bhadra T, Mahapatra CK, Paul SK (2020) Weed management in sugar beet: a review. Fund Appl Agri 5:147–156

Bhatt R (2020) Resources management for sustainable sugarcane production. In: Kumar S et al (eds) Resources use efficiency in agriculture. Springer, pp 647–693. https://doi.org/10.1007/978-981-15-6953-1_18

Bhullar MS, Uppal SK, Kapur ML (2009) Effect of agronomic practices and varieties on productivity of sugar beet (*Beta vulgaris* L.) in semi-arid region of Punjab. J Res Punjab Agric Univ 46: 6–8

Bhullar MS, Uppal SK, Kapur ML (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 47:14–17

Bhullar MS, Thind KS, Uppal SK, Sharma B, Sandhu SK, Kaur S, Kaur T, Sharma S, Kumar R (2013) Annual project report 2012–13: exploring possibility of introducing sugar beet for enhancing economic viability of sugarmills in Punjab. Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab (India)

Bhullar MS, Kaur S, Kaur T, Thind KS, Sanghera GS, Sharma S (2014a) Annual project report (2013–14): evaluation of Sesvanderhave sugar beet genotypes for yield and quality under Punjab conditions. Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab (India)

Bhullar MS, Thind KS, Kaur S, Kaur T, Singh K, Singh O, Sanghera GS, Singh J, Sharma S, Garg T, Randhawa HS, Saini KS, Brar NS (2014b) Annual Project Report 2013–14: exploring possibility of introducing sugar beet for enhancing economic viability of sugarmills in Punjab. Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab (India)

Bhullar MS, Kaur S, Kaur T, Thind KS, Sanghera GS, Sharma S (2015) Annual project report (2014–15): evaluation of Sesvanderhave sugar beet genotypes for yield and quality under Punjab conditions. Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab (India)

Brar NS, Kumar B (2019) Innovative cultivation of sugar beet for sweet returns. In: Rana RK, Singh R, Thakur AK, Chahal VP, Singh AK (eds) Contemplating agricultural growth through farmers' frugal innovations. ICAR-ATARI-1, Ludhiana, Punjab, India, pp 131–132

Brar NS, Dhillon BS, Saini KS, Sharma PK (2015) Agronomy of sugar beet cultivation-a review. Agril Rev 36:184–197

Cioni F, Maines G (2010) Weed control in sugar beet. Sugar Tech 12:243–255. https://doi.org/10.1007/s12355-010-0036-2

Copeland LO, McDonald MB (2001) Seed Science and technology. Kluwer Academic Publishers, Boston, Norwell, Massachusetts, pp 72–124. (in English)

Draycott AP, Christenson DR (2003) Nutrients for sugar beet production: soil-plant relationships. CABI Publishing, Wallingford, p 242

Finkenstadt VL (2013) A review on the complete utilization of the sugar beet. Sugar Tech 16:339–346. https://doi.org/10.1007/s12355-013-0285-y

Freckleton RP, Watkinson AR, Webb DJ, Thomas TH (1999) Yield of sugar beet in relation to weather and nutrients. Agric Forest Meteorol 93:39–51

Garg VK, Srivastava SC (1985) Evaluation of techniques suitable for growing sugar beet on sodic soils. J Indian Soc Soil Sci 33:884–887

Gerhards R, Bezhin K, Santel H (2017) Sugar beet yield loss predicted by relative weed cover, weed biomass and weed density. Plant Protect Sci 53:118–125. https://doi.org/10.17221/57/2016

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

Iqbal MA, Saleem AM (2015) Sugar beet potential to beat sugarcane as a sugar crop in Pakistan. Am Eurasian J Agric Environ Sci 15:36–44

Khan AA (1992) Pre-plant physiological seed conditioning. Hortic Rev 13:131–166

Khan M (2013) Sugar beet 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, p 9

Kropff M, Spitters C (1991) A simple model of crop loss by weed competition from early observations on relative leaf area of the weeds. Weed Res 31:97–106

Kulkarni VN, Rana DK, 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 Sugar beet in India, 28–29 May, Sugar beet Breeding Outpost of IISR IVRI Campus, Mukteswar-263138, Nainital. Organised by Indian Institute of Sugarcane Research (ICAR) and Association of Sugarcane Technologists of India, p 58–62

Kumar V (1993) Effect of irrigation on yield, sucrose content and impurity levels of sugar beet crop. J Indian Soc Soil Sci 41:26–28

Kumar A, Lokesh B (2018) Integrated nutrient management for maximum economic yield of sugar beet and sustainable soil health. Agrica 7(2):156–163

Mall AK, Misra V, Santeshwari, Pathak AD, Srivastava S (2021) Sugar beet cultivation in India: prospects for bioethanol production and value added co products. Sugar Tech 23:1218–1234

May JM, Wilson RG (2006) Weed and weed control. In: Draycott AP (ed) Sugar beet. London, Blackwell, pp 359–386

Misra V, Sah U, Mall AK, Kishor R, Pathak AD (2017) Identification and evaluation of different sugar beet germplasm for high yield and sucrose content under Indian agro-climatic conditions. Bull Env Pharmacol Life Sci 6:292–295

Narang RS, Bains BS (1987) Techniques for planting sugar beet to advance the harvest date in North Indian conditions. Exp Agri 23:99–103

Online database (2020) Supply and demand position of sugar in India. www.indiastat.com. Accessed 5 Jan 2021

Pathak AD, Kapur R, Solomn S, Kumar R, Srivastava S, Singh RP (2014) Sugar beet: a historical perspective in Indian context. Sugar Tech 16(2):125–132. https://doi.org/10.1007/s12355-014-0304-7

Roos H, Brink A (1996) Optimierung von produkteigenschaften durch formulierungsentwicklung am beispiel rübenherbicide. Mitteilungen aus der Biologischen Bundesanstalt für Land-und Fortwirtschaft 321

Rozman C, Kljajić M, Pažek K (2015) Sugar beet production: a system dynamics model and economic analysis. Organ 48:145–154

Saini KS, Brar NS (2017) Sugar beet (*Beta vulgaris* L.) yield response to varying planting methods, densities and depth of sowing under subtropical conditions. Bioscan 12:1715–1720

Saini KS, Brar NS (2018) Crop and water productivity of sugar beet (*Beta vulgaris*) under different planting methods and irrigation schedules. Agric Res 7:93–97

Saini KS, Brar NS, Walia SS, Sachdev PA (2020) Effect of planting techniques, plant densities and different depths of sowing on production economics, water and sugar productivity of sugar beet. J Crop Weed 16:190–196

Salehi F, Esfandiari H, Rahimian MH (2007) Critical period of weed control in sugar beet in shahrekord region. Iran J Weed Sci 2:1–12

Sanghera GS, Singh RP, Kashyap L, Tyagi V, Sharma B (2016) Evaluation of sugar beet genotypes (*Beta Vulgaris* L.) for root yield and quality traits under subtropical conditions. J Krishi Vigyan 5:67–73

Sharma S, Kooner R, Sandhu SS, Arora R, Kaur T, Kaur S (2017) Seasonal dynamics of insect pests of sugar beet under sub-tropical conditions. J Agrometeorol 19:81–83

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

Singh RK, Sharma AK, Singh RK, Prakash B (2013) Problems and prospects of sugar beet cultivation as fodder crop in subtropical India. Souvenir- IISR-Industry Interface on Research and Development Initiatives for Sugar beet in India, 28–29 May, Sugar beet Breeding Outpost of IISR IVRI Campus, Mukteswar-263138, Nainital. Organised by Indian Institute of Sugarcane Research (ICAR) and Association of Sugarcane Technologists of India, p 53–54

Singh S, Sidana BK, Kumar S (2018) Water Productivity of sugar beet vs sugarcane cultivation in Punjab. IJIRST 4:61–69

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

Solomon S, Rao GP, Swapna M (2020) Impact of COVID-19 in Indian sugar industry. Sugar Tech 22(4):547–551

Spaar D, Dreger D, Zacharenko A (2004) Sugar beet. CUP "Orech", Minsk, p 133–135

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

Yonts CD, Smith JA, Wilson RG (1999) Effect of seed type, planter type and depth of planting on sugar beet emergence. J Sugar Beet Res 36:1–9F

Zoschke A, Quadranti M (2002) Integrated weed management: Quo vadis. Weed Bio Manga 2:1–10. https://doi.org/10.1046/j.1445-6664.2002.00039.x