Аграрен университет – Пловдив, Научни трудове, т. LXVII, кн. 1, 2025 г.
Юбилейна научна конференция *„80 години Аграрен университет – Пловдив: Традиции срещат иновации “*
Anniversary Scientific Conference
"80 Years Agricultural University – Plovdiv:Traditions Meet Innovations"
Agricultural University – Plovdiv, Scientific Works, vol. LXVII, book 1, 2025

DOI: 10.22620/sciworks.2025.01.002

EVALUATION OF ROOT SYSTEM PARAMETERS OF CHICKPEA (*CICER ARIETINUM* L.) ACCESSIONS WITH DIFFERENT ORIGIN

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Abstract

The increased demand for protein crops and the challenges associated with their cultivation require profound studies of their adaptive capabilities for further plant breeding improvement and creation of productive and climate-resilient varieties. Water stress tolerance, nutrient use efficiency, and productivity in chickpeas are largely related to the parameters of the plant root system. This study presents data and analysis of root indicators for 22 accession of the "Desi" and "Kabuli" types of different origins, tested in the Second Experimental Field of the Institute of Forage Crops - Pleven. Varieties were identified with root lengths reaching 19-20 cm (Businsky, Blanco Lechoso, and Irenka), with high root weights above 64 g (Garbanzo 1 and Slovak), with an increased number of 51-52, and with tuber weights of 1.45-2.03 g (Garbanzo 1, Slovak, Alfa, and Kr.Kralovej). Garbanzo 1, Sovhoznyj 14, and Progress have the highest specific tuber-forming ability, while VSP 11, Caqui, and Garbanzo negro have the highest specific root length. The cultivars with the best balance between root system and tuber formation are Slovak, Plovdiv 8, Blanco Lechoso, and Irenka. Proven positive correlations were found between plant height and number of tubers (r=0.444), the weight of the above-ground (r=0.582) and root mass (r=0.533), as well as the fresh weight of the root mass with the fresh weight of the above-ground biomass mass (r=0.533) and the length of the roots (r=0.142). The specific nodule-forming ability correlates positively with weight (r=0.294) and with the number of nodules per plant (r=0.245).
Keywords: chickpea, root system, tubers, variety

INTRODUCTION

Chickpeas (*Cicer arietinum L.*) are one of the most important annual legumes grown worldwide. In addition to being a rich source of human dietary protein, it improves soil phytosanitary status through symbiotic nitrogen fixation. (Butcher et al., 2016; Shikhalieva et al., 2016; Janghel et al., 2020).

Chickpeas are grown in more than 55 countries characterized by arid climates and serve as a staple legume in South Asia, the Middle East, East Africa, the Western Mediterranean, Australia, and Mexico. Thanks to its symbiosis with nodule bacteria, chickpeas are considered one of the best precedents for other crops in the areas where they are grown (Foyer et al., 2016; Admas et al., 2021).

It is known that modern legume varieties grow well in both fertile and poorer soils with a pH of 5.0 to 7.5. Grain legumes, including chickpeas, are essentially high-yielding bioinstallations for fixing atmospheric nitrogen. Nitrogen from roots and plant residues is practically not washed away, as it mineralizes gradually over several years (Boivin & Lepetit, 2020; Lindström & Mousavi, 2020).

The study of nodule formation in leguminous crops allows the identification of genotypes with increased number and weight of nodules that remain active until the end of the growing season. When introducing new varieties into production, it is necessary to know not only their productive potential and product quality, but also to have information about their symbiotic activity (Biabani et al., 2011; Marakaeva et al., 2011).

The creation of highly efficient plant-microbial systems in agrocenoses through the selection of new varieties of legumes with high symbiotic potential is a promising direction that allows control over the efficiency of plant biomass accumulation and the quality of the final plant production (Kazydub et al., 2015; Mart et al., 2023).

Global climate change has a significant impact on agricultural production. The decline in yields of major field crops due to prolonged periods without rainfall necessitates an increase in the cultivation of drought-tolerant crops such as chickpeas. Compared to other legumes, chickpeas are very resistant to such abiotic stress (Manish et al., 2020; Oparah et al., 2024). The main characteristics of the plants that determine this adaptability are related to the length and mass of their root system (Kumar et al., 2012). The selection of promising genotypes for combinative breeding is based on the evaluation of chickpea samples in the initial collection according to the parameters of their root system.

MATERIALS AND METHODS

The field experiment was conducted in three successive years – 2023 to 2025, at the Second Experimental Field of the Institute of Forage Crops Pleven, with twenty-two chickpea samples from the available core collection. Of the varieties studied, 20 are of the "Desi" type (Alfa, Beta, Businsky, Irenka, Krajova z Kralovej, Maskovsky Bagovec, Slovak FLIP 84-149 C, VSP 11, Balkan, Progress, Plovdiv 8, Caqui, Garbanzo negro, Tadzikskij 10, Sovhoznyj 14, Dneprovskij 1, Garbanzo, BGE010942, BGE013856), and two (Garbanzo 1 and Blanco Lechoso) belong to the Kabul variety.

The main biometric parameters of the roots of ten plants were assessed at the beginning of flowering after taking soil samples 20/30/40 cm from each repetition of each variant and washing the roots. The measurements of the above-ground and root mass included: plant height at the beginning of flowering (cm), root length (cm), root weight (g), number and weight (g) of tubers per plant.

The following parameters were analyzed: specific root length (cm), specific tuber-forming ability (ratio of fresh tuber weight to fresh root system weight) and tuber biomass security (ratio of number of tubers to root system weight) (Beck et al., 1993). The correlation (r) and variation (CV%) coefficients were calculated using the method of Dimova and Marinov (1999).

The experimental data obtained were statistically processed using Excel software and SPSS 12.

RESULTS AND DISCUSSIONS

A deep and well-developed root system can help the plant continue to grow even in more restrictive conditions by extracting sufficient water and nutrients from the soil layers.

Plant height.

The studied chickpea varieties show significant variation in both plant height and root system characteristics (Table 1).

The average plant height for the sample group is 54.95 cm, with the tallest plants recorded in Irenka (66.68 cm), Slovak (59.42 cm), Kr. Kralovej (58.09 cm), and Garban 1 (57.82 cm), while the shortest plants, around 47-51 cm, were observed in Caqui, Garbanzo negro, and Tadzik 10. In the control variety Balkan, the plants reached a height of 57.09 cm.

Although plant height is a genetically determined quantitative trait, it is significantly influenced by environmental factors. About 50% of the varieties studied have an average plant height for our core collection and are taller than the genotypes, regenerated in hotter environment and analyzed and published by Sagar et al. (2023) and the average of measurement for a local collection of accessions with different origin (Petrova et al. 2020).

Root length.

Variation in root length is relatively narrower than in plant height. The Businsky, Blanco Lechoso, and Irenka varieties were found to outperform the other samples with root lengths of 19-20 cm, compared to an average length of 17.02 cm for the selected sample (Table 1).

The group with shorter roots includes VSP 11 (12.70 cm), Gar. negro (15.09 cm), Alfa (15.51 cm), and FLIP 84-149 C (15.38 cm). The Bulgarian varieties Balkan and Progress belong to the opposite group of genotypes with longer roots (17.18 cm).

It is noteworthy that the Irenka variety ranks first in root length, but not in root weight (56.78 g). In this respect, this variety is surpassed by Balkan, which shows the best indicator (69.72 g). The samples Garbanzo 1 (64.46 g) and Slovak 64.29 g) also perform well in terms of root weight. It should be noted that in most cases, varieties with shorter roots fail to accumulate significant root mass.

According to Mansurov et al. (2019), every quantitative trait, including root length, is influenced by changes in meteorological conditions. The authors found that when evaluating the chickpea samples they studied, root length was a moderately variable trait like that in the study, with a mean of 21.3 cm under restrictive conditions and up to 30-35 cm under favorable conditions.

Number and weight of nodules.

The formation of a significant number of nodules on the roots of leguminous plants is an important prerequisite for subsequent increased nitrogen-fixing capacity. The data obtained show that Garbanzo 1 plants, together with Slovak, Alfa, and Kr. Kralovej, form the most nodules, 51-52 in number, with a root length of 17.18 cm and a fresh biomass weight above the average for the group of samples (except for Kr. Kralovej) (Table 1). The same varieties are distinguished by larger nodules, whose weight can be classified as heavy (1.45-2.03 g), exceeding the average weight by 1.5-2 times. Garbanzo 2 (50.18), Sovhoznyj 14 (50.64), and the Bulgarian variety Balkan (50.92) also stand out with an increased number of nodules.

The Tadzik 10, Garbanzo negro, and VSP 11 varieties have very low pod weight. Based on this trait, it is noticeable that some of the varieties form a larger number of nodules, which are successfully combined with their weight - Garbanzo 1 and Alfa.

These findings show larger variation and formation of bigger number of nodules of the accessions from the core collection than the published results from outer researchers. Walia et al. (2019) observed a proven difference between chickpea lines and varieties in terms of the number of nodules per plant. This trait, both in the present study and in theirs, showed significant variability, with values ranging from 2.8 to 9.9 between genotypes. The authors found that the Myles and Orion varieties formed the largest number of nodules, while the MT292 line and the Sierra variety formed the smallest.

Regarding root system weight, it should be noted that root length is not always the determining factor. In some cases, such as with the Irenka variety, long roots favor the formation of a heavier root system (8.61 g). In the Businsky variety, which also ranks among the top varieties in terms of root length, the root system is significantly lighter (6.68 g). In other cases, such as Slovak, shorter roots did not adversely affect the development of a well-developed root system with a plant weight of around 7.42 g.

The varieties that do not perform satisfactorily form a root system weighing less than 6 g. This group includes Tadzik 10, Caqui, Gar negro, VSP 11, and others.

The size and number of tubers vary among varieties. Sometimes a genotype with many nodules on a single plant, which may be very small in size, has a low total weight of nodules per plant. Conversely, a plant may not form many nodules, but they may be larger in size and thus have a higher total weight.

The results obtained support the studies of Kazydub et al. (2015), who obtained higher values for the number and weight of nodules per plant for some of the chickpea samples. The authors report significant diversity in the analyzed chickpea samples, with the number of nodules ranging from 30 to 61 and weighing from 1.1 to 2.6 g. The results of the study partially support the research of Taspaev (2023), who reports that during his study of the root system of chickpea varieties, the best genotype formed 15 nodules with a total mass of 0.72 g.

Specific root length

Specific root length (SRL) is perhaps the most measured morphological parameter of roots (Figure 1). It is considered to characterize the economic aspects of the root system and is indicative of changes in the growing environment.

Plants with high SRL develop greater root length and are considered to have higher levels of mineral and water uptake, shorter root life, and higher relative growth rates than plant forms with low SRL. High SRR may be the result of smaller diameter or low tissue density. In the study, the SDC ranged from a minimum value of 1.57 cm g-1 mass for Alfa to a maximum of 5.10 cm g-1 mass for VSP 11. Caqui and Garbanzo negro also had high SDC values (4.49-4.88 cm g-1 mass). For more than 50 percent of the analyzed varieties, the SDC is below the average for the sample. The Bulgarian variety Balkan occupies an intermediate position with a specific root length of 3.51 cm g-1 mass.

Specific lump-forming ability

This indicator follows the trend of lump formation. The average SFA for the group of varieties studied is 0.081. Garbanzo 1 has the highest SFA - 0.552, followed by Sovhoznyj 14 - 0.196, Garbanzo 4 - 0.177, and Progress - 0.173. It should be noted that these are genotypes with root characteristics above average in terms of the number of nodules (Figure 2). The lowest SGS values were recorded for Blanco Lechoso (0.001), Slovak (0.001), and Irenka (0.015).

Root system density (security) with tubers

Considering the parameters included in the calculation of root system saturation with nodules (the ratio of root biomass to the number of nodules), lower values of this ratio indicate better provision of root biomass with nodules. The 22 chickpea varieties analyzed (Figure 3) are characterized by good provision of root biomass with nodules, with a lower ratio in four of them - Slovak (0.623), Plovdiv 8 (0.753), Blanco Lechoso (0.894), and Irenka (0.937).

Despite significant differences between genotypes, root characteristics are significantly influenced by environmental factors such as temperature, soil nutrients, etc. Extreme increases or decreases in temperature, as well as low air and soil humidity, lead to a significant reduction in total root length due to a significant shortening of the lateral root length.

According to Dwivedi et al. (2015), biological nitrogen fixation by rhizobia in legumes such as chickpeas is important for plant nutrition and reducing dependence on nitrogen fertilizers. Their study of a set of six chickpea varieties confirms the conclusion that the degree of nodule formation depends on both the plant genotype and its abiotic environment.

Coefficient of variation

When comparing the coefficient of variation (Figure 4) for each of the studied traits, the maximum variability is observed in plant height (44.48%).

The above-ground mass trait is quite variable (36.25%), which is significantly influenced by environmental factors. Root length (14.40%) and tuber weight (17.57%) vary to a lesser extent at an average level. Improving growing conditions could lead to an increase in the value of these traits.

Analysis of the variability of these basic quantitative traits shows that the level of their genotypic variation is much lower than their modification variation. Tuber weight and root system weight are characterized by relatively low variability (0.34%; 3.73%) compared to other traits.

Muriuki et al. (2020), studying chickpea varieties of the Desi and Kabuli types, report strong variability in root mass weight, which is confirmed in the present study. The authors report differences between the two main chickpea types in this respect. Most of the Desi genotypes performed better under drought conditions, while the Kabul types performed better under high humidity conditions. The researchers recommend that these characteristics of the two chickpea types be used in the early stages of any breeding program, which would accelerate the breeding process.

Correlation analysis

Of particular importance for the selection of new varieties is the determination of correlation dependencies not only between traits determining productivity and other economically valuable traits, but also those related to symbiotic selection. Success in research can be achieved more easily if knowledge of the relationships between the relevant traits is available.

In the present study, the correlation coefficients (Table 2) between the studied traits and indicators in the phenological phase of the beginning of flowering, mainly related to the root system, were determined.

It is noteworthy that the development of plant height has a favorable effect and correlates positively with all other indicators.

Proven average dependencies were established between plant height and the number of tubers (r=0.444), above-ground weight (r=0.582), and root mass (r=0.533).

The specific tuber-forming ability trait has a weak but proven correlation with weight (r=0.294) and with the number of tubers (r=0.245). Moderate positive correlations were found between the fresh weight of the root mass and the fresh weight of the above-ground biomass mass (r=0.533) and weak correlations with root length (r=0.142).

The analysis revealed weak to moderate and unproven correlations between the number and weight of tubers and the weight of above-ground (r=0.204; r=0.351) and root biomass (r=0.319; r=0.659). The influence of root length (r=0.360) and weight (r=0.656), plant height (r=0.660), and above-ground biomass weight (r=0.498) on the expression of specific tuber-forming ability is statistically insignificant.

CONCLUSIONS

The varieties with root length reaching 19-20 cm (Businsky, Blanco Lechoso, and Irenka), with high root weight above 64 g (Garbanzo 1 and Slovak), with increased number 51-52, and with tuber weight 1.45-2.03 g (Garbanzo 1, Slovak, Alfa, and Kr.Kralovej).

Garbanzo 1, Sovhoznyj 14, and Progress are distinguished by the highest specific tuber-forming ability, while VSP 11, Caqui, and Garbanzo negro are distinguished by the specific root length. The varieties with the best balance

between the root system and tubers are Slovak, Plovdiv 8, Blanco Lechoso, and Irenka.

Proven positive correlations were found between plant height and number of tubers (r=0.444), the weight of the above-ground (r=0.582) and root mass (r=0.533), as well as the fresh weight of the above-ground biomass mass (r=0.533) and with the length of the roots (r=0.142).

The specific tuber-forming ability correlated positively with weight (r=0.294) and tuber number (r=0.245) per plant.

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