Economical Crop Production and Management of Sugar Beet in Serbia and Montenegro

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Abstract

Sugar beet (*Beta vulgaris* L.) is a member of family *Chenopodiaceae*. It is a crop of area of temperate climate and second of world importance sugar crop, after sugar cane (*Saccharum officinarum* L.). It is mainly produced in Europe and to a lesser extent in Asia and North America. Sugar beet quality is a complex trait conditioned by genetic divergence among cultivars and environmental diverse in the region of growing. One of pertinent agro-technical measures is sowing. Proper sowing (which is during March in the Republic of Serbia and Montenegro) ensures optimal crop density which is important for reaching a high yield. The correct choice of assortment for a certain production area contributes to a larger and more stable production of cultivated plants.

A significant measure of growing technology is properly balanced plant nutrients. NPK mineral nutrients are the main carriers of yield value. Sugar beet

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yields are significantly reduced by lack of soil nutrients. The main nutrient elements—nitrogen, phosphorus, and potassium—have major importance in plant nutrition and the greatest impact on increased technological and yield value of root. Ratio of mentioned nutrients and also the secondary and microelements should suit to the needs of plants and to the natural soil fertility. Yield of crystal sugar, as major production value indicator, has statistically very significant dependence of way of plant nutrition, years, genotype, and their mutual interaction. Intensification of plants nutrition with NPK fertilizers significantly increases the total vegetative biomass yield and root sugar content.

Keywords

NPK nutrition · Growing technology · Production · Sugar beet · Yield

Abbreviations

ETP	Evapo-Transpiration Parameter
pF	Capillary Potential

12.1 Introduction

Sugar beet (*Beta vulgaris L.*) belongs to the family *Chenopodiaceae* and is considered as crop of the temperate region and second, by importance, crop for sugar production worldwide, after sugar cane (*Saccharum officinarum L.*). It is mainly produced in Europe and to a lesser extent in Asia and North America. Sugar beet is a relatively young agricultural crop although it is known as a garden plant as far back as 3000 years ago.

The benefits of its cultivation are multiple and are reflected in its importance for the population nutrition, positive influence on industry, and agro-culture production. The economic value of sugar and other products which are obtained from sugar beet is very high, in comparison with many other field plants. Economically profitable production requires yield higher than 40 t ha^{-1}. For achieving this and more, the production technology must rise to higher level. The technical properties and value of yield of sugar beet depend on: agro-climatic factors, soil, (structure, composition, and cultivation), and cultivation technology (choice of variety, sowing, providing adequate irrigation nutrition, crop protection, and extracting time). Sugar beet quality is a complex parameter, conditioned by genetic differences among grooving sorts and also by different environmental conditions of growing region (Rosso and Candolo 2001; Ćurčić 2014; Bojović et al. 2014; Bojović et al. 2019a, b). It should be emphasized that proper plant nutrition will increase the yield with no negative influence on technological parameters of the roots.

In Serbia and Montenegro, there are favorable soil and agro-ecological conditions for sugar beet production. These conditions are defined by the presence of excellent arable land, relatively favorable conditions of weather and built processing capacities. In Vojvodina, sugar beet is grown mainly on larger agricultural farms, and the reason is using the specific mechanization of production technology and for achievement of better financial results on larger production surface areas (Vlahović et al. 2006).

12.2 Soil Properties and Preparation

12.2.1 Soil Requirements

Sugar beet belongs to the group of plants with the greatest demands from soil. This is understandable considering that its root fully develops in depth of it and for it creates a large organic mass. Soil should be deep, rich in organic matter, good physical properties (structural), loose and fertile. Heavy, compacted, and impermeable soils do not suit the crop, same as too light and sandy soils, which are usually poor in humus. Therefore, best suited soils are: chernozem, alluvial soils, lighter vertisols, and brown forest soil. With modern agricultural techniques (cultivation, fertilization, drainage, irrigation), high yields can also be reached on other soils.

Physical-mechanical properties that affect the water-air-, heat, and biological regime are important for cultivating sugar beet. Plants need a crumbly and stable soil structure. Those soils that quickly lose their structure, increase their compaction, and become unfavorable for production. Excessive compaction soil has negative effect on formation of correct root shape and plant productivity. The optimal air capacity depends on soil moisture and decreases by its increase. The bulk density has variable size and indicates soil compaction. During sowing, at the start of vegetation period, it has lower values; later, the soil subsidence occurs, so it is higher on vegetation termination. On chernozem type soil, the optimal volumetric mass ranges from 1.1–1.3 g cm^{-3}. Only on soils of high fertility, on deep arable land with good physical traits and with neutral to weakly alkaline reaction high yields are obtained. The soil needs to be with good water regime, be permeable, should have the ability to store winter moisture, and groundwater level should not be higher than 1.2 m.

Stanaćev (1979) claims that sugar beet, as a highly productive plant, reacts very much on soil traits. This reaction is manifested in intensity of energy of growth, modification of morphological characteristics, and technological characteristics of its above ground and underground part. Milošević et al. (1989) point out that with favorable climatic conditions, good sugar beet yields can be obtained only on soils of good natural fertility, deep arable layer, favorable mechanical composition, optimal physical-chemical and biological properties.

Sugar beet grows on all continents at different soil types.

For making the right choice of land for cultivation, we must know its requirements from the soil. Stanaćev (1979) emphasizes that the land profile is of special importance. Sugar beet requires a favorable profile structure and its differentiation into genetic horizons or layers. Of special importance is the horizon number, expressiveness, transition from one horizon to another, profile depth, and properties of the parent substrate. Horizon characteristics, such as mechanical composition, porosity, and structure, determine the suitability of the land.

In general, soils with pronounced textural differentiation and compacted layers cannot be considered suitable for it. Soils are considered compacted when the porosity is so low that it reduces soil aeration, interferes with the roots penetration and normal soil drainage. Natural compactness of soil is not only conditioned to their mechanical composition, water regime, or way of origin, but it can also occur as a consequence of using heavy mechanization. Compaction adversely affects water, air, and heat regime of the soil, its biological activity, and the plant in general. Sometimes, anaerobic conditions and water stagnation in the active rhizosphere occur, when, according to Luthin (1966), appear a limited growth of the root system and lot of harmful phenomena that accompany it, lack of oxygen, the appearance of a number of toxic, reduced mineral and organic compounds, anaerobic and slow decomposition of organic matter, with nitrogen remaining organically bound, poor heat regime, the appearance of plant diseases, especially fungal.

Hadzic (1984) states that occurrence of compacted layers, especially if they are in root development zones cause a lot of undesirable consequences. For root then it is difficult to break through, it becomes forked, the thickened root is shorter, and lower yields of poorer quality are achieved.

Factor of fertility is also the soil total and differential porosity. Soils with a total porosity above 45% vol. are suitable for sugar beet growing, while soils with porosity lower than this are considered unhealthy for root system growth. However, differential porosity is also important, i.e., presence of pores of different dimensions which ensure good soil drainage and retention of a certain category and shape of water accessible to plants. According to Kačinski (cit. Živković 1983), the optimal porosity in the arable layer of loamy and clayey soils is 55–65% vol.

We should notice that soil compaction is not always harmful. For example, after sowing, moderate soil compaction ensures better seed-soil contact and increases soil water conductivity. Beside the number and arrangement of layers, their depth must be taken into account for is often the deciding factor for choice of what species to grow. Sugar beet prefers deep soils with a deep humus-accumulative horizon. Skeletal, sandy, or clay soils do not suit. At lowland areas, soils with a profile depth of 100–200 cm are considered deep. It is especially important how deep the physiologically active layer is. For that reason, today, on all those surfaces where the conditions allow, the physiologically active soil layer should be deepened. Impact of mechanical composition of soil can be direct in providing resistance to root penetration and indirect in affecting the soil's water, air, and thermal regime. In sandy and skeletal soils, growing of plants is difficult because of low moisture and not much of nutriments. Extremely clay soils, if they do not have a favorable structure, are compacted, have increased water capacity and unfavorable water-air regime.

Concerning mechanical composition of soil, those with an appropriate ratio of sand, powder, and clay fraction and also a quality of that clay affects the sugar beet. If montmorillonite clay prevails, wide and deep cracks appear at dry period, root system becomes damaged, so when wet period comes, due to drein, anaerobic conditions occur and the plants suffer from lack of oxygen. If the stones and gravel are present in soil, it leads to irregular root growth and its branching.

Soil structure, more precisely its type, is also important. The best are those soils that have a crumbly and granular structure that are also characterized by reduced impact of water dispersion on them and thus provide a continuously favorable water-air regime, while the one-particle structure (in sands) and the coherent structure (in heavy clay soils) are not suitable.

The root system requires normal breathing conditions for normal growth. Lack of oxygen reflects on plant development and can end with decay of plants. The percentage, structure, and rapidity of air renewal in the soil are important. Even before 1927, Kopecky (cit. Baver 1966) pointed out requirement of some plants for air capacity and gave, for sugar beet, limit values of 15–20%, which makes it very demanding for this parameter. In the modern literature, optimal capacity is water–air 1:1. Sugar beet needs good air permeability in arable layer. Soils in which pores less than 0.2 μm predominate is not desirable for air capacity for sugar beet. Beside the amount, the air structure has high importance. Relation between CO_2 and O_2 is variable and depends on root respiration, soil microbiological activity, and the possibility of air renewal. The O_2 content varies from 0.1 to 20% and the CO_2 from 0.1 to 15%. For normal plant growth, the O_2 content has to be more than 10% and growing stops at 5%.

Beside the water-air regime, the soil temperature is of special importance, because it determines the intensity of physical, chemical, and biological soil processes. In addition, each plant species has certain requirements for soil temperatures for optimal development and tolerance limits. Based on their thermal properties, we divide all lands into hot and cold. Cold soils are not suitable for sugar beet growing. Sarić (1971) states the following biological minimum: for the appearance of sprout 2–3 °C; formation of vegetative organs 2–3 °C; formation of generative organs 8–10 °C; fruit formation 10–12 °C. Živković (1983) states that the soil temperature is required for beet germination 3–4 °C while appearance of shoots need 6–7 °C.

Suitable for sugar beet cultvation are medium (3.1–5.0%) to strong (5.01–8.0%) humus soils well provided with calcium. Muckenhausen, cit. Zivkovic (1983). The level of saturation with adsorbed bases, predominantly Ca, should be greater than 90%, while adsorbed sodium or hydrogen is not desirable. Neutral or slightly alkaline soils are suitable (Sarić 1971, pH = 6.5–8; and pH = 6.5–7.2 in nKCl). In addition, the adsorption capacity is of importance and should be higher than 30–40 eq.mol ×/100 g (these have the subtypes and varieties of our chernozem). Zivkovic (1983) emphasizes that redox-potential is important because it affects the soil nutrients. Manojlović et al. (1989) indicate that it should done soil tillage and fertilization that would not lead to damage to chernozem and diminish in its natural fertility (Table 12.1).

Table 12.1 Physical and water–air properties of chernozem in South Banat, Vojvodina

Volume (%)						
Depth	Bulk density g/cm^3	Specific mass gr/cm^3	Total porosity	Max. Water capacity	Water accessible to plants	Air capacity
0–20	1.45	2.67	45.69	44.23	16.15	11.94
30–50	1.45	2.70	48.30	45.15	16.97	11.42
60–80	1.39	2.71	48.71	46.90	19.70	10.11
100–120	1.48	2.75	46.18	45.00	16.93	11.97

Production, beside soil properties, depends on the climate, plants, man, and about improvement of soil characteristics, which is increasingly done in relying on technical capabilities and new knowledge in field of plant growing and science.

12.2.2 Fertility

Fertility of soil is its ability to simultaneously supply plants with water, nutrients, oxygen, and adequate heat throughout the growing season. For normal root growth, soil should be loose and not contain any harmful substance. Fertility is a complex feature of soil that depends on numerous factors as follows:

1. Pedogenetic processes determine the direction and intensity of processes of soil genesis, and in connection with that, they predetermine the characteristics and regimes of the soil.
2. Composition and properties—morphological, physical, chemical, and biological. These include assembly or profile structure, characteristics of individual horizons—layers, profile depth, depth of physiologically active layer, characteristics of individual layers (mechanical composition, structure), specific masses, porosity, water, air, and thermal regime and properties, and physical-mechanical properties. Also, fertility depends on chemical structure of soil solid phase (mineralogical, composition, and properties of humus), characteristics of soil colloids, sorption capacity, acidity and alkalinity, solution, buffer capacity, plant-accessible macro- and microelements, composition of adsorbed cations, presence and absence of toxic substances, soil salinity, i.e., percentage of total and water-soluble salts, content of reduced compounds and gases.
3. Biological factor includes the number and structure of soil microflora and microfauna.
4. Anthropological factor is factor of greatest importance for fertility of arable areas.

12.2.3 Land Tillage

12.2.3.1 Basic Tillage

Soil conditions directly affect the yield during the sugar beet growing because the correct processing provides optimal conditions, longer vegetation, and easier extraction. For that reason, the loosely plowed layer is needed. While growing, a large amount of organic matter is produced and for that production, beside nutrients, enough water is needed. As there is an insufficient or uneven distribution of precipitation in growing season in our climate, soil must retain a larger amount of atmospheric precipitate. This indicates importance of basic tillage. Sugar beet, more than other crops, needs appropriate method, time, depth, quality, and timeliness of tillage. Using heavy mechanization for tillage and transport could damage land composition and a prolonged bad influence in growing subsequent crops can occur (Milošević et al. 1989).

Tillage, if it comes after small grain (which is very usual) could be:

1. Peeling stubble about 15 cm deep.
2. Shallow plowing to a depth of 20–25 cm, with fertilization in early August.
3. Deep plowing to a depth of 30–35 cm (difference is affected by arable layer depth) with fertilization during September.
4. Fertilizing can be one-time.

The benefit of this treatment is multiple. A stable structure of deep loose layer is created, a horizontal and vertical mixing is provided, and if harvest residues are plowed and organic nutrient is added, their layered presence is ensured. Repeated treatment reduces weeds and pest populations and increases population size of beneficial organisms.

Tillage for production intensification was relied on the system of plowing and is doing this way: three plowings with gradual deepening of the arable layer to a depth of 45 cm and with manure applying. Increase of yield by plowing on deepness of 35 cm comparing one on deepness of 25 cm was 10.2%, and for a deepness of 45 cm 15.8%. Stanaćev (1963) proposes three plowings at a depth of 45 cm with the introduction of 1 ton per ha of manure at every 1 cm depth of plowing. Justification of investing in tillage, even if it would lead to an increase in yield is debatable. Therefore, such processing is waived. On some plots manure is used every 30–40 years. By omitting manure, the plowing quality decreases, the appropriate depth is not achieved or the time and interval of performing certain operations do not count. Excessive use of pesticides and herbicides decreases the soil biogenicity. From earlier processing of arable land, only the mixing and overturning of the arable layer remained. By newer understanding, more intensive cultivation is opposite to stability of structural soil aggregates. Therefore, aiming to reduce trampling and deterioration of structural and biogenic soil traits more advanced way of protective tillage was in use. The domain of such processing includes the cultivation of certain plants as the basic crops, intermediate crops for green manure or mulch, and production per system of permanent traces. The system of permanent traces is such that it separates the production surfaces from the surfaces that are trampled by machines. Savić (1989) found that the yield minimization begins with an increase of soil-specific mass over 1.4 t m^{-2}. Trampling soil could be decrease by performing all agro-technical operations at optimal time, related to soil humidity, by aggregating tools, merging of operations, reducing the protection operations, using appropriate pneumatics better organization of extraction, etc.

Lighter soils do not resist to roots permeation, but require more fertilizers, and since they are weaker structures, they do not retain longer the benefits of deep and intensive cultivation. Usually, these soils are in more humid areas, so reduced cultivation is justified.

In Serbia and Montenegro, it is possible to reduce tillage that would correspond to sugar beet cultivation. Instead of this is use of under-digging instead of deep plowing. The under-digger with the feather system does not overturn the soil but shakes it. It is performed at a depth of 45–70 cm. After under-digging, tillage at 30 cm is recommended. On soils of heavier mechanical composition and shallow and uneven shallow arable layer, under-digging enables greater accumulation of water, increases the porosity of deeper layers, and enables deeper penetration of basic root into depth. The achieved conditions enable good yields on less productive lands as well. Rožić (1989) examined the influence of under-digging at a depth of 20, 30, and 40 cm combined with plowing at 20–25, 30–35, and 40–45 cm, respectively. In all variants, the surface treatment was disking. The best results were achieved by plowing at 20–25 cm and under-digging at 40–45 cm. Increasing plowing depth over 35 cm has no significant impact on yield. In 4-year experiments, using under-digging instead of deep plowing led to an increase of yield by 13% on an average.

12.2.4 Pre-Sowing Treatment

For sugar beet sowing, sowing layer preparation is important because it aim is, could provide water contact from deeper layers and be moist to make it ready for sowing. Upper part should be loose and provide aeration and heating. The main goal is to ensure fast and even seed germination and rapid and uniform seed germination. The sowing layer should have three parts: loose, 2–3 cm thick above the seeds and compacted, 3–4 cm thick and then, loose again. Very often, the loose layer is achieved at a greater depth than necessary for sowing seeds. For good preparation of pre-sowing surface is important quality basic processing. At our region, it is often poorly performed for several reasons: previous trampling, untimely harvest, inappropriate plows, bad training of plowmen. After poor plowing, more passes are needed with surface treatment tools. Very often, using of leveler is required. Although this increases production costs, poor plowing causes the surface layer to become excessively crushed during the winter period and turn into dust by frost. At spring, the rain causes the bark occurrence, so germination is very weak. In order for smaller as possible treatment of surface, starting fertilization is increasingly omitted and some of the operations are moved to the period before winter. The land planned for cultivation should enter winter smoothly, without major ridges and depressions. Also, it must not be too finely chopped. The worst thing for the soil is to enter the winter with open furrows because this would require several passages more in the spring with seedbed tiller, and the loss of winter moisture would be inevitable, and the basic aim is to ensure germination and sprouting from winter moisture. Unnecessary trampling with hard machinery should be avoided. One pass more with a seedbed tiller at spring means 5–10% less emergence in field. When surface is left uneven during the winter, at spring the flattened part is undressed and creates a very thick loose layer and at ridges a compacted unfrozen layer exists (Bojović 2014), and so the germination and sprouting becomes uneven.

On sufficiently leveled soil, using the seedbed tillers in one pass is justified because sprouted weeds are destroyed with it, eliminate ascending water flows and create equal conditions for each seed. Ideally, deepness of pre-sowing preparation should be 4–6 cm. On deeply prepared soil, it is impossible to carry out the optimal sowing depth and, in such condition, up to 25% of seeds are sown deeper than 4 cm.

Beside the depth, importance is given to define the correct start of work, for too much of moisture leads to structural change of soil. Starting of surface preparation in our conditions is after the middle of March. With combined crumbs, best results can be achieved.

12.2.5 Nutrient Requirement, Nutrient Deficiency, and Management

12.2.5.1 Sugar Beet Nutrients

Soil fertility for growing a crop is important. It is necessery to known what of soil properties do plant requires.

All fertility factors have equal importance. The deficiency of one factor cannot be recompensed with another, while vegetation period lasts, the fertility of the soil must be at high level, because only in that way can be achieved a high and stabile yields of appropriate quality. Ljubomirovic et al. (2006) followed adding of NPK fertilizers to chernozem for 34 years and found that largest amounts of fertilizers (130,130,130) increased the amount of humus, phosphorus, and potassium; amount of 50, 50, 50 maintained content at initial level, while not using mineral nutrients reduced their level. Long-term use NPK fertilizers affects rising of acidity and decrease of bases amount at adsorption complex, the change in contents of some biogenic elements, but not of accessible microelements (Martinović et al. 1999).

12.2.5.2 Sugar Beet Nutrition

One of the main measures of sugar beet production technology is properly balanced plant nutrition. For high yields accomplishment, not only higher mass of roots and leaves, but also of sugar, plants must be provided with significant amounts of plant assimilates, in a form that is easily accessible to plants. The main nutrients—nitrogen, phosphorus, and potassium, have the greatest importance in plant nutrition and have an impact on yields and increased root technological value, as pointed out by numerous researchers. It is not a unique sugar beet plant nutrition system, because the needs of for certain elements depend on climatic conditions, soil, cultivation methods (natural water regime, irrigation) and growing varieties. In a 3-year average, in Vojvodina, best results were obtained using of 130 kg ha^{-1} of N and 100 kg ha^{-1} of both potassium and phosphorus (Bojović et al. 2014).

The first success in increasing yield was recorded with application of manure (Lidecke and Muller 1965). By acceptance of Liebig's mineral nutrition theory, higher use of mineral nutrients in sugar beet production began. The profitability of direct nitrogen fertilization has been proven by Hellrigel, Marker, Remmy, and other scientists (Buchner 1951). Using of potassium salts began in the 1960s, and so the superphosphate. Amounts of needing macro- and microelements were determined locally, by soil analysis or by symptoms of deficiency in plants. Over time, complex fertilizers are created, the required doses are determined, and the foliar form of fertilization is introduced. The last preoccupation of various scientists is finding of optimal fertilization for maximize yields. For achieving that, nutrients need to be inserted as organic and mineral form. As Draycott (1972) points out, the basic foundations of proper and comprehensive plant nutrition were given by scientists in the 1930s when they studied the mechanism of assimilation of certain plant assimilates and their role in the synthesis of organic matter in plant tissues and sugar accumulation in roots.

Buchner (1951) concludes in his research that nitrogen is a nutrient element of highest importance for plants, and Brandeburg (1931) emphasizes the great role of calcium on acidic and boron on alkaline soils. These studies have diminished the significance of organic nutrients. Despite a significant impact on improving the general soil condition, manure and nutrients of organic origin are a small source of the main nutrients that are slowly released to the forms adoptable to plants. Stanacev (1979) studied manure influence combined with mineral nutrients at different tillage depths. In this study, he finds that use of manure produced minimal increase in root yield. Similar results are stated by Glamoclija (1986), where in examines, 40 t ha^{-1} of manure which was used with mineral nutrients had a small influence on sugar beet because production result was 3.9% higher. In his research, Marinkovic et al. (2001) found out that, on average, applied manure brought higher yield unlike the ones where mineral fertilizers were applied. NPK mineral nutrients are the major carrier of yield of sugar beet. The content and percentage of the major, secondary and microelements elements of nutrition, should suit to the needs of plants and to the natural soil fertility. No single plant nutrition system exists because the need for certain elements depends on climate, soil, cultivation methods (natural water regime, irrigation), and the varieties. It is believed that all three major elements of nutrition are of equal importance for the plant at the beginning of the vegetation, while later, nitrogen and phosphorus are considered important. The quantity and relation between main elements in soil depend on its fertility. Thus, on medium-fertile soils, these assimilates ratio is 1:0.8:1.2. Kuzevski et al. (2008) examined how different portion of NPK influences the chemical composition of root and concluded that mineral nutrition had the biggest influence on sodium content, significantly on α-amino nitrogen and percentage of sugar while potassium showed dependence on other factors, which were not controlled in this experiment.

Most authors conclude that nitrogen, as nutrient, is the carrier of root yield. Lüdecke (1953) from his examining concluded that for high production 120 kg ha^{-1} is the optimal amount of nitrogen. Glamočlija (1986) concludes that increase in nitrogen increases yields of both: sugar and the harmful nitrogen, which diminishes sugar beet quality. Studies by Barocka et al. (1972) showed that increased intake of nitrogen increases the amount of harmful nitrogen, potassium, and sodium, but that higher plant density reduces the bad influence of this excessive nutrition. Trzebinski (1974) in his research found that every 50 kg ha^{-1} of nitrogen reduced sugar content by 1–3%. Holmes and Devine (1976) tested nitrogen levels of 0–201 kg ha^{-1} in 74 experiments that was conducting during 1966–1974. They found that by every kg of consumed nitrogen, sugar yield increased by 20 kg (control—23.7 t ha^{-1}; variant with 201 kg ha^{-1} 44.5 t ha^{-1}). The optimum economy investment was by adding 100 kg ha^{-1}nitrogen. Graf and Müller (1979) recommend application 140 kg of N for agro-ecological conditions in Austria, while Glamoclija (1986) considers that optimum in medium-fertile soils is 100–160 and, on poor, 140–220 kg of N per hectare. Zocca (1982) recommends using 80–100 kg ha^{-1} of nitrogen on soils rich in organic matter in Italy, and on soils low in organic matter should be increased to 120–140 kg ha^{-1} and more than 140 kg of ha^{-1} on lands that are poor in humus (the area of central and southern Italy). Based on numerous research, Milovanović (1984) concluded that at nitrogen quantities higher than 100 kg ha^{-1}, in Srem (Serbia), there is no increase in the root yield, and the sugar percentage decreases, while, by the way, highest by using of 80 kg/ha of nitrogen. Troncoso and Cantos (1990) found that excessive nitrogen use has an adverse impact on the root technological value. Jaćimović et al. (2006) found that high quantity of nitrogen negatively affects refined sugar. Marinković and Crnoborac (1993) conclude that high yield demands proper nitrogen nutrition based on the N-min method. Adding nitrogen above this amount, in the agro-ecological conditions of eastern Srem, rich in chernozem, significantly minimizes percentage of sugar in root.

The phosphorus affects less of the rise of root production than nitrogen. Jelešev (1969) found out that ammonium phosphate gives a higher root yield (59.8 t ha^{-1}) than superphosphate (52.96 t ha^{-1}) and liquid nitrogen-phosphorus fertilizers (52.01 t ha^{-1}). Jekić (1974) states that phosphorus has a greater impact on improving beet root quality and less on the quantity. As Stanaćev (1979) points out, ammonium phosphate is more suitable than superphosphate.

Numerous results of using potassium related on the sugar beet production properties emphasize its great importance, since it is absorbed by plants in large quantities. Central and Western Europe are poor in potassium so higher amounts of this element in plant nutrition are recommended. Studies in Serbia have shown a small influence of potassium on sugar beet productive properties. More intensive potassium nutrition increases the tolerance of sugar beet to pathogens and drought, but also increases "non-sugar" content in the juice. Bornscheuer (1970) states that increasing potassium nutrition significantly increases its share (but sodium also) in juice, but also decreases refined sugar amount. Kessel (1984) found that, in molasses, 65–75% is potassium. Relation potassium–nitrogen was also subject of many science works. By intensively adding potassium, in Western Europe, a significant

Table 12.2 Take out in kg ha^{-1}

Parameter	N	P_2O_5	K_2O	Na	Ca	Mg
1 t of root	1.8	0.3	1.5	0.1	0.5	0.4
1 t above ground part	3.2	0.4	4.3	1.6	1.3	0.6
1 t root + above ground part	4.5	0.6	5.2	1.5	1.6	0.8

rise in production was noticed, only if potassium salts without sodium were used (Draycott 1972). Potassium–nitrogen relationship was also examined by Todorčić (1974) and he found that the right chosen ratio of K and N in certain production conditions has a favorable impact on the rise of production per hectare. The top results were at the ratio K: N = 1:1; 1:1.2, all the way to 1:2.

A large number of researchers state that intensification of mineral nutrition has justifications in irrigation conditions because the utilization of plant nutrients is higher in a favorable water regime. Vučić (1992) emphasize the positive effect of nutrition and watering in vegetation period on rise of productive and technological value of roots.

The latest research shows other ways of plant nutrition. Plant nutrition could be enhanced indirectly with non-symbiotic bacteria (Milošević et al. 1999). Hardy and Eagleshaw (1995) point out that using of nitrogen in the world in recent years has increased 27 times and that it is possible to replace it with 20–60 kg ha^{-1} of non-symbiotic nitrogen fixers.

Large amounts of NPK fertilizers lead to crystal sugar yield loss (Bojović et al. 2014; Bojović et al. 2015). Proper crop protection also helps the utilization of assimilates from the soil. Numerous researchers claim that the correct choice of genotype is important for good production. Elements, C, O_2 and H, N, P, K Na, Ca, Mg, and Fe and microelements B, Cu, Mn, and Zn are important for sugar beet. During the entire vegetation period, plants evenly absorb nitrogen and phosphorus, while potassium is absorbed more intensively in the beginning of vegetation.

Real need for nutrients of sugar beet is greater than those that are taken out by harvest, Table 12.2. Twenty-five-year study in Göttingen shows that at an average yield of 50.8 t ha^{-1}, 1.8 kg of N, 0.3 kg of P_2O_5, and 1.5 kg of K_2O on average was taken out from soil per ton of root. Sugar beet uses only a portion of the applied fertilizers for its growth, and the rest is fixed temporarily or permanently in an unsuitable form or washed into deeper layers. Therefore, a detailed analysis of soil is needed. When planning fertilization, beside plants' requirements for nutrients, their presence, planned yield, pre-sowing preparing, etc. must be known. The N-min method enables obtaining information on available N in the soil before sowing and thus determining the required amount of N fertilizer. Phosphorus fertilization is determined on planned yield and the amount of easily accessible phosphorus. Required K is determined in a similar way. Manure has been used very rarely in our production area. Our areas are usually well supplied with microelements and in case of their need pre-sowing or foliar can be introduced.

Sugar beet requires a special way of fertilization for the uneven rhythm of assimilation of nutrients. When using nitrogen fertilizers, a fear of leaching exists, especially in light soils with low adsorption capacity, but also in places with plenty of winter precipitation. If the fertilizer is applied before sowing, plants number decreases, the maturation slows down, and percentage of sugar decreases. Production technology dictates plant protection before sowing, so nitrogen intake is divided into two third during autumn and one third before sowing. If the entry is done correctly, there is no need for additional nutrition. High doses of N nutrients at pre-sowing or top-dressing worsen the value and quality of yield.

P and K fertilizers are easy to use because they are performed completely with basic processing during the fall. The form of using of these fertilizers do not have influence on productive and qualitative properties. Pre-sowing fertilization with these nutrients did not give satisfactory results. Formulations of complex fertilizers are used for fertilizing sugar beet. Foliar treatment with fertilizers has its justification because of sugar beet large leaf area, especially if it is performed correctly and several times. Because of few unresolved issues such as solution concentrations, light intensity, relative humidity, and washing away by precipitation, this form of fertilization is rarely used for macronutrients. It is more acceptable for microelements, growth hormones, and bio-regulators (Bojović 2014). All previous research shows that foliar fertilization are considered a supplementary form of fertilizing.

12.2.5.3 Water Needs and Irrigation

Sugar beet has high requirements for water. In Vojvodina, in Serbia, according to Dragović (1987), sugar beet consumes an average of 1.8 m^3 water at 1 °C at mean daily temperature. Therefore, due attention must be paid to water regime. Favorable are those soils that absorb water well, leak excess water, keep forms of water accessible for plants and ensure its motion from wetter places to the source of consumption—the root system.

Sugar beet contains a high percentage of water in the above- and underground parts, as well as organic matter which is why it has exceptional requirements for water at the vegetation period. The transpiration coefficient shows plant needs for water and the required water quantity necessary to create a unit of dry matter. Sugar beet has a lower transpiration coefficient than lot of crops. Sorghum, corn, and millet are exceptions. The coefficient of transpiration is subject to significant fluctuations, and it is conditioned by external factors and varietal characteristics of plants.

The water needs are different and depend on developmental phase. If enough winter moisture is provided, sugar beet water needs are minimal at starting phases. At the intensive leaf mass growth (from the formation of rows till the beginning of August), large amount of water is needed. This period is critical. The need for water later decreases, but higher than in initial stage.

Sugar beet development requires a significant amount of moisture. Excess moisture could be harmful because then sugar beet contain small amounts of dry matter and sugar. Excess of air moisture can cause a reduction of transpiration and productivity, and at technological maturity phase, it has a negative effect on sugar accumulation.

Weak and short-term drought is well tolerated, especially if it appears at beginning phases. A stronger drought adversely affects and causes great damage to it. According to most authors, a total amount of precipitate of about 600 mm is aplenty for the effectual sugar beet production. Ludecke (1956) points out that 660 mm is needed on loose terrain, with winter precipitate sufficient on colder 220 mm and 250 mm on warmer soils.

Stanaćev (1979) states that in average, for Vojvodina territory, needs about 620 mm of annual precipitate. With the stated amount of precipitate, the needs for winter moisture are 240 mm and from April to October 380 mm of precipitate. However, according to long-term average yields, sugar beet is successfully produced with 500 mm and even 1000 mm of total annual amount of precipitate (in Vojvodina, sometimes, somewhere, fewer than 500 mm). Vojvodina has semi-arid climate, where large deviations are possible both by two neighboring areas and by years.

Numerous researchers state the required amounts of precipitation for certain agro-ecological conditions. However, the Wolthman schedule is best for Balkans, where the total moisture needs are 620 l/m^2. Of that winter humidity (November–March) are 240 l/m^2 and, during vegetation, 380 l/m^2. The needs by months are: in April—40, in May—50, in June—80, in July—80, in August 65, in September—35, and in October—30 l/m^2.

According to some tests and experiences from practice, sugar beet will have good technological and productive parameters, if it is provided with water as follows: with sufficient moisture in winter, it needs relatively dry March, moderately humid April, humid May, and from June to August plenty of rain. Much of precipitation in September and October, a high yield, but a poor root quality can be expected.

Moisture requirement depends on heat. The loss of water by evaporation is the greatest from June to August when, in Serbia, the air is usually warm and dry. Therefore, importance is attached to the distribution of precipitation while vegetation last. There are disagreements among various authors in these quantities, but all this is explained by Ludecke (1961), who connects the quantities and distribution of precipitation with other climate factors. In the southern area of the northern hemisphere, this need is greater because there is higher degree of evaporation in a relatively short time at vegetation period.

When the sum of precipitation during the year is optimum, the production parameters are always high (Ustimenko and Vakomovskij 1979). Spasić (1989) notices a trend of decrease in yield with a downtrend of the amount of precipitation during the autumn of the year before.

Berenyi's research in Hungary shows that beside precipitation, the temperature and duration of insolation in the specified period affected productivity. At maturation phase of sugar beet, big deviation in precipitation quantity by regions of production happens, which affects quality. Vukov (1972) says that August with average precipitation and September without precipitation give a content of 18.3% of sugar in root while each mm of precipitation in September reduces it from 0.03–0.06%. Spasić 1992 states that at first glance relatively small deviations of temperature, for 1.39 C in average, but with precipitates of 146.5 mm at vegetation period, have impact on quite large distinction in the achieved productivity and sugar content.

12.2.5.4 Relative Humidity

Moderate humidity is the best for sugar beet. High humidity causes poorer transpiration, and this has an impact on the yield because if the plant gives away less water, its absorption is lower and so the intake of nutrients is lower. High humidity in July, August, and September causes the spread of the fungal disease *Cercospora*. Low humidity leads to bed production results. The basic role of air humidity consists in its influence on the soil evaporation of moisture and transpiration of plants. At moderate relative humidity, it has normal growth and the course of physiological processes. The wilting process is associated with low relative humidity and high temperatures. The southern parts of Macedonia and Serbia have a pronounced summer air drought, especially in July and August (53–55%). In that period, in those parts, high temperature prevails, which is accompanied by great evaporation and transpiration, which affects sugar beet productive and qualitative parameters. Surplus of moisture in the autumn period of over 80% affects production in Vojvodina and causes appearance and spread of diseases.

12.2.5.5 Hydrothermal Coefficient

Temperature and humidity as inseparable factors are most often expressed together as—hydrothermal coefficient. According to Štojko (1968), Seljanin's ratio of the sums of precipitation and evaporation is use for a complex assessment of the entire vegetation period or its parts. The consumption of moisture for evaporation is approximately equal to the temperature sum reduced by ten times. To rate the favorable weather conditions with a hydrothermal coefficient, the period of vegetation phase or place of production are classified as follows:

- Greater than 1.3—increased humidity, moderate heat.
- 1.0–1.3—moderate humidity and heat.
- 0.8–1.0—relatively dry conditions.
- 0.5–0.8—dry and quite critical period.
- Below 0.5—a very critical period that causes a complete stoppage of physiological processes.

The stated classification according to the hydrothermal coefficient, has practical significance because of its possible application on smaller time intervals, i.e., decades, for establish excesses during the month. The cumulative assessment of climate parameters has an advantage over individual explication of influence of temperature and precipitation.

For favorable evaluation of hydrothermal coefficient, the following values for sugar beet are taken: from germination to closing of rows—1.3, for the period of intensive growth of to the beginning of August, for the period of technological maturity till the end of vegetation. In our climatic conditions, the deviations are significant, depending on the excess of temperature and humidity for a given period.

When the hydrothermal coefficient is lower during the vegetation period, the yield and sugar content in root are lower.

12.2.5.6 Irrigation

For sugar beet production, irrigation is very important, especially in areas of limited humidity. It reduces the adverse climatic effects and enables more uniform yields. Sugar beet presence on irrigated areas is desirable because this provides its production. It irrigates from furrows, by artificial rain or overflow. Overflowing worsens the soil structure, creates a firmer crust, and increases water consumption. It also affects the quality parameters, so that is why its frequent use is less. Irrigation from furrows gives lower yields compared to artificial rain up to 17% on chernozem (Vučić, Miladinović 1964).

Water needs or ETP (evapo-transpiration parameter) are the starting point for irrigation plan. ETP depends on irrigation regime. It is an orientation and not an absolute size, for agro-ecological conditions should be taken into account. Judging by the ETP, the sugar beet is a plant with low water requirements because it needs much less water to produce 1 g of dry matter than many crops. But this is not the case in practice because it requires plenty of water for biomass production. The sugar beet vegetation period can be divided according to Orlovski (1961), at first year, as proportion—1: 9: 3, while by Zolotarev the percentage ratio is 20–25%: 55–65%: 10%. Vojvodina is our largest irrigation area. Considering the average values of ETP (450–500 mm), such amount of precipitation and reserve moisture of 60 mm of easily accessible water in the soil in Vojvodina are rare, it is not real that varietal potential and intensive agricultural techniques can show the highest level, so irrigation is characterized as a need.

The irrigation effect, rational consumption of water, the irrigation economy, and soil protection depend on the correct irrigation regime. Even the simplest irrigation regime, based on certain principles, is better than spontaneous watering. Schemes of periods of plan using water combined with data of precipitation and reserves of water in the soil could serve for establishing the simple irrigation regime. At vegetation start, watering is not necessary, except when spring is very dry and then with a 20 mm watering norm, but in favorable weather conditions, by sprinkling and not by surface watering methods. In the next period, precipitation is insufficient and water consumption is over 4 mm per day. Drought stops the plants growth, reduces the yield, and increases the harmful nitrogen amount, and usually 2–3 watering with a watering norm of 40–60 mm is needed. Although the needs decrease sharply in the last period of vegetation, drought can negatively affect the yield even then. Normal watering is not necessary, but if performed, in mid-August and the drought continues, watering should be repeated in the first half of September. Later, watering has good impact on yield but bad on sugar content in the root. Humidity of 60% is favorable and 40% unfavorable water supply to plants. According to Orlovski (1961), who quotes Zavigordnia, the watering scheme 60-60-60 gives highest root production and amount of sugar and the least of harmful nitrogen, and 40-40-40 is the best of sugar percentage and gives better result than 60-40-40. The trend of soil moisture is possible to monitor, the technical minimum is lento-capillary humidity, which in heavier soil is 65–70% of the field water capacity and in lighter 50% and in heavy 75%. There are procedures for irrigation regime based on physiological indicators of leaf suction force and water concentration. It is not widely used because it depends on other factors (leaf age, fertilization, air saturation with water vapor, temperature). By possibility of dynamic monitoring water using the water of balance method is acceptable. The bioclimatic method that connects the consumption or need for water for the plant biological traits with climate characteristic is the most acceptable method. Based on it, hydrothermal coefficients, in Vojvodina, for sugar beet has been determined as 1.6–1.7 m^3 ha^{-1} (0.16–0.17 mm) of water. Other approaches are possible, but this is the simplest to apply in a wider irrigation area, on the farm or individual plots Vučić (1981).

It is impossible to access irrigation without knowing the basic water-physical properties of soil because without them irrigation norms, rainfall intensity, and furrow length cannot be determined. Knowing of field water capacity is necessary because this indicator expresses quantity of retained water in soil layer after more abundant moisturizing. A larger amount of precipitation drains down and carries nutrients into the deeper layers and is unfavorable except as a meliorating rinsing of salt marshes. The water in the soil is kept by a low power at a PVK of about 300 mb, which corresponds to a value of capillary potential (pF) of 2.7 and is to some extent easily accessible to plants.

On heavier soils, it causes water to lie down, which slows down growth plants. Lento-capillary humidity shows constant in the soil till whose value water moves quickly towards the place of consumption and is easily accessible to plants and it is of great importance. It shows the lower limit of soil moisture in irrigation, and by that participates to define irrigation norm. It is considered to be held in the soil with the strength of 6.2 b which corresponds to a pF value of 3.6–3.7. Further reduction of moisture of soil leads to initial and permanent wilting, mostly accessible water supplies are depleted, and the rest is kept at a power of 15–50 b (pF 4.2–4.5) and the plants are in a critical situation. Important are infiltration data expressed in mm/h (water column in mm which soil absorbed within 1 h). It has variable value, influenced by agro-technical measures and is always the largest in the first hour, except in sandy soils where the decline in time is minimal. The volume of soil mass (a) is also important. It shows compaction of soil, which is important for water-air regime. For Vojvodinas chernozem, p is 1.30–1.35 mg/m^3, for moister, heavy soils less than 1.2 and for fluvisol of sandy composition even p greater than 1.6 make no problem due to porosity.

Several factors determine irrigation: soil properties, pre-irrigation soil moisture, depth of active rhizosphere, method of irrigation, so for that reason is unrealistic to give average values. The depth of the layer that needs to be wet by watering is the active rhizosphere—layer where the plant absorbs 65–70% of water. It is 60 cm for adult plants, while for younger ones it is lesser. With irrigation by artificial rain, the uniformity of wetting is more favorable compared to irrigation in furrows, so the norm can be lower by up to 10%.

However, the conclusion is that irrigation significantly increases root yield. In experiments (Marinković et al. 2001) in some NS hybrids, the percentage in yield rising with irrigation was 10.8 tha^{-1} or 12% up to 14.5 t ha^{-1} or 17% with a variation of 9–23% among hybrids, while in dry farming conditions this difference was much smaller. Pejić (2010) concluded that irrigation has no strong effect on yield rising, based on performed experiments (2000–2006) where mainly it was 8.01 t ha^{-1} with top-dressing.

12.2.6 Crop Establishment

12.2.6.1 Sowing

Its production is influenced by the following factors: agro-climatic conditions, soil (composition, structure, and cultivation) and cultivation technology: choice of varieties, sowing, providing adequate crop nutrition, irrigation schedule, crop protection, (Kosanović et al., 1952; Žeravica, 1965; Shestakova, 1969; Vučić, 1973; Stanaev and Stefanovic, 1974; Draycott et al., 1977; Spasić, 1987; Ming et al., 1989; Stewens et al., 2011; Terzić et al., 2018) and time of extraction. When choosing an assortment, we have to opt for several varieties, which differ from each other by ripening time. Those varieties have to show a higher ability of adaption in different environment area.

Among the major agro-technical measures for sugar beet production there is sowing. Sowing that is done well ensures optimal crop density and high yield. In Serbia and Montenegro, sugar beet is sown after middle of March (Filipović et al. (2009) claim that every day of delayed sowing, 70 kg / ha of sugar is less). Temperature can then be unfavorable and unstable, so we must know the features of seeds and seedlings soil at the time of sowing, germination, and sprouting (Redfearn 1995; Sabovljević et al. 1995). Glamočlija (1986) states that a seed fraction above 4 mm gives higher plants develop with higher sugar yield than a fraction less than 3 mm. Glamočlija (1986) also claim that from larger seeds grow higher plants with longer root and higher sugar yield. Milošević (1989) examined the influence of seed size on germination and found out that the largest fractions of 4.5–5 mm and 4–4.5 mm have the highest value of germination. Dokić et al. (1992) did not find a significant connection of the seed size and productive and quality properties of sugar beet. Quality of seeds are important for it to provide good field germination, good penetrating power, and thus achieve an optimal plant number and even growing at the beginning (Glamočlija 1986). Many researchers have examined the germination and emergence of varieties related to their genetic constitution (Durr 1992; Lovato and Cagalli 1992). In controlled conditions at $t = 5/15$ °C, higher total germination and germination energy have fractions of larger seeds while at $t = 20$ °C this difference is smaller (Bojović 2010). Results of sugar beet seed properties research have found application in the seed technology of other field plants. Properly processed seeds are an important prerequisite for successful sowing and by that, a yield. The sugar beet germ is tender and so it should not be sown deep. Sowing depth is conditioned by soil type and humidity conditions. In mass conditions, it is usually performed at 2–3 cm deep. In dry conditions and on lighter soils, the sowing depth is 4–5 cm. Very deep sowing reduces the access of air to the seeds, which prolongs germination; the path of the germ to the surface is prolonged and this causes excessive elongation of the hypocotyl part of the germ and leads to shortening of the roots. If germinating is from the depths, field germination reduces, germs often decay while the others are depleted, the germ is thin and isn't good base for future growing. High concentrations of salt in the sowing layer (if the pre-sown mineral fertilizer and herbicides are applied shallowly or poorly balanced or there is its stronger presence in the seedling zone) reduce the germinating of plants. Germinating decreases with the bark forming. Sowing too shallow sowing is not right because of the loose and dry layer at the surface, and for that reason seed is at small contact with the soil, the inflow of water is difficult, so germination will be difficult, prolonged, and often depends on precipitation. It needs to be underlined that the sowing depth must be uniform. In general, below 50% of field germination is low germination, 50–65% moderate, 65–80% good, and over 80% very good. Seed mass is small, depends on the size and amounts, per hectare, 1.5–3 kg. The number of seeds for sowing is expressed in sowing units. 1 unit is 100,000 seeds.

$$\text{Seed quantity} = \frac{\text{Row length (m) per 1ha} \times 100}{\text{Seed distance in a row (cm)}}$$

Sugar beet is usually sown between row spacing of 50 cm and in-row spacing 15–19 cm. The best schedule is when sowing at 10 cm with thinning. According to many authors (Smith et al. 1977; Glamočlija 1986; Filipović et al. 2007; Bojović 2014; Bojović et al. 2015), vegetation space weakly affected the increase of yields and this was by extended time of growing. For an earlier extraction period, a smaller vegetation space is better, unlike for a later one, where larger space is better. Stanaćev (1979) found that the best production and quality value were the highest at 1000 cm^2. Lüdecke (1953) pointed 74,000–95,000 as the most suitable density. Glamočlija (1990) states that crop density has high influence on yields. In his researches, few densities (60,000, 80,000, 100,000, 120,000 to 140,000) of two varieties of sugar beet with plant nutrition which levels differed were examined. When density of crop and quantity of mineral nutrients rise, content of sugar gradually falls and "harmful" nitrogen increases. Varieties react differently on crop density and nutrition. Filipović et al. (2007, 2008) concluded that increase of plant density increases sugar beet root yield. Thus, the highest density (120,000 plants per hectare) brings the highest yield, which is on average 5.6% higher than at the lowest density. The highest crystal sugar yield (12.43 t ha^{-1}), was at a highest examined density and the lowermost at a density of 100,000. The tolerance to stress caused by lack of precipitation, high air temperatures and other environmental factors of some genotypes, is advantage in production in dry farming conditions, especially when crop irrigation is impossible. Such varieties have great coefficient of utilization of applied mineral nutrients and in general higher productivity (Čačić et al. 2000; Dobrovnaya et al. 2009; Pejić et al. 2010; Bojović et al. 2014). The assortment choice that fits production territory brings a larger and more stable production. The rhythm of growing and the facility to use a certain vegetation space for the highest possible sugar beet yield is what makes difference between two varieties. They also differ greatly in maturing time for cost-effective sugar processing. Certain varieties have the property of prolonging the growing period and during the autumn they create a significant part of organic matter. When choosing an assortment for growing in a certain production area, producer should choose several varieties, which have different ripening time. We can distinguish three basic types of sugar beet varieties: Z-high-sugar content types, N- normal, and E- high yield types (Bojović 2014). It is profitable that varieties of Z-types are sowed for their earlier extraction. Varieties of the normal type are appropriate for the medium harvesting period, and varieties of E-type are in optimal technological maturity much later, so they should be removed last (Stanaćev 1979). It is economically justified to grow varieties of all three of types. Stanaćev (1976) suggested that ratio should be: 25% of Z-type ,40% of N-type, and 35% of E-type for Vojvodina production territory. The proposed ratio gives the possibility for gradually harvested from the fields and processed, depending of its technological maturation time. It provides good technological properties of root and new sowing of winter cereals on those fields.

The yield per ton depends on the root yield, sugar content in the root, and the purity of the sugar beet juice (Campbell and Kern 1982; Smith et al. 1977). Smith et al. (1977) found that the juice purity depends on genotype, soil type, plant nutrition, and density of crop. Among the mentioned factors which are crucial for quality, nitrogen nutrition is crucial in Beek and Huijrbregts's (1987) opinion. Most scientists agree with some differences between varieties related to uptake and transformation of mineral nutrients, but these differences are not yet so great as to have some relevance to practice. However, when using very large content of N, P, and K, the high-sugar content varieties deteriorated to a lesser extent the quality for processing than the high yield types (Stanaćev 1973).

New varieties, of both domestic and foreign origin are constantly appearing, which by some of their characteristics deserve the attention of producers (Figs. 12.1 and 12.2). For higher results in different climate and soil conditions, varieties must have a higher adaptive ability. At the Institute of Field and Vegetable Crops, Novi Sad, the following varieties were created: Sara, Mara, Lara, Drena, Rama, Ilina, Vera, Irina, Nora, and others. Bojović (2014) states that the year has a greater impact on quality parameters relative to the locality, while the interactions of cultivars × years and cultivars × locality were very similar for yield value.

Sugar yield and root yield are the basic indicators of the value of sugar beet varieties. Basic indicator of technological value of a particular genotype is the sugar content. NS varieties, Vera and Nora, had a high root yield, while the Vera variety had a higher sugar content (16.35%) and belongs to the sugar type (Z). Varieties Vera and Nora have genetic resistance to Rhizomania and good technological characteristics, recommended for early and medium extraction periods in all growing regions in Serbia and Montenegro.

The amount of sugar and non-sugar substances are related with environment and used agro-technics, but these characteristics are features of each variety (Čačić et al. 1997; Čačić et al. 2000; Kolarić et al. 2015). By using plants that improved by biotechnology, production could be higher, using of pesticides and erosion can be reduced, and the groundwater quality can rise (Stojšin 2001). Fundamental science,

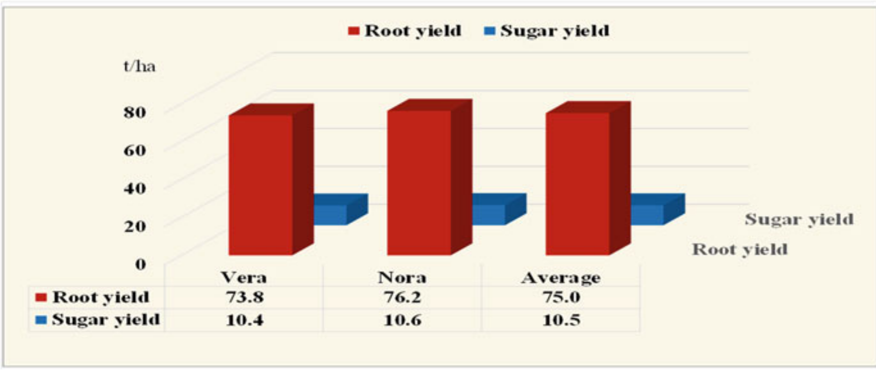

Fig. 12.1 Root yield and sugar yield at NS variety Vera and Nora

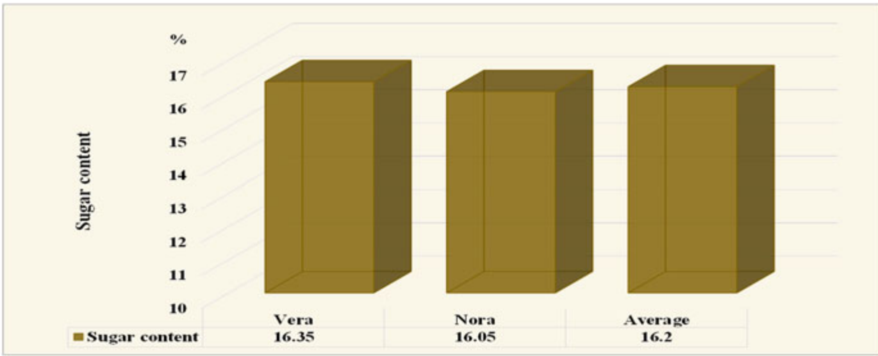

Fig. 12.2 Sugar content at NS variety Vera and Nora

more often than at other cultivars, changes completely in the genetic composition of cultivated varieties of sugar beet several times. Breeding has aim to increase rising of fertility potential and by that, economical and profitability production.

The Institute of Field and Vegetable Crops in Novi Sad mainly effectively followed European and world trends in creating varieties. They did not lag those from multinational companies in terms of their characteristics. In the recent years, the increase in fertility potential is due exclusively to the improved genotype and is 2% per year, which is a great success for geneticists and breeders in Serbia and Montenegro (Kovačev et al. 2006). In the production of sugar beet, the most important is the amount of moisture and nutrients at a depth of 60–90 cm, Kovačev et al. 2011 (Fig. 12.3).

a b

Fig. 12.3 Sugar beet (**a**) and poppy in chernozem soil (**b**) in Bački Petrovac, Serbia

12.2.7 Weed and Control: Cultural, Chemical, Nanotechnology, etc.

Good yield requires proper crop protection. Proper protection consists of multiple use of chemicals on seeds and young plants. The most common sugar beet disease is caused by the pathogens, *Cercospora* and Rhizomania. Chemical preparations are used to control both. Omission of protection treatments causes the leaf mass to completely perish, leading to yield loss (Duffus and Ruppel 1993; Rossi 2000). At larger attack of parasites, in Serbia, amounts of sugar decreases by 1–2% (Glamočlija 1986; Bojović 2014). Kuzevski et al. (2000), in experiments performed 1996–1997 record that in intolerant varieties, have the yield decrease 30.94 t ha^{-1} and the sugar content for 3.31%. The mentioned researchers conclude that by monitoring the sugar beet root juice chemical composition, attack of Rhizomania can be established.

Weed control is an important agro-technical measure during the cultivation of sugar beet. Before the middle of the twentieth century, weed control was performed by mechanical inter-row cultivation or manual hoeing. Discovering selective herbicides contributed that human work is less necessary. Biological control measures, although promising, have almost reached expected level. At South Banat territory, it has been noticed over 160 weed species. Although mostly the same weeds are found in sugar beet growing areas, the composition and number of weed species differ, so no field herbicide used in other countries can be recommended without field trials and inspections in certain conditions and areas. Control by herbicides can be accepted only if high yields are achieved.

Weeds cause the greatest damage to plants after germination and affect the yield of sugar beet to its complete absence. Thus, Wicks and Wilson (1989) state that weeds that germinate up to 8 weeks or within 4 weeks of formation of two pairs of leaves cause the greatest damage. Dawson (1965) found that 132,000/ha of plants *Chenopodium album* reduced sugar beet production by 94%. In experiments by

Brimhall et al (1965), the species *Sinapis arvensis* together with other broadleaf weeds diminishes by 95–100%. The studies of Wicks and Wilson (1983) show that in field experiments that for every 1120 t ha^{-1} of dry matter of weed mass root yield decreases by 10–15 t ha^{-1}.

As it was said, weed control is most often done with herbicides nowadays. By the application time of herbicides, we distinguish three periods as follows:

1. Before sowing—those herbicides that evaporate easily at higher temperatures and those which depend on precipitation. It is introduced with seeders or discs and is recommended for dry areas.
2. After sowing and before germination—pre-emergence, numerous of herbicides are applied. They are adopted through the roots, so their application depends on precipitation, which means that at lack of precipitation, their action is absent also.
3. After germination—post-emergence, used preparations with numerous active substances.

The plant absorbs these herbicides through the leaves and further sends them into other parts of the plant through the conducting bundles. With precipitation, they can be absorbed through the root. One preparation cannot destroy both narrow-leaved and broad-leaved weeds, so we regularly use them in combinations. Lasting of herbicides is problem, so it is better to apply them repeatedly in reduced quantities. Application has to be repeated in the germ leaf phase of weed until the first pair of leaves develop. The effectiveness depends not only on the spectrum and residuals of the herbicide but also on the climatic conditions after application, type, structure, pH, organic matter content, and soil moisture.

We must mention that residues of persistent herbicides can show phytotoxic effects on sugar beet.

We will mention the herbicides used in Serbia:

With active substance S-metolachlor 960 g L^{-1} against annual grass and broad-leaf weeds—before sowing and after germination with 1.4–1.5 L ha^{-1} depending on the percentage of humus once.

Propaquizafop 100 g L^{-1} once when the weeds reach the stage with 3–5 leaves or twice when the weeds are in the stage with more than three leaves in another 15–20 days later.

Cyclosidim 100 g L^{-1}.

Fenoxaprop-P-ethyl when weeds are in phase 2 and before flowering of leaf crops once.

Quizalofop-P-tefuryl once when the weeds are at 3–5 leaf stage or twice within that phase and after 10–15 days in reduced quantities.

Haloxyfop-R-methyl once in the phase of 3–5 leaves or twice at same phase and after 10–15 days in reduced quantities.

Cletodim, after the emergence of crops once.

Desmedipham + phenmedipham once or twice after crop emergence.

12.2.8 Interculturing

12.2.8.1 Cultivation Technology

Crop Rotation

The crop rotation today has much smaller importance, relative to few decades ago, because of agricultural development, especially the mechanization, use of pesticides and mineral fertilizers. This created the possibility that the crop rotation is more conditioned by the market and economic policy than the growing conditions and plant characteristics. However, negative consequences of this have been noticed, especially on keeping of soil biogenicity and its structure.

Sugar beet is a plant that, due to its production requirements, requires production within the crop rotation. It is very sensitive on successive cultivation on the same plot. Cultivation in monoculture and even frequent (to 2–3 years) leads to reduced yields for not providing the soil recovery that cannot be compensated by fertilizers, have good condition for diseases and pest attacks so cultivation in crop rotation is recommended, which provides a return to the same plot only after 4–5 years. Research experiments at Rimski Sancevi, near Novi Sad, conducted a long-term cultivation of sugar beet in monoculture. After the first 10 years of performing experiments, Stanaćev (1973) introduces that there was a decrease in sugar beet yield by 26% compared to five-field crop rotation. Stanaćev et al. (1983), states that after 20 years the yield in monoculture will be 23.5% lower compared to five-field. So, after the initial drop in yield, the yield stabilized during continuous cultivation on the same area. On this experiment fields, there were clear negative changes in soil porosity, microbiological activity, composition, and amount of humus. For proper crop rotation establishment, biological traits of culture and soil and climate conditions must be known. In regions with insufficient rainfall or poor distribution of it, plants with less water demand and soil draining are better as pre-crops. In humid regions, perennial grasses and legumes are desirable. In region with heavier mechanical composition of soil, pre-crops whose root can easily penetrate are desirable, while for those with a lighter mechanical composition, those are crops with a shallower root and lower water requirements. Sugar beet should not be grown behind those crops that have common pests and diseases. In our production conditions, the best pre-crops are small grains. It is usually wheat, because it leaves enough time for adequate preparation of the soil for growing sugar beet. Good pre-crops are also the vegetables, but their representation is small on cultivating area so they are not so important. Potatoes and soybeans are also a good pre-crop, but not in dry years if water consumption is not compensated with winter moisture.

Unsuitable pre-crops for sugar beet are fodder beet, oilseed rape, cabbage, kale, and other crucifers (*Brassicaceae*) because they support the spread of aphids, nematodes, and viruses. The pre-crops impact quality, same as the yield. Legumes leave the soil enriched with nitrogen, so they can reduce sugar utilization by rising of harmful nitrogen amount. Sugar beet, as a pre-crop, is suitable for many cultivated plants (spring barley, wheat, legumes) because the land for its cultivation is well cultivated several times and the harvest residues were plowed. In some localities, yield reducing of corn, sunflower, and hemp was noticed, and of soybeans also, in some more arid areas, if their pre-crop was sugar beet. This is possible for two reasons: Sugar beet gives a high yield and above ground masses, and when it is plowed, it uses so much water to decompose it, so in regions with a lack of precipitation, it is bad as a pre-crop (Glamočlija 1986). Also, if the extraction is performed at increased humidity, its structure is disturbed, it becomes compressed, as a result of which the water-air regime is disturbed, and the biogenic activity is reduced, decreases the yield of crops which are subsequent.

It is considered that the sugar beet participation in crop rotation conditioned on the humidity of the region. Thus, in humid regions, the share of beets can be up to 30%, in regions with uneven distribution of precipitation is 20–25% and in regions with unfavorable humidity up to 20%.

12.2.9 Crop Care Measures

Sugar beet is a highly intensive field crop and for expression of its greatest yield potential, it requires much of work and resources. If these requirements are met, it becomes the most profitable crop. Care begins almost post sowing and includes various operations and procedures: rolling, breaking the bark, cultivating and hoeing, thinning, feeding, irrigation and protection from weeds, diseases and pests.

After sowing, periodically going around is important and sometimes, rolling and harrowing measures are necessary. Rolling doesn't belong to regular measure, but it can be carried out, especially in drier areas or when sowing accompanied dry weather for the surface layer to be compact and come into contact with deeper, wetter soil layers. Crust can occur if heavy rain falls after sowing, thus disrupting aeration and making germination and sprouting more difficult. Then the breaking of the crust is approached, usually by hilling. This measure is not used today. When the crop sprouts, inter-row shallow hoeing (cultivation) is started and if the sowing was not at the final distance, thinning. Hoeing is done for better rooting, better change of gases, uniform absorption of precipitation, faster heating. Hoeing does performed if not all weeds are not destroyed by herbicides and if due to heavy rains, soil structure is severely damaged.

Thinning of plants is the best in the phase of the first pair of permanent leaves and is completed until the appearance of the second pair of permanent leaves (in 8–10-days). The optimal density is about 10^5 plants per hectare (45×25 and 50×20 cm), with $8x10^4$ plants realized during sowing. If the crop is irrigated, the crop density should be slightly lower. From thinning to closing the rows, inter-row cultivation and hoeing are performed. If more hoeing is needed, the first one is at the depth of 4–5 cm and each subsequent one is deeper (up to 10 cm).

Top-dressing is performed with cultivation. It performs not before the sprouting so sprouts would not be damaged. If it is done before closing the rows, it must be at the afternoon, because the leaves are more bent and the damage is less. When soon as the plants develop cotyledon leaves, fed can start. Top-dressing could be done once or twice with 30–60 kg ha^{-1} of nitrogen on soils that are light, shallow, cold, and poor in nitrogen. In fertile soils, this operation is not necessary. If nutrition is done before closing the rows, quality may decrease so it shows that it must be done when a sugar beet has four leaves maximum. Feed can be done with hoeing or superficial. If it is superficial, inter-row cultivation must be immediately done after mixing the soil with fertilizer. This feeding is best performed while the leaf is wet to prevent burns on the leaf. Nitrogen supplementation through leaves has no great justification.

Irrigation is important because, in conditions of limited areas, it reduces the adverse effects of climate and enables more uniform yields. Sugar beet should be present on irrigated areas because that ensures its production.

12.2.10 Intercropping

Cultivated plants grow mainly as monocultures. In agriculture, monoculture has facilitated work operations such as weed removing and harvest. This system maintains crop productivity by using chemical inputs including fertilizers and pesticides but reduces the plant and microorganism diversity (Brooker et al. 2015). Lessening of resources, like arable land, water and energy, high need for devise and practiced new strategies and techniques of production is present, to fulfill the expanding needs for food and forage through sustainable utilization of available inputs (Jabbar et al. 2010). Various environmental and socio-economic reasons have been suggested for explaining the well-known concept of intercropping.

In agriculture, more studies on intercropping have been carried out for evaluation of potential agronomic and economic benefits. Importance of interactions among crop species in shaping the structure and dynamics of plant association is widely acknowledged. Benefit of it is great. Intercropping systems can enhance crop produce. Sometimes productivity is enhanced in intercrops (Fukai and Trenbath 1993), but most of the studies find intercropping plant yields intermediate. Intercropping means that at least two crops species are grown on the same plot of land simultaneously and that results in higher yield. In intercropping systems, both negative interaction (competition) and positive interaction (facilitation) can occur simultaneously. Competition prevents crop growth by sharing the limited resources or allelopathy, whereas facilitation increases crop performance by improving the micro-environment for utilizing resources (Brooker et al. 2015). Intercropping is a widespread agronomic practice in the tropics because it reduces the loss caused by pests, diseases, and weeds and also it guarantees better yield (Andrews 1974). Similarly, Banaszak et al. (1998) carried out experiments with intercropping and found that new varieties of oil radish and white mustard as intercrops had reduced the *H. schachtii* infestation by about 20–40% in sugar beet crop. In order to evaluate the effect of intercropping sugar beet with oilseeds (mustard and canola) and lentils, three sugar beet varieties *viz.*, Kaweterma, Aura, and Pamela were tested against four intercropping systems (sugar beet only, sugar beet + mustard, sugar beet + canola, and sugar beet + lentil). Among the sugar beet varieties, Kaweterma had excellent performance in growth, yield, and quality traits. Sugar beet yields and monetary benefits were also maximized in lentil intercropping compared to cereals and oilseeds intercropping. It is recommendation that intercropping of sugar beet variety Kaweterma with lentil should be practiced for higher qualitative, quantitative, and monetary benefits (Usmanikhail et al. 2012).

There was an experiment with sugar beet as monoculture and wheat and intercrop at small or suitable presence of phosphorus. In intercrops, production of dry matter diminished in wheat and increased in sugar beet. The rate of photosynthesis in wheat was lower and in sugar beet it was higher. In intercropping it is fallowed with transpiration rate lowering and higher using of water in the after species. Contents of P, K, and Fe decreased in wheat intercrop and it rose in sugar beet. The similar effect of intercropping was observed in the short-term hydroponic experiment. The three root parameters—length, soluble carbohydrates, and activity of secretory acid phosphatase which are in connection with plants phosphorus-deficiency, raise in both intercropping, regardless of the phosphorus amount. Results show an inter-specific interaction which is above the different capacity nutrient acquisition in the intercropping (Hajiboland et al. 2018).

12.2.11 Crop Management under Abiotic Stress Condition: Drought, Salt, and High Temperature Stress

12.2.11.1 Conditions of Cultivating

Sugar beet is one of major crops grown in temperate climates, especially the northern hemisphere. It is largely distributed because it easily adapts to various agro-ecological conditions. Area of growth is between 30–60°N and 25–35°S latitude. In Serbia conditions, it prefers a moderately warm, sufficiently humid and sunny climate, with sufficiently humid winters, warm and humid May, relatively cool June and July and sufficiently sunny August, and similar September when sugar in sugar beet accumulates, and October sunny and cool. For its production and quality, agro-climatic conditions are not fully defined, but limit values exist.

Rise in global temperature, increased drought, increase in CO_2 levels, and various forms of pollution in different ecological conditions strongly affect all crops (Glamočlija 1986; Glamočlija 1990; Popovic et al. 2016; Popović et al. 2020a, b, c; Terzić et al. 2019; Lakić et al. 2019a, b, Božović et al. 2018; Božović et al. 2020; Rajičić et al. 2020a, b). The weather conditions of an area vary from year to year. Sugar beet, beside ability to adapt, reacts fast on climate changes that greatly affect its productive and qualitative properties. Natural conditions cannot be changed by the will of man but production process and variety can be changed and adjusted. It is possible to regionalize its production, based on plant requirements and production conditions. Quantity and quality are influenced ecological factors: temperature, precipitation, humidity, length of insolation, soil properties, etc. These factors' influence is complex.

12.2.12 Thermal Conditions

Knowledge of production area thermal conditions means a lot for production success. Significant variation of temperature, while vegetation last, have the greatest influence on root quality in Serbia and Montenegro.

Since sugar beet is a plant of early sowing, minimum and maximum temperatures have a great influence on seedlings and shoots. The optimum temperature for germination and sprouting is 25 °C, minimum is 4 °C, and maximum 28–30 °C. Critical temperatures are especially important during sowing and sugar beet germination. The minimum temperature of soil at a depth of 5-6 cm is 6 °C which is optimal for sowing. The minimum temperature for germination of sugar beet is 4–5 °C, which shows that it is resistant to low temperature but then is a fairly long period from germination to sprouting: at $T = 4.4$ °C is 22 days and at 10.3 °C only 9 days. For sowing, the critical T is 4 °C but at T higher than 28 °C the seed can germinate just at high relative humidity. The total sum of T for germination and sprouting is 100–125 °C.

Low, critical temperature affected germination and cotyledon phase until the appearance of the second pair of first leaves. During this period, low T can have a vernalization effect, which, on a greater or lesser extent, at sensitive varieties, lead to appearing of stalks during the summer, which depends on low temperatures lasting. Frost damage depends on moisture of the soil and the previous effect of high temperature on water absorption by plants. Sugar beet is not sensitive to weak frosts in both spring and autumn. However, susceptibility to frost is dependent on the sprouts age. Young, newly sprouted plants can withstand frosts down to −6 °C. In the sprouting (cotyledon outbreak), they are sensitive to frost—it suffers if temperature is less than −3 °C. Critical low temperatures at cotyledons period, which ranges up to −7 °C (in Vojvodina), lead to deterioration of crops state, caused by frost. Adult plants (in autumn) can withstand frost up to −5 °C. Late in autumn, at relatively low T, sugar beet vegetates and increases root yield and sugar content. Sugar beet tolerates low temperature without harmful consequences for processing at autumn if it is in the soil. If the frosts are stronger, and especially if the periods of freezing and melting alternate, it suffers damage and root quality reduces.

Sugar beet has moderate heat requirements. It tolerates both low and high temperatures quite well. Its vegetation period lasts from 120 to 200 days. Most authors agree that the growing season requires temperature between 2400 and 2600 °C. Broadly speaking, the sum of temperatures depends on latitude and is 1900–3600 °C. At the Pannonian plain, it is around 3000 °C (Spasić 1992). Temperature and its sum that sugar beet need are different through vegetation period. Stanaćev (1979) states that the optimal mean temperature for the sugar beet vegetation period is 15.3–16.4 °C. It slightly differs in Europe from North to South. Glamočlija (1986) finds in his experiments that the optimum average temperature is 18 °C, and that high temperatures in July and August reduce the final yield, but, at the end of the season, plant growth does not depend on thermal conditions. The required mean temperature during vegetation differs and is: Part I from germination to row formation (about 60 days), − 10.7 °C ($\Sigma = 650$ °C), Part II from the assembly of rows till beginning of August—18.8 °C (Stanaćev 1979). In Pannonian lowland, it is often warmer 2–3 °C than in Europe. In Part III, which is the maturation and sugar accumulation phase, from the beginning of August until sugar beet extraction, – 16.5 °C ($\Sigma = 1000$ °C) is preferred. In Pannonia, temperature oscillations in that period are frequent in certain years, and this leads to quality deviations. The longer vegetation period leads to higher yield.

The role of heat in sugar synthesis process is large depending on the phenological phase. The most intense accumulation of sugar is at $T = 25$ °C and stagnation occurs when the average daily temperature drops below 6 °C. According to Glamočlija (1986), the formation of organic matter is slowing down if temperature is less than 12 °C but also greater than 30 °C. High summer temperatures, especially in the root zone if they are higher than 30 °C, decrease turgor in the leaves, reduce the photosynthesis intensity, and cause leaves drying. The transport of assimilates from the photosynthetic apparatus to root is slowed down and that indirectly effect the absorption of water and nutrients. According to Bojović et al. (2014), the optimal temperature for photosynthesis intensity is 20–25 °C. The tests were conducted under strictly controlled T in the root zone. At the stated T, the highest sugar yield was obtained.

12.2.13 Light

Sugar beet places great demands on light, especially when sugar accumulates most intensively in the root. The sugar percentage is positively correlated with insolation length from August to October. Also, its use of sunlight is poor, only about 2%. It is estimated that lasting of insolation in July, August, and September is more important for the ripening and quality. According to photoperiodic reaction, sugar beet is a long-day plant and for that, at first year, it easily brings a flower and vice versa, in the southern areas with a shorter day, it hardly gets a flowering stem. Since sugar beet intensively makes organic matter, it needs many sunny days during growth. Certain intensity of light is needed for enabling the best assimilation, better sugar content, and largest amount of organic matter. Lack of light decreases the total sugar beet yield and quality, while content of non-sugar substances increase (Bojović 2014). The best flows of assimilates from leaf to root occur during sunny and cloudy days shift. During sunny days, the assimilation takes place intensively, and when it is cloudy, the products of photosynthesis are transported to the root. According to insufficiently checked data, for sugar beet quality, at ripening period (August–October), about 700 h of sunshine are needed. In most production areas and years of production, the stated number of hours is lower. With a smaller number of hours of insolation, sugar content is usually lower.

12.2.14 Relation to CO_2

Content of carbon dioxide greatly affects photosynthesis. The main sources of CO_2 are soil surface and air currents. Sugar beet consumes large amounts of CO_2 and reduces its concentration. Under good growing conditions, photosynthesis is generally limited with amount of CO_2 in the ground layer. It is possible to increase the concentration of CO_2 in the ground layer of the soil by applying organic fertilizers and appropriate tillage and in the same way the yield of sugar beet.

12.2.15 Salt Impact

Sugar beet is relatively resistant to total soil salt. Sarić (1971) states that it thrives at a salt content of 0.8–1% of the soil dry weight, which means, at a strong degree of salinity. A decline in crop yields leads to a reduction in the economical production. Climate change contributes to this, so alternative crops are often introduced into the crop rotation (Popović et al. 2020a, b, c). By present cultivation system, early sowing affects high yield. For achieving of high production results, early sown plants germinate quickly and have speeder row closing in comparison one sown at usual date. Therefore, variety must have a lower temperature of emergence minimum and of leaf formation (<3 °C; Milford et al. 1985), faster growth at $T < 10$ °C (Milford et al. 2010) and lower sensitivity on freezing, to ensure yield formation in a vegetative phase.

12.3 Future Prospects

The knowledge, ability, and skill of the producer are measured by the achieved yield and its quality. The sugar industry has become, in the true sense of the word, a large food industry, whose development is closely connected with the general development of industry in the world, and it is moving in terms of increasing capacity and at the same time in terms of increasing labor productivity. The level of agricultural technology, assortment but also climatic and soil conditions also dictate the yield. That is why we should always strive for new knowledge, and perfect the skill of forming yields, while preserving nature. Climate changes, fast growing world population, increased importance of ecological awareness in industry are factors which affect all aspects of human life, even on the production of sugar beet.

Where is the place of sugar beet in the world of tomorrow? Today sugar beet is the main source of sucrose for the European countries and further (especially the central and southern parts of the Europe) and is involved in agricultural plans of around 50 countries of the temperate regions of the world. Around 20% of world sugar production was made out of sugar beet (FAO 2009). Since sugar is strategical product which is needed in many industries (confectionary industry, beverage and alcohol industry, pastry industry), growing this crop will be continued. The aim of sugar beet growing will be focused on achieving greater white sugar yield (around

15 t/ha) with lower inputs and lower usage of pesticide by using conventional cultivation systems or organic growing in the world and even in Serbia and Montenegro. Due to unstable oil production and limited oil sources, new technologies are oriented towards new generations of biofuels from renewable sources where sugar beet offers interesting solutions using post-harvest sugar beet waste (biomass, sugar beet root residues, etc.).

Sucrose, stored in the sugar beet root, presents an economical source of bioethanol since it can be easily processed by microbes in the fermentation reactions. Also other fuels can be produced from sugar beet such as biomethane, biomethanol, and biohydrogen. In the future, solving the problem of weeds in sugar beet fields using transgenic or GM technologies will also present one of the challenges of sugar beet breeding with different opinions and effects on the environment. Sugar beet is an economically important crop, and the growth of world surfaces is expected in the future in Serbia and Montenegro.

The general tendency of the national economy in our country, in this economic branch is oriented towards increasing the beet processing capacity with the aim of completely freeing the country from sugar imports and with the task of eliminating its deficit despite the planned increase in consumption of this important food. In 2021, the average yield is 55 tons per hectare from 36 thousand hectares. In 2020, the yields were from 35 to 55 tons per hectare, even up to 60, so the yield this year is around the average. Starting from the current situation and our needs, the medium-term plan for the next period envisages a significant increase in the total production of sugar beet. This increase should be achieved to a greater extent by increasing the yield per unit area (hectare) and to a lesser extent by increasing the area under sugar beet.

12.4 Conclusion

In the world and in Serbia and Montenegro, a decline in sugar beet yields leads to a reduction in the economic budget. Climate change significantly contributes to reduced yields. For successful production planning, proper application is necessary for all measures in cultivation technology. Important measures of sugar beet production technology is properly balanced plant nutrition. NPK mineral nutrients are the major carrier of sugar beet productivity. Intensive NPK nutrition significantly increases the vegetative biomass quantity and root sugar content. Lack of soil nutrients significantly reduces yields. The major nutrients—nitrogen, phosphorus, and potassium, play an important role in plant nutrition and greatly impact yield and increase technological value of root. The quantity and ratio of the major, secondary, and microelements should be adjusted to the needs of plants and the natural fertility of the soil. Single plant nutrition system does not exist because the plant needs for certain elements depend on weather conditions, soil, cultivation methods (natural water regime, irrigation), and genotypes used in production. Crystal sugar yield, as major indicator of productive value, has statistically very significant dependence of way of plant nutrition, years, genotype, and interaction of them.

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