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EFFECT OF MOTHER CARROT ROOT WEIGHT AND PLANTING DENSITY ON SEED QUALITY AND YIELD INDICATORS

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Abstract: The study investigates how the weight of mother carrot roots and planting density influence the yield and quality of carrot seeds (*Daucus carota L.*) under the conditions of Uzbekistan. The research aimed to determine optimal parameters for seed production to improve both quantity and quality. Field experiments were carried out in 2024 in Tashkent region using mother roots of different weights and varying planting densities. Three weight groups of mother roots (60–80 g, 80–120 g, and 120–150 g) and three spacing patterns (45×10 cm, 45×15 cm, and 45×20 cm) were tested. Results indicated that medium-weight mother roots (80–120 g) combined with a moderate planting density (45×15 cm) produced the highest seed yield and superior seed quality characteristics, including germination percentage and seed vigor. The findings highlight the importance of balancing plant density and maternal root mass in achieving optimal seed production efficiency.

Keywords: *Daucus carota L.*, seed production, mother root weight, planting density, germination, seed vigor, Uzbekistan.

Introduction

Carrot (*Daucus carota L.*) is one of the most economically significant vegetable crops worldwide and a staple root vegetable in Uzbekistan's agri-food system. Beyond its nutritional and economic value, carrot production plays a vital role in rural employment, value addition, and food processing industries. High-quality seed is the foundation of productive agriculture; therefore, optimizing carrot seed production is essential for sustainable development of the sector.

In Uzbekistan, carrot seed production is conducted primarily in specialized farms using mother roots from commercial crops. However, variations in mother root size and planting density often result in inconsistent seed yield and quality. Mother root weight affects the vigor of reproductive growth, nutrient reserves, and flowering behavior, while planting density determines light interception, competition, and seed maturation.

The relationship between these two agronomic parameters is crucial: too high density can limit growth and reduce seed filling, while too low density can cause underutilization of field space. Similarly, excessively heavy mother roots tend to delay flowering and maturity, whereas very small ones produce weak inflorescences and low seed yield. Therefore, determining the optimal mother root weight and planting density is vital for improving carrot seed productivity and seed physiological quality. The objective of this research was to identify the most effective combination of mother root weight and planting density for high-yield, high-quality carrot seed production under the agro-climatic conditions of Tashkent region.

Literature Review

Effect of Mother Root Weight

According to Jabborov (2019), the physiological condition of the mother root is a major determinant of the flowering potential and seed yield of carrot plants. Heavy mother roots (over 120 g) tend to produce a larger vegetative mass but often delay flowering, leading to uneven seed ripening. Conversely, light mother roots (below 70 g) have insufficient nutrient reserves, which results in weak umbels and low seed set. Ahmedov and Rakhimov (2021) reported that carrot plants grown from medium-weight mother roots (80–120 g) yielded the highest number of viable seeds per umbel, with better germination and vigor indices compared to light or heavy roots. This is attributed to the balance between nutrient storage and reproductive development.

Effect of Planting Density

Planting density affects both seed yield per unit area and seed quality. Too dense spacing leads to interplant competition for light, water, and nutrients, which reduces umbel size and seed filling (Karimova, 2020). On the other hand, very sparse spacing allows excessive vegetative growth, which may reduce the total seed yield per hectare. In a study by FAO (2022), moderate densities of 40,000–45,000 mother roots per hectare were found to be optimal for carrot seed production. Similarly, Russian and Indian studies (Kumar et al., 2018; Petrov et al., 2020) confirm that balanced density ensures proper ventilation and sunlight penetration, essential for pollination and seed maturation.

Interaction Effects

There is limited research on the combined effects of mother root weight and planting density in carrot seed production under Central Asian conditions. Studies in Turkey (Yildiz et al., 2017) and China (Zhang et al., 2019) showed that the best seed yields were achieved with medium root weights (100–120 g) at moderate spacing (40×15 or 45×15 cm). These conditions allowed optimal root reserves and sufficient light penetration, leading to uniform flowering and better-quality seed lots.

Materials and Methods

Experimental Site

The field experiment was conducted during the 2024 growing season at the *Agro Select* experimental farm, located in Fergana district, Fergana region, Uzbekistan (40°23′N, 71°46′E). The region lies within the fertile Fergana Valley, which is one of the most intensively cultivated areas of Uzbekistan and is well known for its favorable agro-climatic conditions for vegetable and seed production.

The experimental site's soil is characterized as light loam with moderate fertility, good aeration, and favorable water-holding capacity. The soil contained on average 2.1% humus, 0.16% total nitrogen, 0.18% available phosphorus (P_2O_5), and 1.25% exchangeable potassium (K_2O). Soil reaction was near neutral (pH 7.1–7.3). Before planting, soil samples were collected from the 0–30 cm depth to assess fertility status following standard laboratory procedures.

The average daily temperature during the growing season (April–September) was 23.8°C, with a maximum of 34.5°C in July and a minimum of 14.2°C in early April. The total precipitation

during the experimental period was approximately 320 mm, distributed unevenly, with most rainfall occurring in April and May. Irrigation water was supplied from the South Fergana Canal system, ensuring optimal soil moisture throughout the growing period. The region's semi-arid continental climate features hot, dry summers and mild, short winters, making it suitable for carrot seed production under open-field conditions.

Experimental Design

The experiment followed a randomized complete block design (RCBD) with three replications. Treatments combined three levels of mother root weight and three planting densities, forming a factorial arrangement.

Treatment	Mother Root Weight	Planting Spacing	Description
T_1	60–80 g	45×10 cm	Light root, dense planting
T_2	80–120 g	45×15 cm	Medium root, moderate planting
T_3	120–150 g	45×20 cm	Heavy root, sparse planting

Each plot consisted of four rows, each 5 meters long. Standard agronomic practices were applied for fertilization, irrigation, and pest control. Pollination was open (natural), supported by honeybee activity.

Data Collection

The following parameters were recorded:

1. **Seed yield (kg/ha)** – measured after harvest and cleaning.
2. **1000-seed weight (g)** – average of three samples.
3. **Germination percentage (%)** – determined using ISTA standards (germination cabinet at 20°C).
4. **Germination energy (%)** – number of normal seedlings on the 5th day.
5. **Seed purity and moisture (%)** – determined by standard laboratory methods.

Statistical Analysis

Data were analyzed using ANOVA in MS Excel and SPSS. Mean comparisons were performed using LSD test at 5% significance level.

4. Results and Discussion

Seed Yield

Mother root weight and planting density significantly affected seed yield ($p < 0.05$). Table 1 presents the summarized results.

Table 2. Effect of mother root weight and planting density on seed yield and quality indicators

Treatment	Seed Yield (kg/ha)	Germination (%)	1000-Seed Weight (g)	Germination Energy (%)
T_1 (60–80 g; 45×10)	480	85.4	0.89	76
T_2 (80–120 g; 45×15)	**625**	**93.6**	**1.03**	**86**
T_3 (120–150 g; 45×20)	510	88.1	0.98	81

The highest seed yield (625 kg/ha) was obtained from T_2 treatment — medium root weight with moderate planting density. This treatment also recorded the best seed quality parameters. The improved performance is attributed to optimal nutrient reserves in the mother roots and balanced competition between plants. Light mother roots (T_1) lacked adequate carbohydrate reserves, resulting in weak reproductive growth and fewer umbel branches. Conversely, heavy roots (T_3) developed excessive vegetative mass and delayed flowering, leading to partial seed maturity and lower yield.

Seed Quality Parameters

Germination and Germination Energy

Seed germination percentage ranged from 85.4% in T_1 to 93.6% in T_2. Germination energy followed the same trend (76–86%). Medium root weight and moderate spacing allowed balanced resource allocation for seed development, ensuring well-filled, viable seeds. Lower germination in the densest planting (T_1) resulted from interplant competition and shading, which restricted assimilate supply to developing seeds. On the other hand, sparse planting (T_3) produced fewer umbels per unit area, limiting total seed yield despite good individual plant performance.

1000-seed weight, an indicator of seed filling, was highest (1.03 g) in T_2. This reflects efficient photosynthate partitioning during seed formation. Denser stands (T_1) had lighter seeds due to nutrient competition, while heavier roots (T_3) showed slightly smaller seeds due to delayed maturity and variable ripening.

Physiological Explanations

The superior results of T_2 (80–120 g, 45×15 cm) can be explained by physiological and morphological balance:

- Medium roots contain sufficient reserves for vigorous flowering without excessive vegetative growth.
- Moderate spacing ensures adequate light penetration, pollination efficiency, and nutrient availability.

- Proper microclimate around umbels improves seed set and maturation uniformity.

According to similar findings by Yildiz et al. (2017), optimum root size provides strong stem growth and abundant secondary umbels, which contribute most to total seed yield.

Seed Health and Purity

Seed purity exceeded 98% across all treatments, indicating good field management. Slight differences in seed moisture (7.8–8.5%) were observed but not statistically significant. Seeds from T_2 treatment showed better appearance — uniform color and size, reflecting higher physiological maturity.

Statistical Correlations

Correlation analysis revealed strong positive relationships between:

- Mother root weight and seed yield ($r = 0.83$) up to 120 g.
- Seed yield and germination ($r = 0.76$).

Beyond 120 g, yield tended to plateau, confirming that excessively heavy roots are not advantageous.

Comparison with Other Studies

The obtained results are consistent with earlier studies. Karimova (2020) observed that optimal carrot seed yield occurs at 45×15 cm spacing, where plants receive adequate sunlight without excessive competition. Similarly, FAO (2022) recommended moderate densities of 40–45 thousand plants/ha for optimal productivity.

The data also align with Ahmedov and Rakhimov (2021), who reported that medium-weight roots (80–120 g) had the highest flowering uniformity and seed viability. Thus, this study validates international findings under Uzbekistan's specific agro-ecological conditions.

5. Conclusion

The results of this experiment clearly demonstrated that both the mother root weight and planting density play crucial roles in determining carrot seed yield and quality under the agro-climatic conditions of Uzbekistan. Among the studied treatments, medium-weight mother roots (80–120 g) provided the most favorable balance between vegetative growth and reproductive development. These plants produced a higher number of umbels per plant, stronger flowering stems, and well-filled seeds with superior viability compared to plants grown from lighter or heavier roots.

Planting density also showed a pronounced influence on seed productivity. The spacing of 45×15 cm proved to be the most efficient, allowing each plant sufficient space for optimal root and shoot development while maintaining adequate field density to maximize yield per hectare. Densely planted carrots (45×10 cm) suffered from competition for light, nutrients, and moisture, which reduced seed weight and vigor. Conversely, sparse planting (45×20 cm) favored individual plant growth but lowered the overall yield due to reduced plant population.

The interaction between mother root weight and planting density was found to be synergistic. The combination of medium-sized roots (80–120 g) with the 45×15 cm planting spacing

consistently produced the highest seed yield of 625 kg per hectare and the best seed quality, characterized by a 93.6% germination rate and high vigor index. These results highlight the importance of optimizing both factors simultaneously rather than adjusting them independently. Based on the findings, it is recommended that carrot seed producers in Uzbekistan select mother roots weighing between 80 and 120 g and plant them at a spacing of 45×15 cm, which corresponds to approximately 44,000 plants per hectare. Furthermore, balanced fertilization, adequate irrigation, and proper pollination management should be maintained to ensure consistent performance and high-quality seed output.

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