BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg

BIOECOLOGICAL CHARACTERISTICS OF FODDER BEET (Beta vulgaris L.)

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doi:**https://doi.org/10.5281/zenodo.23978098**

Abstract. This article provides a scientific overview of the botanical and morphological structure of fodder beet (Beta vulgaris L.), its biological development characteristics, and its responses to environmental factors. The effects of temperature, light, soil moisture, soil composition, and mineral nutrition on the growth and development of fodder beet are analyzed. The article also discusses the plant's growing season, root development, photosynthetic activity, tolerance to drought and salinity, and its importance in livestock production. Studying the bioecological characteristics of fodder beet is of considerable scientific and practical importance for its efficient cultivation under various soil and climatic conditions and for achieving high yields.

Keywords: fodder beet, Beta vulgaris L., bioecology, morphology, root crop, growing season, photosynthesis, environmental factors, drought, salinity, yield.

Introduction. The sustainable development of the livestock sector in agriculture largely depends on establishing a reliable forage base. Providing livestock with high-quality, nutritious, and energy-rich feed throughout the year is one of the pressing issues of today. In particular, the shortage of succulent feed during autumn and winter and early spring can negatively affect livestock productivity. Fodder beet is one of the important forage crops that plays a significant role in addressing this problem. It is distinguished by its high biological productivity, high carbohydrate content, succulence, and good palatability for farm animals.

Fodder beet belongs to the family Amaranthaceae and represents one of the cultivated forms of beet used for various agricultural purposes. Its main economically valuable part is the enlarged root, while its leaves are also used as livestock feed.A thorough study of the biological and ecological characteristics of this crop is particularly important for identifying opportunities to improve its growth, development, and productivity, especially in regions with hot and arid climates.

Fodder beet is a biennial plant. During the first year, it develops its vegetative organs, including leaves and a large storage root in which nutrients accumulate. During the second year, the nutrients stored in the root support the development of generative organs, the formation of flowering stems, flowering, and seed production.

The taxonomic classification of fodder beet is as follows:

- Kingdom: Plantae;
- Clade: Angiosperms;
- Clade: Eudicots;
- Order: Caryophyllales;
- Family: Amaranthaceae;
- Genus: Beta;
- Species: Cultivated beet (Beta vulgaris L.).

Botanical and Morphological Characteristics of Fodder Beet. Depending on the variety, the root of fodder beet may be round, oval, cylindrical, or conical. Its color can range from white and yellowish to pink or reddish.The degree to which the root is embedded in the soil depends on

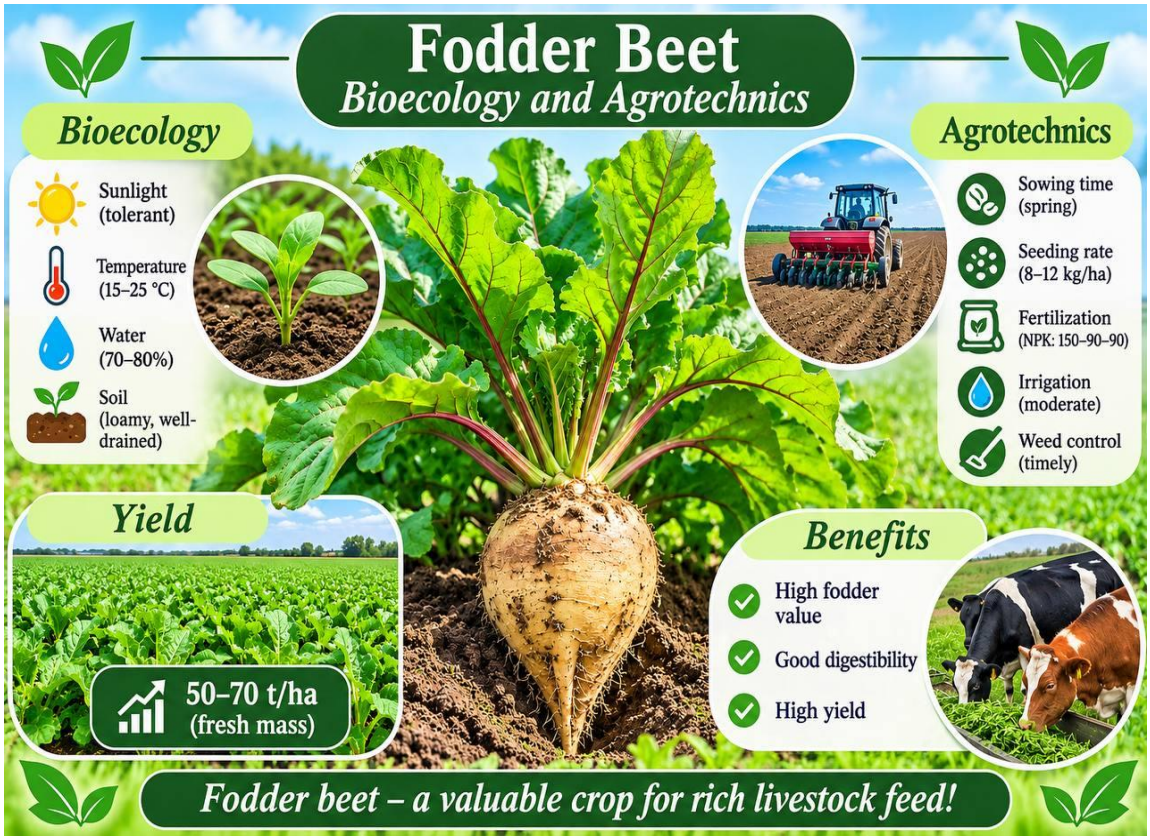
varietal characteristics and the mechanical composition of the soil. In some varieties, most of the root is located above the soil surface, whereas in others, it penetrates more deeply into the soil.Morphologically, fodder beet consists of several main organs: the root system, storage root, stem, leaves, and generative organs.The root system of fodder beet is well developed and consists of a main taproot and lateral roots branching from it. The roots are capable of penetrating deep soil layers. This enables the plant to utilize water and mineral nutrients from deeper soil horizons.Root system development depends on the mechanical composition, density, moisture content, and nutrient availability of the soil. Roots develop actively in loose, fertile, and well-aerated soils.The storage root is the main economically valuable organ of fodder beet. Organic substances produced during photosynthesis, primarily sucrose and other carbohydrates, accumulate in it. The shape, size, and chemical composition of the root depend on varietal characteristics, agricultural practices, and environmental conditions.In the anatomical structure of the storage root, conducting tissues, parenchyma cells, and tissues responsible for the accumulation of reserve nutrients play important roles.The leaves of fodder beet are large, petiolate, and heart-shaped or ovate. They are arranged in a rosette at the upper part of the storage root. The leaf blades have a broad surface adapted to absorb sunlight and carry out photosynthesis.The degree of leaf development directly affects the overall biological productivity of the plant. Adequate development of the leaf surface contributes to greater carbohydrate accumulation in the storage root.During the first growing season, fodder beet primarily develops its vegetative organs. In the second year, it produces a flowering stem. The flowering stem grows upright and bears small, greenish flowers. The flowers are generally arranged in inflorescences. Pollination occurs mainly through wind.Seeds develop within fruit clusters. Studying the characteristics of generative development is important in plant breeding and seed production.

Biological Development and Growth Stages. Fodder beet has a biennial biological development cycle. Its life cycle consists of several successive stages.

Seeds germinate under favorable temperature, moisture, and oxygen conditions. Initially, the seed coat softens, the embryonic root develops, and subsequently the aboveground part emerges through the soil surface. Germination depends on seed quality, sowing depth, and soil moisture.During the seedling stage, the first leaves develop, and the root system begins to grow. Young seedlings are particularly sensitive to competition from weeds during the early stages of development. Therefore, maintaining weed-free fields is essential.During the formation of the leaf rosette, new leaves emerge and the leaf surface expands. Photosynthetic activity increases, leading to enhanced production of organic substances.

The formation and enlargement of the storage root represent the most important stage in the biological development of fodder beet. Organic substances synthesized in the leaves are transported to the storage root, where they accumulate as reserve nutrients. Adequate moisture, mineral nutrition, and light have a positive effect on root enlargement.During the ripening stage, which occurs toward the end of the growing season, the lower leaves begin to turn yellow and dry out. The accumulation of dry matter and carbohydrates in the storage root continues. The degree of crop maturity depends on varietal characteristics and environmental conditions.The growing season of fodder beet varies depending on the variety and cultivation conditions. According to the FAO EcoCrop database, cultivated beet has a crop cycle of 160–240 days [1].

BG Pulse Journal USA
ISSN:1947-2536 http://www.bgpulseusa.com/index.php/bg
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The Response of Fodder Beet to Environmental Factors. The growth, development, and productivity of fodder beet are closely associated with environmental conditions. These factors include temperature, light, water, soil conditions, and mineral nutrition.Fodder beet is a crop adapted to temperate climatic conditions. Moderate temperatures are favorable for its growth and development.According to the FAO EcoCrop database, the optimal temperature range for cultivated beet is 15–25°C. A sharp increase in temperature may negatively affect physiological processes in the plant, particularly photosynthesis and water exchange [1].Low temperatures slow down seed germination. Severe frost can damage seedlings and leaves. Young plants are particularly sensitive to sudden temperature fluctuations.Under high-temperature conditions, the plant can continue growing to a certain extent if soil moisture is sufficient. However, prolonged heat stress may accelerate leaf senescence and restrict storage root formation.Fodder beet is a light-loving plant. Light is the primary energy source for photosynthesis and ensures the production of organic substances.Under sufficient light conditions, the photosynthetic activity of leaves increases, resulting in greater carbohydrate accumulation in the storage root. Insufficient light leads to poor leaf development, reduced photosynthetic intensity, and decreased productivity.Dense planting may cause leaves to shade one another. Under such conditions, the photosynthetic activity of lower leaves decreases. Therefore, it is necessary to establish appropriate sowing rates and ensure optimal plant spacing.Water plays an essential role in the vital processes of fodder beet. It is involved in seed germination, mineral nutrient uptake, photosynthesis, transpiration, and cell growth.Adequate soil moisture during the early stages of plant development promotes uniform seedling emergence. During subsequent stages, water is essential for storage root formation and enlargement.Water deficiency reduces leaf turgor, restricts stomatal activity, and decreases photosynthetic intensity. As a result, the increase in storage root mass slows down.A study published in 2022 by Khaembah and

co-authors found that water and nitrogen deficiencies reduce leaf development, nitrogen uptake, and total dry matter production in fodder beet [5].Fodder beet develops well in fertile, deeply cultivated, structurally stable, and well-drained soils. Sandy loam, loamy, and medium-textured soils are considered suitable for its cultivation.A soil reaction close to neutral or slightly alkaline is desirable. According to FAO data, the optimal pH range for cultivated beet is 6–7 [1].In acidic soils, the uptake of certain nutrients may be disrupted. In heavy, compacted, and waterlogged soils, root system development is restricted.Improving soil fertility, applying organic fertilizers, and enhancing soil structure help fodder beet fully realize its biological potential.

The Role of Mineral Nutrition in the Growth and Development of Fodder Beet. Nitrogen, phosphorus, and potassium are the primary nutrients required for the growth and development of fodder beet.

-Nitrogen affects leaf and stem development, chlorophyll formation, and photosynthetic activity.

-Phosphorus participates in energy metabolism, root system development, and generative processes.

-Potassium plays an important role in water regulation, enzyme activity, and increasing the plant's tolerance to unfavorable environmental conditions.

-Boron is involved in cell wall formation, the functioning of growing points, and the normal development of the storage root.

-Magnesium is essential for photosynthesis as a structural component of the chlorophyll molecule.

Nutrient deficiencies or excessive fertilizer application can negatively affect the physiological condition of the plant. Therefore, mineral fertilizer application rates should be determined according to soil analysis and the biological requirements of the crop.

Drought and Salinity Tolerance of Fodder Beet. Fodder beet can adapt to certain unfavorable environmental conditions to some extent. Its root system, cellular osmotic regulation, and physiological adaptation mechanisms play important roles in this process.Under drought conditions, the plant partially closes its stomata to reduce water loss. As a result, transpiration decreases; however, carbon dioxide uptake is also restricted, leading to a reduction in photosynthetic intensity.Under saline conditions, the osmotic pressure of the soil solution increases. This makes water absorption by the roots more difficult. Although certain beet varieties demonstrate a degree of tolerance to salt stress, severe and prolonged salinity reduces plant growth and productivity.A scientific review published in the journal Plants in 2021 analyzed the responses of cultivated beet to drought and salinity at morphological, physiological, and molecular levels [3].Therefore, when cultivating fodder beet in saline areas, it is important to select suitable varieties, monitor irrigation water quality, improve drainage systems, and reduce soil salinity.

Photosynthetic Activity and Biological Productivity of Fodder Beet. Photosynthesis is one of the fundamental physiological processes in plants, through which organic substances are produced. In fodder beet, photosynthesis takes place primarily in the leaves.Carbohydrates produced in the leaves are transported through the phloem to the storage root, where they accumulate as reserve substances. Therefore, well-developed foliage that remains physiologically active for an extended period is essential for achieving high storage root yields.

In a study published in the European Journal of Agronomy in 2016, Chakwizira and co-authors investigated the relationships between canopy formation, light interception, and water and nitrogen availability in fodder beet crops [4].The research findings confirm that water and nitrogen availability significantly influence leaf expansion, development, and plant biomass formation.

Agroecological Characteristics of Fodder Beet Cultivation. Achieving high fodder beet yields requires consideration of the natural and climatic conditions of the region, as well as appropriate agricultural practices. Land selection, soil preparation, seed sowing, irrigation, fertilization, and harvesting are all important aspects of crop cultivation.For fodder beet, fertile, weed-free, and well-drained fields should be selected. The soil is deeply plowed in autumn and leveled and finely prepared before sowing. Excessive soil compaction can interfere with the normal development of the storage root.The sowing date is determined according to the climatic conditions of the region, soil temperature, and moisture content. High-quality seed material should be used to ensure uniform germination. Sowing depth and row spacing should be adjusted to the mechanical composition of the soil and the agricultural machinery being used.Fodder beet is considered a moisture-demanding crop. Maintaining optimal soil moisture is particularly important during seedling emergence, leaf canopy development, and the period of intensive storage root growth.Irrigation rates should be determined according to soil type, groundwater depth, precipitation, and the developmental stage of the plant.The scientifically justified application of organic and mineral fertilizers increases crop productivity. Nitrogen fertilizers promote leaf mass development, while phosphorus and potassium fertilizers support root system development, metabolism, and yield formation. Fertilizer application rates should preferably be determined based on agrochemical soil analysis.Fodder beet roots are harvested at the stage of biological maturity. When determining the harvesting period, the condition of the leaves, root size, varietal characteristics, and the risk of frost should be taken into account. Harvesting and storing the roots without causing mechanical damage are important for preserving their quality.

Conclusion. Fodder beet (Beta vulgaris L.) is one of the important forage crops characterized by high biological productivity. Its primary agricultural value is determined by its ability to produce large storage roots, its high content of easily digestible carbohydrates, and its role as an energy-rich feed source for livestock.Based on the analysis of scientific literature, the following conclusions can be drawn:

1. Fodder beet is a biennial plant. During the first growing season, it develops leaves and a storage root, while generative organs are formed during the second year.
2. The growth and development of the plant are directly dependent on environmental factors such as temperature, light, soil moisture, soil fertility, and mineral nutrition.
3. The development of the leaf canopy and the intensity of photosynthesis play an important role in storage root formation and enlargement.
4. Although fodder beet has a certain capacity to adapt to drought and salinity, severe stress conditions reduce its biological productivity.
5. Mineral nutrition, particularly the elements nitrogen, phosphorus, potassium, and boron, plays an important role in the normal development of the plant.
6. Cultivating fodder beet in accordance with local soil and climatic conditions is important for strengthening the forage base of livestock production.

In general, an in-depth study of the bioecological characteristics of fodder beet is essential for assessing its ecological adaptability, increasing its productivity, and scientifically improving cultivation technologies.

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