THE EFFECT OF MINERAL FERTILIZERS AND PLANTING DENSITY ON THE GROWTH AND DEVELOPMENT OF FODDER BEET

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Abstract. Particular attention is given to the effects of nitrogen, phosphorus, and potassium on vegetative growth, leaf formation, root development, and biomass accumulation. Planting density affects the availability of light, water, nutrients, and physical space for individual plants, thereby influencing both individual plant productivity and yield per unit area. The analysis indicates that excessive planting density can increase competition among plants, while insufficient density may result in inefficient utilization of the growing area. Balanced mineral nutrition, combined with an appropriate planting density, creates favorable conditions for vigorous growth and effective root development. The interaction between plant density and fertilizer application should therefore be considered when developing fodder beet cultivation technologies.

Keywords: fodder beet, *Beta vulgaris* L., mineral fertilizers, planting density, plant population, nitrogen, phosphorus, potassium, plant growth, root development, biomass, yield, nutrient management.

Introduction. Fodder production is one of the most important components of sustainable livestock farming. The availability of high-quality feed directly affects animal health, productivity, and the economic efficiency of livestock production. Among forage crops, fodder beet is particularly valuable because it produces a high amount of succulent biomass and contains readily available carbohydrates and other nutrients.

Fodder beet belongs to the genus *Beta* and is cultivated primarily for its enlarged storage roots. The roots can be used as a succulent feed for cattle and other livestock. In addition to the roots, the leaves can also contribute to the feed supply when properly managed.

The growth and development of fodder beet depend on several environmental and agronomic factors. These include soil fertility, temperature, moisture availability, planting date, cultivar characteristics, weed control, irrigation, planting density, and mineral nutrition. Among these factors, planting density and fertilizer management are particularly important because they directly influence the availability and utilization of essential resources.

Planting density determines the amount of soil and above-ground space available to each plant. At excessive density, plants compete for sunlight, water, and nutrients, which may reduce individual root development. At very low density, individual plants may develop larger roots, but the total number of plants per hectare is reduced, potentially decreasing productivity per unit area.

Mineral fertilizers are essential for supplying nutrients required for plant growth. Nitrogen is closely associated with leaf and vegetative development, phosphorus supports root growth and energy metabolism, and potassium contributes to water regulation, enzyme activity, and carbohydrate transport. Efficient fertilization therefore requires a balanced supply of nutrients rather than excessive application of a single nutrient.

The objective of this article is to analyze the effects of mineral fertilizers and planting density on the growth and development of fodder beet and to discuss their importance for improving crop productivity.

During the growing season, observations should be conducted at different growth stages. The following parameters are recommended:

1. emergence rate;
2. plant survival;
3. plant height;
4. number of leaves per plant;
5. leaf area;
6. root length and diameter;
7. average root weight;
8. fresh root biomass;
9. total fresh biomass; and
10. dry matter accumulation.

At harvest, root yield and total biomass yield should be measured for each experimental treatment. The results can be expressed in tonnes per hectare.

The data should be statistically analyzed using analysis of variance (ANOVA) to determine the effects of planting density, fertilizer treatment, and their interaction. Mean comparisons can be conducted where statistically significant differences are identified.

Effect of planting density on plant growth. Planting density has a significant influence on the growth pattern of fodder beet. The availability of sufficient growing space allows individual plants to develop their root systems and leaves effectively.

At low planting densities, plants have greater access to light, soil moisture, and nutrients. Consequently, individual plants may develop larger leaves and heavier storage roots. However, because fewer plants occupy each hectare, the total yield per unit area may not necessarily be optimal.

As planting density increases, the number of plants per unit area increases and land resources are utilized more intensively. However, excessive density may lead to strong competition among plants. Competition for light can reduce the efficiency of photosynthesis, while competition for water and nutrients can limit root development.

The response of fodder beet to planting density can therefore be described as a balance between individual plant growth and the number of productive plants per hectare. The optimal density is the level at which the crop can maximize yield without causing excessive competition.

Mineral fertilizers have an important role in supporting the vegetative development of fodder beet.

Nitrogen is particularly important during the early and middle stages of crop development. Adequate nitrogen availability promotes leaf production and expansion, resulting in a larger photosynthetic surface. A well-developed leaf canopy increases the crop's capacity to produce assimilates that can subsequently be transported to the storage root.

However, excessive nitrogen application may result in disproportionate vegetative growth. Excessive leaf development does not always lead to a proportional increase in root yield and may reduce fertilizer-use efficiency. Therefore, nitrogen should be applied according to soil nutrient availability and crop demand.

Phosphorus contributes to early root establishment and supports energy transfer within plant cells. Adequate phosphorus nutrition can promote root-system development, which is particularly important for a root crop such as fodder beet.

Potassium plays an important role in maintaining plant water balance and regulating physiological processes. It also participates in carbohydrate metabolism and assimilate transport, making it particularly relevant to the development of storage roots.

The storage root is the primary economic component of fodder beet. Its development depends on the combined effects of genetic potential, nutrient availability, water supply, and plant population.

Under favorable nutritional conditions, fodder beet plants can develop a larger root system and accumulate greater quantities of carbohydrates and dry matter. Adequate potassium and phosphorus availability can support root development, while nitrogen contributes indirectly by maintaining a healthy photosynthetic canopy.

Planting density also affects root size. At high density, competition may limit the lateral expansion of roots. As a result, average root weight may decline even when total root yield per hectare increases.

Therefore, evaluating only individual root weight is insufficient for determining the best treatment. Both individual plant productivity and total yield per hectare should be considered.

The effects of mineral fertilizers and planting density are closely interconnected. When plants are grown at a higher density, the total nutrient demand of the crop increases. Adequate nutrient availability is therefore particularly important for maintaining crop growth under dense planting conditions.

However, fertilizer application cannot completely compensate for excessive planting density. Even when nutrients are available in sufficient quantities, plants may still experience competition for light, water, and physical space.

Conversely, at very low planting density, high fertilizer rates may not produce an economically proportional increase in yield because the number of plants capable of utilizing the available nutrients is limited.

The most effective production strategy is therefore to combine an appropriate planting density with balanced mineral nutrition. This approach improves the efficiency with which plants use soil resources and applied fertilizers.

The following table provides an illustrative example of how the effects of planting density and mineral fertilization can be presented. These values are hypothetical and should be replaced by actual experimental data before publication.

Agronomic and economic considerations. Efficient production should not be based solely on maximizing yield. The economic efficiency of fertilizer use must also be considered. Higher fertilizer rates increase production costs, and the additional yield obtained from extra fertilizer may eventually become smaller than the additional cost.

Similarly, high planting density may require greater inputs of water and nutrients. Under irrigated and fertile conditions, a relatively high plant population may be productive. Under water-limited conditions, however, excessive density can increase competition and reduce yield stability.

Therefore, recommendations for fodder beet production should be adapted to local soil and climatic conditions rather than applying a single universal planting density or fertilizer rate.

Conclusion. Mineral fertilizers and planting density are important factors affecting the growth and development of fodder beet. Planting density determines the amount of growing space and resources available to individual plants, while mineral nutrition determines the availability of essential elements required for physiological development and biomass production.

Appropriate planting density promotes efficient utilization of light, water, and soil nutrients. Excessive density may increase competition and reduce individual root size, whereas insufficient density can result in underutilization of the production area.

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