Sugar Beet Crop Production and Management

11

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Abstract

Sugar beet (*Beta vulgaris* L.), which is generally regarded as a temperate crop, is grown in winter in countries with subtropical climate characteristics. Its vegetation period is half that of sugar cane; however, the yield is higher and less water is needed in the growing period compared to sugar cane. Environmental and agronomic factors significantly affect the sugar beet yield and quality. In order to improve the quality of sugar beet and to obtain maximum yield from it, it is necessary to select the most appropriate varieties, sowing time, sowing method, sowing density, sowing depth, fertilizer type and amount, and irrigation plan. The most suitable air temperature for the development of sugar beet is between 15 and 25 °C. In conditions other than these temperatures, yield and quality are adversely affected. Therefore, the planting date should be determined to coincide with the given temperature range. The sowing method, density, and depth significantly affect the yield and quality. 11–12 plant m^{-2}, 45–50 cm row distances, 20–25 cm plant distance in row, and 2–3 cm sowing depth are ideal for sugar beet agriculture. Insufficient or excessive irrigation has negative consequences for sugar beet as well as for all agriculture. For an adequate and effective irrigation, the soil moisture level should be monitored at a depth of 0–90 cm and the amount of 600–700 mm of water that is needed and cannot be met by precipitation should be given with irrigation at least 75–80% of the field capacity in each irrigation. Planning the techniques to be applied in agricultural production according to the needs of the plant in sugar beet, as in other crops, is an important issue that ensures an increase in production and quality.

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Keywords

Crop management · Cultivation · Irrigation · Plant density · Sugar beet

Abbreviations

BBRO	British Beet Research Organization
ET	Evapotranspiration

11.1 Introduction

In addition to being an important source of energy for human food, sugar beet is the most important sugar production source for the world's sugar needs, together with sugar cane as an important commercial commodity and industrial production tool. Currently, approximately 22% of the world's total annual sugar production is produced from sugar beet. The climatic characteristics of the region are an important determining factor in the yield and quality of sugar beet. Sugar beet is a long day plant and requires a lot of light and warmth. Less or too much light affects the sugar formation in sugar beet through photosynthesis. Overcast and cloudy weather adversely affect the photosynthesis in the plant. A total temperature of 2400–2800 °C is needed during the growing season for the development of sugar beet. Especially in June and July, the desire for lighting and warmth reaches its highest level. Sugar beet is a plant that grows well in clear and sunny weather. Long-term low temperatures that occur in the first cultivation period initiate vernalization of the plants and cause low yield.

Vegetation of beets starts at 7 °C in spring and ends at 5 °C in autumn. The length of the vegetation period between these temperature limits should be at least 170 days. During the vegetation period, the highest beet growth and sugar accumulation are observed at temperatures above 15 °C, especially at 20–25 °C (Draycott 2006). At higher temperatures, the growth and sugar accumulation slow down. Sugar beet is very sensitive to low temperatures during the first stages of the growth period. Young seedlings can be damaged by prolonged temperatures as low as 1–4 °C. In the last periods of the growth, on the other hand, the harvest can withstand cold temperatures down to −5 °C and photosynthesis continues. In the dry years, sugar content decreases especially when the temperature is above 30 °C in July and August and the day and night temperatures are close to each other. During the growth period, in addition to temperature and precipitation, the effect of relative humidity is also important, and relative humidity of 60–70% is considered ideal for sugar beet (Petkeviciene 2009).

Crop rotation has a significant impact on production quantity and quality. For this reason, shifting plant production to different areas from year to year will ensure that the nutrients needed are met from different depths. On the other hand, with the cultivation of different agricultural crops, the efficiency of crop-specific diseases and pests will decrease, and an increase in production will be achieved. Crop rotation is one of the most effective ways to reduce the weed population, including disease, pests, and vernalization. To be able to eliminate all these factors that directly affect yield and quality, it is important not to include plants of the same species in sugar beet crop rotation (Koch et al. 2018).

When wheat is planted after sugar beet, it can increase wheat yield by around 15%. If the applied crop rotation interval is not sufficient to prevent the spread of beet cyst nematode and seeded beet, it is necessary to extend the cycle interval to obtain high yield and to produce quality beets. It can be said that legumes, potatoes, and cereals are suitable as the pre-plants for sugar beet cultivation. Forage beet, sunflower, seed beet, rice, hemp, spinach, mustard, rapeseed, carrot, radish, cabbage are not suitable pre-plants for sugar beet as they cause many diseases and pests, especially nematodes (Götzea et al. 2017).

Legumes such as alfalfa, chickpeas, beans, lentils, and vetch can be counted as the best pre-plants in sugar beet due to their deep rooted and extensive root system. Legumes increase the presence of nitrogen and organic matter in the soil by absorbing the free nitrogen of the air through the podocytes (active nitrogen bacteria) in their roots and create a loose soil structure. In determining the pre-plants, the planting and harvesting dates should not be delayed at a level that will adversely affect the development of the main crop, and it should also be suitable for the conditions of the region and the sugar beet.

11.2 Soil Management and Preparation

Sugar beet is a deep-rooted crop and requires deeply cultivated soil. Compacted soil structures and hardened soils are not suitable for sugar beet cultivation. In other words, the taproot does not form a root but creates root bifurcations, cannot grow and develop, and thereby root yield decreases. First of all, no matter what tillage method is used, deep tillage of the soil every few years in autumn according to the planting rotation is an important issue to establish the deep root structure of the beet.

11.3 Autumn Tillage

Autumn tillage is an important process, especially in arid and semi-arid climates, depending on the soil structure, to facilitate the preparation of the seed bed in the spring by making maximum use of the winter precipitation, and to facilitate the conversion of the base fertilizers into a more useful form in the spring. Autumn tillage is generally carried out by chopping the stubble and mixing it into the soil with tillage tools or tool combinations such as moldboard plow, disc harrow, and rototiller (Fig. 11.1).

In sugar beet cultivation, the field is usually plowed at a depth of 25–30 cm in autumn with a moldboard plow or chisel. For the preservation of the soil structure

Fig. 11.1 Stubble-ploughing

Fig. 11.2 Reversible plow and field preparation

and for a sustainable agricultural production, due care must be taken to ensure that the tillage is done in an appropriate soil weathering in all agricultural operations. The fact that soil weathering is suitable for cultivation will prevent the formation of clod and clumping and will also ensure good soil ventilation. When this type of field is prepared, large clods will not form on the land, and an ideal structure will be created for other processes that will support plant production by providing a homogeneous field surface. Improper tillage and wrong sowing time can cause a yield loss of around 30%.

Moldboard plow is the most preferred tillage tool in primary tillage, which is generally applied to remove previous crop residues, improve drainage, and provide a uniform and flat seedbed with medium to fine texture (Fig. 11.2). The first factor in whether the tillage will be done with or without a plow is the soil texture. The parameters related to the soil texture to be taken into consideration regarding the soil cultivation method can be summarized as follows.

Fig. 11.3 Subsoiler

In heavy clay soils (clay loam, silty clay loam, sandy clay loam), it is recommended to make a rough plowing as early as possible in autumn (late October) in order to benefit from the freezing and thawing effect in winter months. Medium-heavy soils (silty loam, sandy loam) can be tilled more easily than heavy soils, but too early plowing will cause the soils to be smeared, especially during the rainy winter months. For this reason, late autumn tillage is recommended. In light soils (loamy sand, sand), it is an important issue to prefer equipment that will prepare it in a single pass with combined tools according to the condition of the soil in spring, instead of plows, which will eliminate the negative effects of erosion (Brown 1999).

Especially in heavy textured soils, it is important to plan the deep cultivation of the soil with a 3–4 year transformation in order to prevent the negative effects of the hard structure created by tillage at the same depth on deep-rooted plants such as sugar beet. The processing performed with subsoiler or chisel will help the root of sugar beet to go deeper, reach water and air more easily, accelerate beet development, increase yield and quality, and prevent salinity to a certain extent (Figs. 11.3 and 11.4). In the context of mitigating the negative effects of this hard layer, subsoiling is also crucial in autumn when the soil is dry enough to effectively eliminate disturbance from tractor tracks and headland turns. The most effective application method is 60–90 cm depth and a width of 1.5–2 times the depth in subsoiling.

Very important benefits of autumn release are known, such as mixing base fertilizers, providing natural processing through winter precipitation and frost, and accelerating the decay of plant residues mixed with the soil (Martindale 2013). For this, although it is not indispensable, it is recommended to apply all of the potassium fertilizer and 2/3 of the phosphorus fertilizer to the soil before autumn cultivation.

Some tillage methods such as minimum tillage, no-till, low-till, non-plowing, eco-tillage are widely applied in light-structured soils such as sandy, sandy-loamy, etc. These methods are mostly applied for erosion control. In these methods, the use of combined tillage tools and herbicides to create a suitable field in sugar beet and to control weeds increases the efficiency. Soil structure and biological activity in the soil are more positive in terms of agriculture in the minimum tillage method. This

Fig. 11.4 Chisel

Fig. 11.5 Minimum tillage practices in the field

provides an advantage at the point of making soil tillage, where the highest energy consumption occurs, more economical (Fig. 11.5).

11.4 Seedbed Preparations

In sugar beet agriculture, a tight and thin seed bed with sufficient air/water ratio, suitable for water retention is desired. Before the seedbed preparation, half of the nitrogen fertilizer and 1/3 of the phosphorus fertilizer left from autumn are given to the soil. If tillage cannot be done in autumn, all phosphorus and potassium fertilizers can be applied in the spring. Since the spring season is usually rainy, there is usually limited time for preparation. Therefore, soil weathering is very important for good preparation. In sugar beet, the seed bed should be loosened as much as the seed sowing depth, the germination path should be short, the water, air, and temperature values should be in a balanced structure. For correct sowing by leaving the seeds at

Fig. 11.6 Spring tine cultivator

Fig. 11.7 Combined tillage tool

the desired depth and ensuring a normal field output, the seed bed should be free of stones, clods, and plant residues, the field should be smooth and the soil should be loose enough in the area to contact the seed. For sugar beet, a 5–8 cm deep seed bed prepared with a harrow, cultivator, or combined tools and a shallow cultivation as much as possible can be suggested as suitable solutions (Figs. 11.6 and 11.7).

Soil preparation should be completed in a single pass as much as possible in order to create a suitable moisture environment in seed bed preparation and to ensure a particle structure of less than 3 mm around the seed. A flat field surface should be created to reduce harvest losses and to ensure a good seed-soil contact. For this, the timing of preparation (i.e., soil condition) is crucial. As a precaution against the possibility of compaction in the soil, settings such as wide tire, double wheel use, and low tire pressure and removing unnecessary weights on the tractor can be solutions (BBRO 2019).

11.5 Soil Requirements of Sugar Beet

The fact that sugar beet is a plant where yield loss is frequently seen due to its physiologically weak soil structure and sensitivity to insufficient drainage conditions requires due attention to the physical, chemical, and biological structure of the soil. When a general definition is made for sugar beet, it is physically not stony, gravelly, sandy, clayey, or heavy in structure, well ventilated, deep groundwater level below 120–150 cm, good drainage, chemical and biological structure neutral-slightly alkaline (pH = 6.4–7.6), soil rich in organic matter with high water retention is defined as an ideal soil structure (Draycott 2006).

Although it is stated that loamy soils are ideal for sugar beet cultivation, soils ranging from sandy loam to clay loam are the soil types where beet cultivation is common. However, it is necessary to consider the possibility that the technological quality of sugar beet will decrease as it moves away from the optimum soil criteria.

Since sugar beet uses high amounts of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) during its development, the soil and plant should be supported with the main nutrients determined to be deficient in order to maintain the productivity level.

11.6 Water Use and Irrigation

Although it varies according to the climate and the length of the growing period, an average of 550–750 mm of water is needed in the cultivation of sugar beet without irrigation (FAO 2020). With the distribution of annual precipitation according to months being proportionally equal, it is ideal that half of it occurs seasonally during the growing period and the remaining half as winter precipitation. The need for water in crop production is a concept related to evapotranspiration (ET_o). In the estimation of ET_o in plants, the crop coefficient (k_c) is given as 0.4–0.5 in the emergence period, 0.75–0.85 in the growing period, and 1.05–1.2 in the ripening period. To give an average value, this value can be taken as 0.9–1.0 at the end of the season and 0.6–0.7 at the harvest time (Fig. 11.8).

Irrigation, which is the application of water that is necessary for growth and cannot be provided by natural precipitation, should be applied in an amount that will ensure sufficient moisture in the plant root zone, especially in arid and semi-arid climatic conditions. In addition, irrigation has important benefits such as controlling the temperature in the soil, washing off excess salt, softening the hard layer, helping to take the fertilizers into the plant.

In general, the amount of water retained by the sugar beet is 1% of the total amount of water evaporated during the growing season. In this case, irrigation can be thought of as the completion of water lost through evaporation from plants and soil.

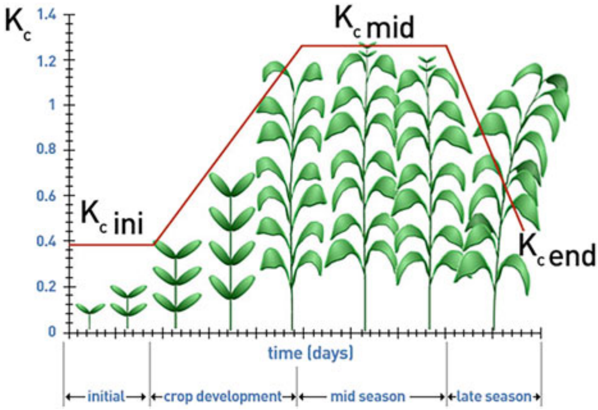

Fig. 11.8 Change in plant water consumption coefficient depending on the beet's development period (FAO 2020)

The sugar beet plant is sensitive to water deficiency, especially when there is not enough rainfall at the time of germination and 3–4 weeks after emergence. In cases where precipitation delay and irrigation cannot be done adequately, it becomes difficult to obtain the necessary plant for optimum efficiency and yield loss may be equivalent to late planting (Hassanli et al. 2010).

Weather has a great impact on agriculture. Sugar beet produces high levels of dry matter in favorable weather conditions, especially in sufficient rainfall and irrigation conditions. The daily water consumption of beets is 1.1–1.5 m^3 in the leaf forming phase, 5.6–8.2 m^3 in the root formation phase, and 6.1–6.8 m^3 in the sugar accumulation period. These amounts increase 2.5–3 m^3 per day as the average daily temperature increases 1 °C (Tortopoğlu 1994; Vazifedousta et al. 2008).

Sugar yield of each 25 mm of irrigation water applied on sandy soils increases by 0.4 t ha^{-1}, this amount being 50% more in dry years (Ober 2004). With the increase in the amount of irrigation water, the sugar content decreases proportionally and the sugar yield increases. For optimum sugar yield, it is sufficient to apply 65–70% of the full water amount in each irrigation (Mahmoodi et al. 2008; Abyaneha et al. 2017; Abbas et al. 2018).

In the traditional method, when the leaves are dark green or the leaves lose their vitality at noon and do not return to their original state in the evening, it is considered that the time has come for irrigation sugar beet. In addition, if the leaves do not break or crack when the leaves are folded transversely, the irrigation is late. One of the factors affecting irrigation planning is soil structure.

Light soils require more frequent irrigation than medium and heavy soils, and higher parts of the field than pits. After knowing about the irrigation time according to the leaves, the moisture presence of the soil should be examined for a definitive decision. If the soils taken from 0 to 60 cm or 0 to 90 cm depth of the soil do not take the shape of a ball and disperse after slightly compacted, it can be thought that it is time to water.

The duration of irrigation is as important as the determination of the irrigation time. The effective root depth of the plant is taken into account in determining the irrigation time. It is known that the roots reach a depth of 90 cm in sugar beet. In a good irrigation planning, monitoring the movement of water during irrigation will be beneficial in terms of preventing unnecessary water loss. Effective root depth can be taken as 60 cm in sugar beet. In this case, water application should be stopped when the irrigation water reaches a depth of 40 cm. When the water is cut off, the topsoil is at the saturation point and it reaches a depth of 60 cm in 1–2 days with the downward movement of the water by gravity.

Water consumption in sugar beet is highest in June, July, and August and it is more sensitive to water deficiency. Irrigation can be started in these months by making thinning-singling and applying the remaining nitrogen fertilizer. Due to the high water holding capacity of heavy textured soils such as clay or clay loam, the number of irrigation is naturally less than that of light textured soils. Daytime irrigation should be avoided to reduce irrigation losses and increase productivity. For high and quality yields, 80 ± 20 mm of water should be given in each irrigation at 10–15 day intervals, depending on the soil structure and the rainfall in July and August (Carlson and Bauder 2020; FAO 2020).

In general, irrigation and nitrogen have mutual effects on plant growth in crop production. Nitrogen must be balanced with the irrigation water needed for a high production. In other words, in case of insufficient nitrogen amount, high production potential cannot be reached even if the amount of water is sufficient. When there is enough nitrogen as needed by the plant, excessive irrigation causes nitrogen to be washed out. This also leads to a possible loss of production. In cases where precipitation is irregular or insufficient, the benefit of nitrogen decreases if irrigation is not performed within 3–4 weeks after planting (Zarski 2020).

11.7 Irrigation Methods

11.7.1 Surface Irrigation

In this method, which is called surface or flood irrigation, water is applied uncontrolled in the direction of the slope or in the direction perpendicular to the slope. Surface irrigation, which is a primitive method, has low investment costs. It is difficult to maintain a homogeneous distribution of water and erosion can occur. This method can generally be applied by small farmers on sloping fields with a smooth field surface and low slopes (Fig. 11.9).

In this method, the problem of ponding is frequently experienced in areas with height difference in the field and thus equal water distribution cannot be achieved. Surface irrigation method, as a method where salinity and drainage problems are seen, is recommended to be applied in irrigation of plants that are resistant to moisture deficiency in the soil, diseases caused by wetting the root collar and are frequently planted.

Fig. 11.9 Surface Irrigation Method

11.7.2 Drip Irrigation

It is a method with high installation cost, where irrigation water is applied to the soil surface in drops with or without fertilizers, under low pressure (Stevanato et al. 2019). However, since it requires less labor forces and allows automatic irrigation, it is especially applied in greenhouses where initial investment costs are high and in the cultivation of plants with high economic value. The basic principle here is to give the required amount of water to the root zone of the plant at frequent intervals in low amounts without creating stress on the plant. Water is given only to the root zone of the plant instead of the entire soil surface in the form of drops by means of drippers. Drops move vertically and laterally in the soil, wetting a larger area under the soil than on the surface and providing sufficient moisture for the plant roots. It is considered as the method with the lowest water loss and the highest irrigation efficiency. The heart of the drip irrigation system is drippers. The drippers are made of plastic and mounted on pipes with a diameter of 12–32 cm and called lateral. Drippers drop the water onto the soil with a flow rate of a few liters per hour. A drip irrigation system consists of four parts apart from the drippers. These are control unit, main pipeline, side main pipeline, and laterals (Fig. 11.10).

11.7.2.1 Advantages of the Drip Irrigation Method

- Water usage efficiency is high, water loss is also very low due to low evaporation.
- The product quality is high, the development of diseases and pests is less.
- Weed growth is lower.
- Since only the root zone of the plant is wetted, soil tillage, spraying, harvesting, and transportation can be done at the same time during irrigation.
- Weather conditions have no effect on irrigation.
- Fertilization and spraying can be done together with irrigation.

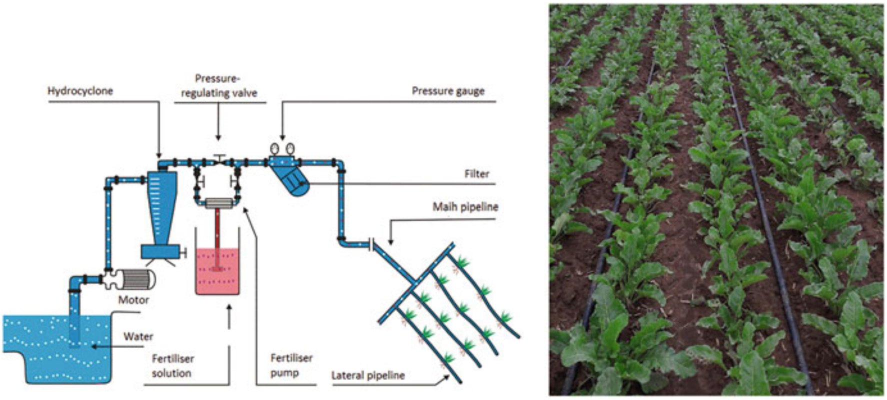

Fig. 11.10 Elements of the drip irrigation system

– It can be applied successfully and easily on sloping lands.
– Labor requirement during irrigation is low.
– It is a suitable method for irrigation automation applications.

11.7.2.2 Disadvantages of the Drip Irrigation Method

– The system is very sensitive to clogging. It is necessary to apply the filtration with precision.
– It can cause salinity problem. For this reason, especially in rainy periods, the system should be operated and the salt should be washed.
– Initial investment costs are high.
– Agricultural practices such as hoeing can damage pipes. Therefore, it is recommended to install the system after the hoeing.
– Not suitable for emergence irrigation.

11.7.3 Sprinkler Irrigation

It is an irrigation system in which water is sprayed in droplets through sprinkler heads under certain pressure. The system works by means of pipes and irrigation heads placed in the field at certain intervals. In order for the water to be supplied under pressure from the nozzles, the water must be taken from a pump or from a high source. At least 2.5 bar is sufficient for the sprinkler system to work effectively. The system generally works as a closed system and consists of the main pipe, side lines, pump, and sprinkler heads (Fig. 11.11).

For an even distribution of water in sprinkler irrigation, a 50–60% overlap is planned in the wetting areas. Since the homogeneity of irrigation deteriorates in windy weather, the headers are placed closer in mandatory situations. For an ideal irrigation in the sprinkler irrigation method, the application should be made according to the physical properties of the soil. Incorrect and irregular irrigation

Fig. 11.11 Sprinkler irrigation system

causes excessive water use, salinity, deterioration of land quality, increased desertification, and economic losses.

11.7.3.1 Elements of the Sprinkler System (Fig. 11.12).

(a) Water source: Stream, lake, caisson well, deep well, pond, dam, irrigation canal are the main sources. The quality of the water is an important factor in irrigation without interruption.
(b) Pump unit: It is the power unit that provides pressure in the system. Centrifugal pumps are common in sources with low suction height, and vertical shaft deep well or submersible pumps in deep wells. The pumps are either powered by fuel or electricity. Electric motor driven pumps have advantages in terms of ease of use and low operating costs.
(c) Pipelines: The transmission of the water taken from the source to the lateral lines is provided by the main pipe, and the transmission of the water taken from the main pipeline to the sprinkler heads is provided by the lateral pipes.
(d) Sprinkler heads: These heads are located in the lateral pipelines. The connection between the lateral pipelines and the sprinkler heads can be adjusted with the riser pipes according to the plant height.

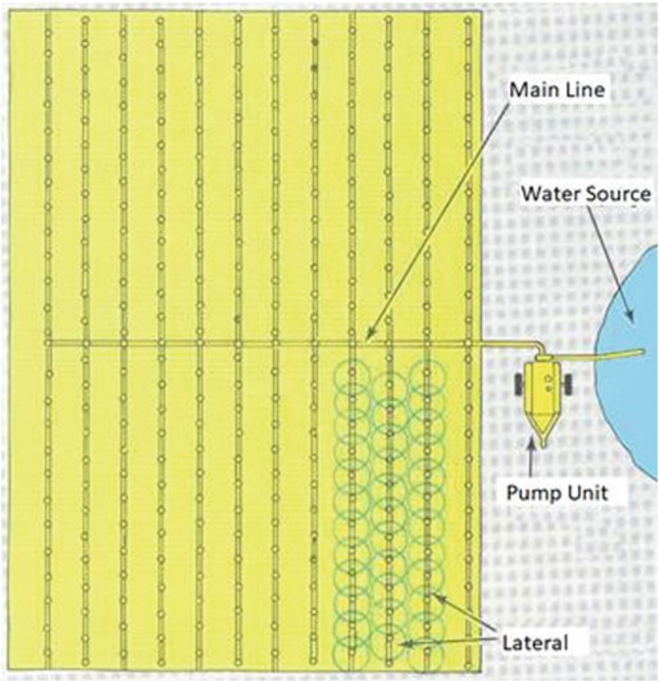

Fig. 11.12 Elements of the sprinkler system

11.7.3.2 Advantages of the Sprinkler Irrigation Method

– High water use efficiency allows effective irrigation even in places where water is scarce.
– It is suitable for irrigation without causing erosion on sloping lands.
– It prevents plant emergence problems caused by slipping.
– Operating cost and labor requirement are low.
– It is the most suitable irrigation system in shallow and permeable soils with low soil depth.
– Salt, dust, and pests in the soil can be washed with sprinklers.
– It has the possibility of controlled irrigation suitable for places with high groundwater and drainage problems.
– The transmission of water through pipes provides easy application opportunity.
– Fertilization can be done with irrigation water.
– It can be used to protect plants from frost and heat.

11.7.3.3 Disadvantages of the Sprinkler Irrigation Method

– The initial installation cost is high, especially in fixed systems (Stevanato et al. 2019).
– Wind has a negative effect on water distribution.
– Power required for pumping increases fuel consumption and operating costs.

11.7.3.4 Installation of Sprinkler Irrigation System

– The main pipes should be parallel to the slope direction.
– Sprinkler lines should be in a vertical position parallel to the leveling curves.
– When the wind speed is high, the lateral lines should be perpendicular to the wind direction.
– Short laterals instead of very long sprinkler laterals reduce labor and provide even water distribution.
– The movement of the laterals on the main line should be arranged in a way that requires the least amount of labor.
– The system should be arranged as square or rectangular as possible so that lateral movements are easy and fewer heads work together.
– The pipe dimensions and layout of the system should be such as to minimize annual costs.
– Having the pump unit in the field is the most economical way of working.

11.7.4 Center and Linear Pivot Irrigation System

Drought, climate variability, and irregularity in precipitation make the sustainability of existing resources even more important. It has become imperative to use limited water resources effectively and to ensure the correct operation of mechanized sprinkler systems in facilities. For these purposes, mobile pivot irrigation systems, whose use is becoming widespread day by day, are divided into two: linear and center pivot irrigation systems.

Center pivot irrigation systems are automatic systems made of galvanized steel pipes, moving from the center, rotating around a fixed tower. The inner surfaces of the pipes are coated with PVC to provide resistance against chemicals. The system moves in a circular rotation on a reinforced concrete platform and performs irrigation automatically. Center pivots can start from 50 m and reach a radius of 1100 m. Thus, one machine is sufficient for 380 hectares of land. In addition, these systems have brought a different and effective usage understanding to irrigation management with their powerful and easy-to-use control panels. The lifespan of this type of systems varies approximately between 25 and 30 years. Irrigation efficiency is as high as 90–95% and it can work on sloping lands such as 15% (Fig. 11.13).

Linear moving irrigation systems have been developed to irrigate geometrically shaped fields. Linear systems can operate effectively on lower slopes such as 4–5%. The systems are 1000 m long and can irrigate up to 98% of the land without leaving any unirrigated areas and operate smoothly. With these systems, it is possible to apply chemical applications together with irrigation, as in sprinkler irrigation systems (Fig. 11.14).

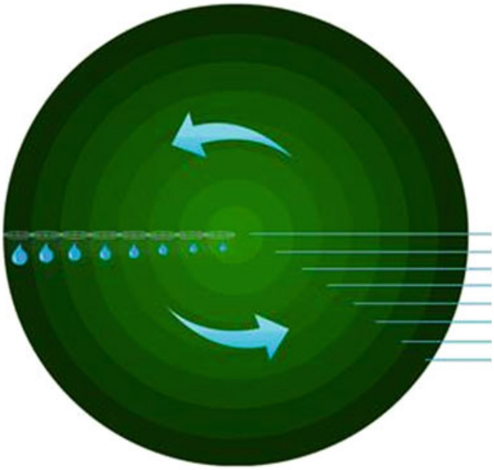

Fig. 11.13 Working principle of center pivot irrigation system

Fig. 11.14 Linear pivot irrigation systems and sprinkler head

11.7.5 Subsurface Drip Irrigation

Subsurface drip irrigation is an irrigation method in which water is given just below the soil surface through point or line source drippers. The materials used in this system, the planning and operation of the method are based on the same design principles as in the surface drip irrigation method. In the method, the laterals are placed under the soil at a depth of 0.02–0.70 m with 0.25–0.50 m intervals. Chemicals are used against clogging due to plant roots (Lamm and Camp 2007). In subsurface applications, no flow or evaporation loss occurs due to the direct application of water to the plant root zone, and the irrigation efficiency exceeds 95%. Within the scope of sustainable water management, subsurface drip irrigation method can be offered as a solution to save water in sugar beet cultivation (Fig. 11.15). In a study comparing linear, sprinkler, surface, and subsurface drip irrigation systems, linear pivot irrigation method gave the best results in terms of

Fig. 11.15 Subsurface drip irrigation applications

beet yield, and subsurface drip irrigation system gave the best results in sugar content and refined sugar yield (Turkseker 2018).

11.8 Crop Establishment

11.8.1 Sowing

Temperature and humidity are the main factors determining planting time. Sowing should be started immediately when soil conditions become suitable for sowing. Sowing should be done in weathered soil at the earliest date when the soil temperature is 5–7 °C, and the possibility of late frost is very low. Accordingly, planting should be started towards the middle of March under favorable conditions in the northern hemisphere and should be completed by April 15 at the latest. In sowing performed after this date, 0.5–0.6 t ha^{-1} daily yield loss occurs (BBRO 2019). In the winter sugar beet cultivation applied in the semi-tropical or tropical climate zone, the most suitable planting time was determined as 1–15 October, and the vegetation period was 195–210 days (Ozgur and Erdal 2002; Gadallah and Tawfik 2017; Gobarah et al. 2019). In winter sugar beet cultivation, the fact that the harvest date coincides with the months of June and July, when the temperature is at its highest, is an important problem and it is necessary to process the beet quickly. Otherwise, high sugar loss in beet silos is inevitable. Tables 11.1 and 11.2 are prepared to assist in selecting row spacing. In the case of planting in rows selected according to field emergence rates in the region shown as dark in the table, the number of plants required per unit area will decrease and the producer will suffer economically. For high profits in beet cultivation, field emergence rates and in-row spacing should be determined correctly.

Table 11.1 Number of plants per area in 45 cm row spacing in case of no double and missing seed (×1000 ha−1)

Seed spacing (cm)	Number of sowing seeds	Field establishment rate (%)				
		40	50	60	70	80
8	278	111	138	166	194	222
10	222	88	111	133	155	177
12	186	**74**	92	111	129	148
14	159	**64**	**79**	95	111	127
15	148	**59**	**74**	88	104	118
16	139	**56**	**69**	83	97	111
17	131	**52**	**65**	**78**	91	104
18	123	**49**	**61**	**74**	86	98
19	117	**46**	**58**	**70**	81	93
20	111	**44**	**55**	**67**	**78**	89
21	106	**42**	**52**	**63**	**74**	84

Table 11.2 Number of plants per area in 50 cm row spacing in case of no double and missing seed (×1000 ha^{-1})

Seed spacing (cm)	Number of sowing seeds	Field establishment rate (%)				
		40	50	60	70	80
8	250	100	125	150	175	200
10	200	80	100	120	140	160
12	167	**67**	84	100	117	134
14	143	**57**	**71**	86	100	114
15	133	**53**	**67**	80	93	107
16	125	**50**	**63**	**75**	88	100
17	118	**47**	**59**	**71**	82	94
18	111	**44**	**56**	**67**	**78**	89
19	105	**42**	**53**	**63**	**74**	84
20	100	**40**	**50**	**60**	**70**	80

In the literature, it has been determined that the optimum plant density for the highest yield and quality is 80,000–100,000 plant ha^{-1} (Jaggard et al. 1995; Ecclestone 2011). Nowadays, in many countries where beet planting is carried out, in order to provide 80,000 ha^{-1} beets, the row space is 45–50 cm, and the distance is 20 cm. Seed germination rates have increased significantly in recent years. Accordingly, if 80% field germination is obtained, 89,000 plants ha^{-1} is provided at a 20 cm row planting distance. Depending on the agricultural technique applied in the period from singling to harvest, 12–20% of the existing beets are lost due to agricultural applications and pest damage. The amount of seed needed in planting should be calculated by taking this into consideration. With plant numbers above 100,000 plant ha^{-1}, high yields can be obtained, but high profits may not be obtained. It is not possible to obtain high yields with plant numbers below 80,000 plant ha^{-1}. The most suitable plant number for high yield and high quality

Fig. 11.16 Mechanical and pneumatic precision sowing machines used in sugar beet cultivation

sugar beet production has been determined as 100,000 plant ha^{-1} by the British Beet Research Organization (BBRO) (BBRO 2019). Seed distances are an important factor that determines the production quality of sugar beet. It is important that the seed is placed on the row properly, which will have an equal living space according to the structure, texture, and soil weathering conditions. Sowing depth is 2.5–3 cm on average (Fig. 11.16). In arid regions and light soils, a roller can be offered as a solution to increase the planting depth by 1–2 cm, to prevent evaporation when necessary and to ensure the contact of the seed with the moist soil (Fig. 11.16) (see Fig. 11.17).

Sowing speed is also important in terms of determining the evenness of seed distribution in row. The optimum sowing speed should be 4–5 km h^{-1}. Before planting, a proper seedbed should be prepared, and a good soil structure should be provided. Especially in clay soils with low organic matter content, too thin soil surface due to improper or excessive processing will reduce field emergence and cause losses. In addition, the formation of a crust layer on the soil after rain or emergence irrigation should be considered as a factor that will cause losses in this context. The shoot that emerges from the seed forms a yellow fold in a way not to exceed the crust layer; therefore, sufficient field emergence cannot be provided and the desired result cannot be reached. In case of dry sowing in fields where soil weathering is not suitable, 15–20 mm exit irrigation should be done immediately by sprinkling. With timely planting and field emergence, sufficient vegetation period will be ensured, sufficient technological maturity will be achieved and finally high quality beet production will be achieved.

Practical applications such as strip processing and direct drilling for sugar beet are becoming widespread for reasons such as ensuring sustainability in agriculture, protecting soils from erosion, and reducing soil processing costs (Fig. 11.18). In strip tillage, time and energy are saved by tilling only the sowing rows. In the direct drilling method, the plant residues on the planting line are crumbled in a way that

Fig. 11.17 Roller application

Fig. 11.18 Field tilled with the strip tillage method

does not affect the germination of the seed, and the furrow is cleaned for sowing (Fig. 11.19).

11.8.2 Plant Population

In the period when the beet has four to six leaves, ten rows are counted in different parts of the field and the average number of plants is found:

50 cm row spacing.

Plants per 20 m row $\times$ 1000 = plant population (000 plants ha^{-1}).

45 cm row spacing.

Plants per 22 m row $\times$ 1000 = plant population (000 plants ha^{-1}).

Fig. 11.19 Types of direct sowing machines used in sugar beet cultivation

For an ideal structure, 900–1200 cm^2 of living space is sufficient for each plant. This area is regulated by thinning and singling. After the beet emerges to the field surface, plants can be found at a distance of less than 17 cm. Seedlings at distances less than 17 cm should be thinned, and plants closer than 5 cm should be singled out and brought to equal in-row spacing. Thinning is the arrangement of narrow plant spacing on the row, and singling is the reduction of multiple plant shoots to one due to double seed filling in seed holes during sowing. In ideal production conditions, there should be 80,000–100,000 ha^{-1} plants in the land after thinning (Jaggard et al. 1995; Ecclestone 2011). In cases where the plant density falls below 60,000 plant ha^{-1}, if the time is not too late for the beet to complete its growing period, replanting is necessary to increase production. In this case, soil fertility, seasonal conditions, and irrigation possibilities should be considered.

Plant density is a controllable factor that determines the level of production. The low plant density, that is, the distance between the beets in the field, causes an increase in the nutrients that each plant will receive and causes it to grow too much. Overgrowth, non-sugar substances increase in plants, while sufficient sugar accumulation slows down and quality deteriorates. As the spacing in the row increases, the proportion of plant leaves decreases and the water loss in the soil increases. The reason for the sparseness may be the germination power of the seed, pesticide, field emergence, sowing distance in the row, pests, seedbed preparation, frost after planting, improper hoeing, disease, and drought. A good seed bed preparation and suitable weathering increase field yield, and homogeneous plant density is achieved.

11.8.3 Weed Competition and Hoeing

The soil surface remains empty for 1.5–2 months until the development in the initial period is slow and the beet covers the field completely by expanding its living space. Weeds grow very quickly by using air, water, and nutrients quickly, and they can reduce the habitat of other plants and make them unproductive and cause losses. In addition, they create a living environment for pests and increase losses in mechanical harvesting. The most effective method of weed control is hoeing. Although the inter-

Fig. 11.20 Sugar beet hoeing with inter-row hoeing machine

row hoeing machine is preferred against weeds, it is more effective when applied in combination with the in-row tape herbicide application (Fig. 11.20).

Hoeing is an effective tool for breaking the crust layer and controlling weeds. Depending on the weed density and precipitation conditions in the field, two or more hoeing can be done. The first hoeing is carried out when the rows are clear with the start of the seedling emergence. Second hoeing can be done within 15–25 days under suitable conditions after thinning-singling. Weed control with hoeing greatly affects the root yield of the beet. Hoeing has an important role in providing a clean field in order to realize quality production by reducing harvest losses. The combined use of mechanical and chemical weed control methods at certain rates increases the effectiveness of weed control (Kaya and Buzluk 2006).

11.9 Future Prospects

Technological and genetic studies carried out in sugar beet strengthen the thoughts that the increase in production will continue. Developed technologies in tillage, cultivation, and other agricultural practices support increases in crop production. Establishing a deep root structure and meeting high water needs are absolutely essential, among other factors, for high production. Another issue is finding solutions to prevent sugar losses during storage after harvest.

By developing agricultural techniques and applied methods in sugar beet cultivation, 24 t of sugar ha^{-1}has been obtained in field trials. Although it is stated that there are still many unfavorable conditions to achieve this yield in field production, it is known that there is an opportunity to reach this goal agronomically (Hoffman and Kenter 2018). However, the biggest threat to reaching this potential is shown as possible future climate change. It is estimated that the risk of drought, the intensity of diseases and pests will increase with climate change (Kremer et al. 2016). Increased production, prolongation of beet processing times, earlier beet harvest and longer storage periods are the situations where losses are expected to increase (Hoffman and Kenter 2018). In summary, it is foreseen that efforts to accelerate processing times, improve storage properties, reduce processing and storage losses, and increase production will intensify.

11.10 Conclusions

Despite the high energy requirement in its production, sugar beet is an important product with its feature increasing the yield of the next crop and increasing soil fertility in the crop rotation cycle. In addition, by-products of sugar beet constitute an important input used in bioethanol production and animal nutrition. In this respect, it can be said that beet is a strategic energy crop. In sugar beet producing countries, beet yield varies between 60 and 140 t ha^{-1}, and digestion varies between 16 and 18%. These values are not considered sufficient, and higher values are aimed with new agricultural techniques and genetic studies. It is estimated that this target can be achieved if new techniques are developed and sufficient water is provided, in addition to the agricultural techniques practices required for the supply of 100,000 plant ha^{-1}.

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