Chapter

Production and Salinity Tolerance of Fodder Beet (*Beta vulgaris* L. ssp. Maritima)

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Abstract

Fodder beet (*Beta vulgaris* L. ssp. maritima) belongs to the Amaranthaceae family. It was introduced first in the Europe and then to USA in 1800 and is currently being grown under cool environmental conditions of the world. It can be cultivated at temperature ranging from 8°C to 25°C. Both shoots and roots of fodder beet can be used as a feed for livestock. In the face of changing climate, there is a dire need to find out climate-resilient crops in new niches that can fulfill the growing needs of farming communities. In this context, fodder beet could be a good option for growers having sizable marginal as well as salt-affected soils. The chapter discusses in detail the efficient salinity-tolerance mechanism of fodder beet that enables it to survive under moderate salinity. Selective ion uptake mechanism, efficient antioxidant defensive mechanism and osmoregulation by accumulation of compatible solutes enable it to thrive well under saline environment. Hence, fodder beet is a relatively salt-tolerant crop that can be successfully grown on normal, marginal as well as salt-affected soils to fulfill the fodder requirements of livestock in fodder-scarce times and salinity amelioration.

Keywords: fodder beet, salinity, compatible solutes, salt tolerant crop, livestock

1. Introduction

1.1 Origin, history, and adaptation

Fodder beet (*Beta vulgaris* L. ssp. maritima) is known to have been originated in Mesopotamia (Middle East) and ancient Greece in 500 BC chiefly used as animal fodder [1]. It belongs to the Amaranthaceae family, which consists of about 105 genera separated into 1400 species, mainly herbaceous dicotyledonous plants [2]. *It was introduced firstly in Europe and then to USA in 1800 and is currently grown under cool environmental conditions of the world, mainly Northern America and New Zealand at 600–1000 m altitudes in the tropics*. *It can be cultivated at a temperature ranging from* 8 to 25°C. However, frost can damage the seedlings below −3°C. Suitable soil pH for beet cultivation is greater than 6.5 but acid soils are not adequate for beet growth. The crop is relatively salt tolerant and can also be cultivated with brackish water. It is drought tolerant and could be grown successfully at the end of a dry summer when other crops cannot be grown [3]. Both shoots and roots of fodder beet can be used as a feed for livestock. Roots of fodder beet contain sugars mainly in the form of sucrose (up to 60%), low crude protein (approximately 10%) as well as neutral detergent fiber contents (approximately 12%). The shoots of the beet make up about one-third of the dry matter of the whole plant and are considered to possess high protein content of 11.4–15.8% [4].

1.2 Soil and climate

The crop can be successfully grown on friable, deep, and well-drained soil containing sufficient calcium contents. Usually well-drained sandy loam soils are good for fodder beet cultivation. For good beet growth, soil pH should be 5.8–7.8. It is suitable for cultivation on temperate areas of the globe having mild winters and moderate summer temperature. The average annual precipitation for its development should be 60–65 cm. The suitable temperature for garden beet growth is between 15.5 and 25°C. It is a biannual crop and heat can damage its growth during the second year of its growth mainly at the start of pollination and seed formation.

2. General insights into salinity stress

The process of soil salinity is natural and closely linked with the formation of landscape and soil. Nevertheless, human-induced practices can promote salinity processes and hence may cause long-term degradation of water and land resources. When a high concentration of sodium salt adversely affects the growth of plants then salinity becomes a land issue, but whenever it affects the uptake of water because of the high concentration of salts in the water it becomes a water issue. Salinization is a serious problem of irrigated arable lands across the world. According to assessments, around more than 6% area of the world is affected by salinization due to natural causes or faculty irrigation practices. This situation has rendered the soils unfit for agriculture production annually [5]. When the saturation extract electrical conductivity in the rhizosphere surpasses 4 dS m^{-1} at the temperature of 25°C then the soil is recognized as saline soil and these soils possess exchangeable sodium greater than 15%. At this electrical conductivity, the crop yield is reduced by most crop plants [6].

The chief cause of the salinization of water and land in semiarid and arid areas of the world is mainly excessive irrigation. Salt stress occurs as ions such as electrically charged atoms or compounds in the soil. Due to mineral weathering, these salts are released in the soil. However, they might accumulate due to irrigation water application or sometimes from low groundwater they may travel upward in the soil. Low precipitation is unable to leach down these ions from the soil profile; as a result, accumulation of salts occurs in the soil and causes salt stress problem [7]. Water-soluble salts are contained by all soil types. Plants uptake essential nutrients in the form of soluble salts but excessive accumulation of these nutrients in the soil intensely suppresses the plant growth. The saline area in the world is increasing continuously each year mainly because more areas are being covered under irrigation [8].

3. Fodder beet as fodder crop in the world

In the face of changing climate, there is a dire need to find out climate-resilient crops that can fulfill the growing needs of the farming community. Fodder beet is a halophyte that can successfully be grown on salt-affected lands throughout the world. It not only fulfills fodder requirements of the ruminants and other cattle but also proved helpful for effective utilization of salt-affected marginal lands where no other crop can be grown. In countries like Pakistan and India, it can successfully be grown from August to September to fulfill fodder needs during the peak winter months where no other fodder crop can survive. Fodder beet has the ability to tolerate salinity as compared to other fodder crops; hence it can be successfully grown on salt-affected soils across the Globe. The scope of crop production has been limited due to millions of hectares of marginal and salt-affected soils [9]. For grazing young stock and to fill the feed gaps in the late lactation, fodder beet could be good choice as a feed for lactating cows. Likewise, in coastal areas of many European countries, the fodder beet is cultivated as a fodder and forage crop [10]. At South Island in New Zealand, fodder beet cultivation has become a renewed interest, particularly because dairy herbs fodder beet is being used for winter feeding of the livestock. Due to the wide acceptance of fodder beet in New Zealand, it is being cultivated on about 6–10,000 ha of land annually [5, 11].

4. Adverse effects of salinity stress on plants

Due to soil salinization and increased use of irrigation water with poor-quality water, soil salinity has become one of the most brutal abiotic stresses that limit crop productivity in many sections of the world [12]. There are numerous adverse effects of salinity stress on plant growth and development. Two major threats of salt stress to plant growth are osmotic stress and ionic stress. Firstly, soil salinity represses the growth of plants due to osmotic stress followed by the toxicity of ions [13]. Salinity stress also causes oxidative stress in plants. Various metabolic and physiological processes are adversely affected by salt stress in plants. The prominent symptoms of salinity stress include a reduction in leaf area, leaf abscission, enhancement of leaf succulence and thickness, reduction in length of internodes, and shoot and root necrosis [14]. Soil salinity stress also results in reduced water absorption capacity of roots, with a concomitant increase in the rate of transpiration, which is facilitated by high salt accumulation due to osmotic stress in plants and soils. As a result, osmotic stress due to salinity causes numerous biochemical changes inside the plant cell such as nutrient inequity, disruption of membranes, reduced ability to quench reactive oxygen species (ROS), and decreased stomatal conductance and photosynthetic activity [15]. Salinity stress is also known as hyper ionic stress. When plants are exposed to high NaCl concentrated soils, then salinity stress causes Cl^- and Na^+ ions accumulation in plant tissue, which is considered as the main harmful effect of salinity stress. The ionic balance of the plant cell is disturbed and significant physiological disorders may take place due to the introduction of Na^+ and Cl^- ions into the cells. K^+ ions are a key element for crop productivity but uptake of these ions is inhibited because of excessive concentration of Na^+ ions inside the cells. Consequently, deficiency of K^+ ions inside the cells results in less productivity and ultimately death of the plants. Moreover, reduction in leaf area, dry and fresh weight of root and shoot is a common feature of salinity stress [16].

Enhanced production of reactive oxygen species (ROS) as a result of salinity stress causes the creation of superoxide, singlet oxygen, hydrogen peroxide, and hydroxyl radicals. These ROS result in various oxidative damage to cellular components such as lipids, proteins, and DNA and also interrupt important cellular functions in plants [17].

5. Mechanism of salinity tolerance in fodder beet

Various biochemical and physiological mechanisms are involved in surviving fodder beet plants under high salt concentration.

5.1 Salt tolerance and ion homeostasis

Under salt stress conditions, maintenance of ion homeostasis is important for normal growth. Under extreme salt concentration, the halophytic plants are unable to tolerate salts in their cytoplasm, so the surplus amount of salt is either translocated to the vacuoles or seized in older tissues, which are finally scarified to protect the plant from salt stress condition. NaCl is the major salt present in the saline soils. Na^+/H^+ antiporters transport Na^+ ions that have entered the cytoplasm to the vacuoles. Vacuolar type H^+-ATPase (V-ATPase) and vacuolar pyrophosphatase (V-PPase) are two kinds of H^+ pumps that exist in the vacuolar membranes. The activity of these H^+ is upregulated under salt stress to mitigate the effects of salinity on plants [18]. Fodder beet plants develop efficient methods to keep low level of ion concentration in the cytoplasm. A significant role is performed by membranes and their related components for ion concentration maintenance within the cytosol during the stress period by regulation of ion transport and uptake. Different channels and the carrier proteins, symporters, and antiporters carried out the phenomenon of ion transport. Maintenance of cellular Na^+/K^+ balance is very essential for plant survival under salinity stress. During salt stress, due to enhanced Na^+ concentration in the soil, competition occurs between K^+ and Na^+ ion for the transporters because both these elements have the same transport mechanism, which reduces the uptake of K^+ [19].

5.2 Compatible solute accumulation and osmotic protection

The compatible solutes can be defined as a group of organic compounds that are chemically diverse and these are polar, uncharged, and naturally soluble. At high concentration, they do not hinder cellular metabolism. Polyols, proline, glycine betaine, and sugar are the main compatible solutes [26–28]. Arginine, cysteine, and methionine amino acids constitute about 55% of the total free amino acids and exposure of salinity stress decreases the concentration of these amino acids while the concentration of proline increases under salinity stress conditions [20]. Increased proline concentration in fodder beet helps the crop to cope with salinity stress and accumulation of proline is an eminent feature for salinity stress mitigation. It was also observed in some previous studies that higher proline accumulation in olive plants increased salt tolerance by improving photosynthetic activity, antioxidative enzymatic activity, and plant growth and helped to maintain suitable water balance in the cells under salt stress conditions [21]. During recovery from stress, proline accumulation in fodder beet served as an organic nitrogen. Glycine betaine plays a vital role in the mitigation of stress in the fodder beet by raising the cell osmolarity during salinity stress. Glycine betaine helps in protein stabilization, provides protection to the cell through osmotic adjustment, guards the chlorophyll against stress injuries as well as reduces reactive oxygen species. Salinity stress in fodder increased the accumulation of soluble sugars. These sugars serve as a source of carbon storage, provide osmoprotection, and help in the scavenging of reactive oxygen species [22].

5.3 Role of antioxidant enzymes in salinity tolerance

Salinity stress in plants may cause overproduction or disruption of electron transport chains (ETCs) in subcellular organelles such as chloroplasts and mitochondria. In this scenario, molecular oxygen or $^1O_2$ acts as an electron acceptor, causing the accumulation of reactive oxygen species (ROS). This singlet oxygen ($^1O_2$), the superoxide radical, the hydroxyl radical (OH^-), and hydrogen peroxide (H_2O_2) are all strongly reactive compounds and hence can cause damage to the cell integrity. Upregulation of antioxidant defensive mechanisms in fodder beet plants plays a vital role in the detoxification of ROS, which are otherwise triggered under salinity stress. The activity of antioxidant enzymes is positively correlated with salinity tolerance. Three specific traits help the plants to better adapt under salinity stress environment mainly through ion exclusion and tissue tolerance ability. Thus antioxidant enzymes contribute in maintaining tissue turgidity and in the mechanism of salinity tolerance [12].

5.4 Roles of polyamines in salinity tolerance

In abiotic stresses, the polyamines play an important role such as salt stress and stress tolerance in plants is correlated with an increase in the level of polyamines. Endogenous polyamines level in fodder beet and other salt-tolerant plants increases with exposure to salinity stress. Polyamines play a positive role in salt stress by maintaining the membrane integrity; regulating the genes expression for solutes synthesis, which are osmotically active; reducing reactive oxygen species (ROS); and most importantly controlling the Na^+ and Cl^- ion accumulation [23].

5.5 Hormonal regulation of salinity tolerance

The increased concentration of abscisic acid (ABA) can reduce the impact of salinity stress on assimilates translocation and photosynthesis. The positive association between salinity tolerance and ABA accumulation is attributed to the K^+, Ca^{2+} accumulation, and accumulation of sugars, and proline in root vacuole, which restrict the uptake of Na^+ and Cl^- [24]. The compounds like brassinosteroids (BRs) and salicylic acid (SA) have hormonal properties and paly a role in plant responses to abiotic stresses. The application of these compounds improves salt tolerance in plants by regulation of various physiological and biochemical processes [24].

6. Mechanism against salinity-induced oxidative stress

Salinity stress results in a continuous increment in cellular membrane injury and a reduction in relative water content. Further, increased ion leakage of cellular membranes due to salinity stress results in malfunctioning of cellular membranes. It has been observed that plasma membrane deteriorates owing to the salt ions action. Cell membrane stability and maintenance of suitable relative water content are significantly reduced by salinity stress [25]. The primary site of salt injury is the plasma membrane because salt stress causes changes in plasma membrane permeability and the lipid composition of membranes and also alters the activities of membrane-bound enzymes. That is why plasma membrane permeability is an effective selection criterion for salinity stress in fodder beet and other plants. Alteration in plasma membrane permeability occurs significantly in salt-sensitive crops but in the case of fodder beet is less affected under salinity stress. The inherited and induced protection of membranes in fodder beet and some other salt-tolerant crops helps in the maintenance of cell membrane permeability and stability of the plasma membrane. Sustained composition of lipids and protein and accumulation of several protecting agents under salt stress in salt-tolerant crops help to retain and stabilize plasma membrane integrity. In salt-tolerant crops such as fodder beet, some specific protein and lipids are induced under salt stress and contribute to the maintenance of cellular membrane function and structure. Cellular membrane stabilization and protection are also achieved by proline, glycine betaine, and polyamines and these are known as protecting agents of the cellular membrane. It has been proved that salt stress correlates with plasma membrane permeability and this feature of plasma membrane is a useful character for selecting salt-tolerant crop genotypes [26, 27]. An important adaptive mechanism of fodder beet plants and other halophytes under salinity stress is the expression of stress proteins, which helps in the maintenance of cell membrane integrity, topology, and native configuration. Under wheat plants exposed to salinity stress, protein content and molecular weight of the protein were found to decrease, which ultimately affected the activities of different proteins. This change in protein activities suggests that only some proteins are directly participating in salinity tolerance [28].

7. Osmotic adjustment under salinity stress

To reduce cell water potential, fodder beet and other halophytes accumulate inorganic ions in their vacuoles because the consumption of energy from synthesizing organic compounds is far less than absorbing inorganic ions [29]. Under salt stress, the main inorganic osmolyte in the vacuole is Na^+ ion. In many plants, salt stress inhibits the accumulation of Mg^{2+} and Ca^{2+}. But fodder beet crops can accumulate Ca^{2+} and Mg^{2+} ions under salinity stress and hence contribute to better osmotic adjustment. To maintain various enzymatic processes, it is essential to maintain low Na^+ ion and high K^+ ions in the vacuoles. Under salinity stress, absorption of K^+ is inhibited while the absorption of Na^+ is increased in many halophytes. But in case of fodder beet, the accumulation of both Na^+ and K^+ ions increases under salt stress. This phenomenon proves that fodder beet plants may have a distinctive pathway for absorption of Na^+ independent of K^+ pathway [30].

When plants are exposed to salinity, their primary reaction is osmotic stress. To alleviate osmotic imbalances due to salt stress, osmotic adjustment is very essential for the maintenance of cell turgor [31]. It encompasses cellular accumulation of solute in response to a reduction in the water potential of the environment. Fodder beet plants have a high osmotic adjustment capacity, as reflected by the organic and inorganic osmolyte accumulation in salinity stress [32]. Earlier in the chapter, it has been emphasized that accumulation of glycine betaine, proline, free amino acids, and choline occurs in fodder beet leaves when the concentration of NaCl is increased in the growth medium. Under normal growth conditions, high level of glycine betaine in young leaves of fodder is detected because glycine betaine is primarily synthesized in the old leaves and then translocated to the young leaves; that is why young leaves of fodder contain a high accumulation of glycine betaine. It is important to point out here that a glycine betaine plays a key role in fodder beet exposed to salt stress [33]. Similarly, proline accumulation was found to occur mainly to facilitate osmotic adjustment and salinity stress mitigation in many halophytes and fodder beet plants. It has been proved that proline concentration in shoots of fodder beet and other salt-tolerant plants was higher than in salt-sensitive plants [34]. High proline concentration in salt-tolerant genotypes of fodder is induced by cellular demand for membrane stabilization and osmotic adjustment. But the contribution of proline for osmotic adjustment and salinity stress mitigation is small as compared to the contribution of glycine betaine. The presence of inorganic salt ions in fodder beet and other halophytes also plays an essential role in an osmotic adjustment under salinity stress. In an earlier research investigation, it was proposed that high levels of ions such as Cl^-, K^+, and N^+ in shoots of fodder beet seedlings played a role in salinity stress mitigation and effective osmotic adjustment during salinity stress [35].

8. Biochemical indicators of salinity stress

Adaptive mechanisms that are utilized by plants to survive under salinity stress and metabolic sites which damages due to salt stress are not well understood. Due to this, no well-defined salinity stress indicator is accessible to help plant breeders for the improvement of tolerance to salinity of main crops. In recent times plant breeders have effectively enhanced salt stress forbearance of some crops such as fodder beet using seed yield or vigor of the plant as the key selection criteria but in order to have more convenient and practicable selection crop must possess distinctive indicators of salt stress at cellular, tissue or whole plant level [36].

Some of the biochemical indicators of salinity stress are discussed below:

8.1 Biochemical markers

As already discussed, osmotic adjustment to mitigate salt stress can be accomplished by accumulation of high levels of inorganic ions or low-molecular weight organic solutes. Both of these play a key role in salt stress tolerance in higher plants. The compatible osmolytes that are found in fodder beet and higher plants are organic acids, sugars with low molecular weight, polyols, and nitrogen-containing compounds [37].

8.2 Soluble sugars

In glycophytes in saline situation, sugars contribution is up to 50% of total osmotic potential. Despite a significant decrease in the net CO_2 assimilation rate the soluble carbohydrate accumulation has been reported widely in plants under salt stress. It has been found that salt-tolerant crops such as fodder beet accumulate high levels of soluble sugars under salt stress conditions. It is evident that considerable variations in the soluble sugars accumulation in response to salinity stress exist at both intraspecific and interspecific levels and even among all genotypes of different salt-tolerant plants [38].

8.3 Soluble proteins

In fodder beet and other salt-tolerant crops, proteins that accumulate under salinity stress may provide a storage form of nitrogen, which is reutilized when stress is over and may also play a part in osmotic adjustment. When salt-tolerant plants such as fodder are exposed to salt stress, the accumulation of soluble proteins is increased to play a role in mitigating the adverse effect of salinity. The soluble proteins are the essential molecular markers for betterment of salt tolerance by the means of genetic engineering techniques but the use of soluble proteins as biochemical indicator depends on the nature of plant cultivar or species [39].

8.4 Amino acids and amides

In fodder beets and higher salt-tolerant plants, the accumulation of amino acids has been reported under salt stress. In salt-tolerant plants, glutamine and asparagine amides have also reported to accumulate under salt stress. It has been reported that total free amino acids tend to be higher in leaves of fodder and salt-tolerant lines of sunflower than in salt-sensitive lines of fodder beet, sunflower, safflower and *Lens culinaris* [40]. For example, proline is accumulated at a higher level in fodder beet under salt stress.

8.5 Polyamines and polyols

Accumulation of polyamines can also be used as an indicator of salinity stress. In several studies, it has been reported that the accumulation of polyamines increased when plants were exposed to salinity stress [41].

Polyols are also thought to play a role in salt tolerance in salt-tolerant plants. Polyols accumulate in the cytoplasm of salt-tolerant plants to overcome the osmotic disturbances, which occurred due to high levels of inorganic ions that are compartmentalized in vacuoles. Polyols also play a part in oxygen radical scavenging. Polyols accumulation has been reported in several studies in response to salt stress in many higher plants; thus it can also be used as a biochemical indicator of salt stress [42].

8.6 ATPases

One of the important factors responsible for salt tolerance of plants is the regulation of ion transport. A significant role is played by membrane proteins in selective distribution of ions with the cell or whole plant. Salinity tolerance in plants is linked with low accumulation and uptake of Na^+ ions. ATPases can be used as a biochemical indicator of salinity stress because it has been reported that the activity of ATPases increases in roots, leaves, and cells of tested plants under induced salinity stress. It was found in wheat and fodder beet that activity of ATPases increased in salt-tolerant genotypes as compared to salt-sensitive genotypes under induced salinity stress [43].

9. Antioxidants and ROS-scavenging

Plants are protected from oxidative damages by antioxidant defense machinery. Several enzymatic antioxidant defense systems are possessed by plants such as super oxide dismutase, peroxidases, glutathione reductase, catalases, ascorbate peroxidase, dehydroascorbate reductases, monodehydroascorbate, glutathione peroxidase, glutathione-S-transferase, guaiacol peroxidase, ascorbic acid, glutathione, phenolic compounds, alkaloids, α-tocopherols, and non-protein amino acids, which help to control the negative effects of uncontrolled oxidation as well as provide protection to plant cells from oxidative damages caused via scavenging of ROS. The ROS also effect the gene expression of many genes and thus control many processes like abiotic stress (salinity) response, programmed cell death, growth, pathogen defense, cell cycle, systemic signaling, and development [44].

ROS are recognized as the main cause of cellular damage under biotic and abiotic stresses. During aerobic metabolism when electrons from the electron transport chains in chloroplast and mitochondria are leaked and react with oxygen in the nonappearance of other acceptors the active oxygen species such as hydrogen peroxide, hydroxy radical, super oxide, and singlet oxygen are produced [45]. Nonetheless, by superoxide dismutase (SOD), plants can eliminate super oxide, which catalyzes the dismutation of super oxide into H_20_2 and O_2 and is essential in the prevention of metal ions reduction and hence the synthesis of hydroxyl radicals. An ascorbate peroxide, which is located in the thylakoid membrane, can also eliminate hydrogen peroxide [46].

It has been reported that the production of ROS is increased in plants in response to different abiotic stresses such as salinity stress, drought, high- and low-temperature stress, water-logging stress, light stress, etc. [47]. One of the key limiting factors in crop production is oxidative stress. Due to the production of ROS under salinity stress, the plants come under oxidative stress. It has been reported that ROS, which is generated during metabolic processes, results in damage to cellular functions, which finally lead to senescence, disease, and ultimately cell death. As discussed earlier, efficient defense systems of plants scavenge ROS by antioxidant enzymes. Several attempts have been made by researchers to lessen the oxidative damage under the salinity stress by the management of enzymes that can scavenge ROS by technology used for gene transfer [48].

In a comparison of the antioxidant production mechanism in salt-sensitive and salt-tolerant plants, it was found that peroxidase activity increases while a decline was noted in SOD activity [49].

10. Salinity tolerance improvement in fodder beet

When comparing with other fodder and forage crops fodder beet is a fodder crop with salt tolerance ability as it can be successfully grown on salt-affected lands. The most serious and important threats to crop productivity worldwide are drought and salinity [50]. Estimates show that excessive and regular irrigation results in the salinization, which leads to the desertion of 107 hectares of arable land annually. Moreover, 0.25–0.5 M ha of agricultural land is lost yearly in semiarid and arid areas because of the salinity problem worldwide [51, 52]. Salt stress causes a reduction in field crop production of most crops [53]. It has been reported that salinity greatly influenced the growth attributes of fodder beet genotypes. Fodder beet has the greater ability to thrive best under salinity stress with the highest biomass production than other fodder crops. Overall, fodder beet plants grew successfully under moderate salinity up to 200 mM saline soil [54].

Fodder beet is a more salt-tolerant crop and can be grown on saline soil than other forage and fodder crops. Fodder beet is used as animal feed in many European countries as well as in Egypt. The roots and leaves can be fed to animals in both fresh and silage form [55]. On saline barren lands, high economic yield production can be achieved by growing fodder beet as a fodder crop [56]. All parts of fodder beet such as tuberous roots and aboveground leaves are utilized as animal feed alone or in combination in Europe and numerous other countries of the world [57]. There is a dire need to identify mutants to develop high biomass-producing, high-protein fodder beet plants with the ability to grow not only on normal soils but also on salt-affected soils in the world.

11. Future perspectives

Fodder beet is a potential high-biomass fodder crop that can be introduced with guaranteed success to fulfill the fodder needs of small ruminants as well as lactating cows and buffaloes. There is dire need to promote its seed production in the northern parts of Pakistan like Swat, Naran, and Kaghan to provide seed to the local growers. This will help to reduce reliance on imported seeds on one hand and promote its cultivation during fodder-scarce months, which is a limiting factor for the livestock industry in the country. Fodder beet can also be used for effective utilization of sizable salt-affected soils in Pakistan, which otherwise remain barren or could not be used for any crop production. It will help the local growers to improve their socioeconomic conditions.

Fodder beet can be cultivated and promoted as a potential fodder crop in Pakistan and other countries of South Asia along with the conventional crops such as Oat (*Avena fatua*), Barley (*Hordeum vulgare* L.), Alfalfa (*Medicago sativa* L.) etc. The cropping season of fodder beet in Pakistan also matches with the conventional fodder shortage period for livestock.

In the future, the main area of research should be to develop local fodder beet varieties adapted under local agroecological conditions with the ability to produce high fresh biomass on normal as well as saline environmental conditions.

12. Conclusion

Fodder beet crops can thrive under moderate salinity due to an efficient salinity tolerance mechanism. Generally, salt stress reduces the shoot and root growth of fodder beet plants. The ability of fodder plants to survive under salinity stress depends on the stage of crop growth, the intensity of salinity stress, and duration of salinity. Fodder beet being a halophytic plant possess the ability to selectively uptake beneficial ions like calcium and potassium and reduce uptake of toxic and harmful ions like Na^+ and Cl^-. Moreover, the efficient antioxidant defensive mechanism makes it able to thrive under the saline environment by deleting reactive oxygen species generated in the chloroplast and mitochondria. The enhanced concentration of compatible solutes such as polyols, proline, glycine betaine, and soluble sugars in fodder beet under abiotic stresses makes it suitable to grow under abiotic stresses especially under saline environments. Thus, it can be concluded that fodder beet is a relatively salt-tolerant crop, which can be successfully grown on normal, marginal as well as under salt-affected soils to fulfill the fodder requirements of livestock in fodder-scarce times.

Conflicts of interest

The authors declare no conflicts of interest.

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