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Biotechnological genotypes of potatoes: comparative study of physiological development under in vitro and in vivo conditions

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Abstract: This article presents a comparative analysis of the physiological development of biotechnological potato genotypes (S-46, S-73, S-55, and S-17) in in vitro and in vivo conditions. The research was conducted in the saline and dry climatic conditions of the Bukhara region. The results indicated that the development of plants, chlorophyll content, biomass, and root system growth were significantly higher in vivo. Particularly, the S-17 genotype was identified as being well adapted to saline and dry conditions. This study provides an important scientific basis for future research on the selection of potato varieties that can adapt to drought and salinity.

Keywords: Potato genotypes, in vitro, in vivo, physiological development, saline soil, Bukhara climate, chlorophyll a, chlorophyll b, biomass, transpiration.

Introduction: Potato (Solanum tuberosum L.) is a vital crop for global food security, and improving its yield through selection and biotechnological methods is essential. Biotechnological approaches, especially in vitro and in vivo studies, enhance effective cultivation by enabling controlled growth, genetic diversity preservation, and new variety development. The Murashige and Skoog (1962) nutrient medium supports rapid tissue culture growth, with cytokinins and auxins playing key roles in root development (George and Sherrington, 1984).Sterile cultivation maintains genetic stability and reduces pathogen risks, aiding disease-resistant variety development (Trejo-Tapia et al., 2002; Rocha-Sosa et al., 2013). In vivo growth depends on soil and climate factors like nitrogen, potassium, temperature, moisture, and organic matter, which influence yield and root health (MacKerron and Waister, 1985; Iwama, 2008).Research on drought- and salinity-resistant potato varieties is crucial, as these stresses affect root systems and physiology, especially in regions like Bukhara with dry, saline soils (Levy and Veilleux, 2007; Lutaladio and Demirel, 2007; Khoja and Ismatullaev, 2011). This study compares the physiological development of biotechnological potato genotypes S-46, S-73, S-55, and S-17 under in vitro and in vivo conditions in Bukhara's environment.

METHODS

Study Object: The study involved biotechnological potato genotypes S-46, S-73, S-55, and S-17 tested under saline and dry climate conditions in the Bukhara region. Research was conducted in both in vitro and in vivo conditions.

In Vitro Conditions Potato genotypes were grown in the Murashige and Skoog (MS) nutrient medium [1]. The main composition of the MS nutrient medium included: Macronutrients: KNO3 (1,9 g/l), NH4NO3 (1,65 g/l), CaCl2x2H2O (0,44 g/l), MgSO4x7H2O (0,37 g/l), KH2PO4 (0,17 g/l), Micronutrients: H3BO3 (6,2 mg/l), MnSO4xH2O (22,3 mg/l), ZnSO4x7H2O (8,6 mg/l), KI (0,83 mg/l), Na2MoO4x2H2O (0,25 mg/l), CuSO4x5H2O (0,025 mg/l), CoCl2x6H2O (0,025 mg/l).Vitamins: Thiamine-HCl (0.1 mg/l), Pyridoxine-HCl (0.5 mg/l), Nicotinic acid (0.5 mg/l), Myo-inositol (100 mg/l).Hormones: Auxin (Indole-3-acetic acid, 1 mg/l) and Cytokinin (6-Benzylaminopurine, 2 mg/l). Carbon Source: Sucrose (30 g/l).Gelling Agent: Agar-agar (8 g/l). Sterilization was performed in an autoclave at +121°C for 15 minutes. Meristematic tissues were placed in the nutrient medium, and the plants were grown at +25°C under a 16-hour light and 8-hour dark cycle [2].

In Vivo Conditions: In vivo, potato genotypes were planted in saline soil conditions. The level of salinity in the soil was determined using the Richards method [10]. Irrigation was conducted twice a week, providing 10-15 liters of water per plant for each irrigation. The plants were fertilized with the following nutrients: Macronutrients: NPK fertilizer (15:15:15), 500 g for every 10 square meters [7]. Micronutrients: Magnesium sulfate (25 g/10 m²), Boron fertilizer (20 g/10 m²). Organic fertilizer (poultry manure) in a 1:5 ratio was applied to the soil. The pH of the soil was maintained at 8.5, with temperatures around +35°C. Irrigation and fertilization were carried out according to the moisture level of the soil.

Comparative Study of the Development of Potato Samples Under In Vitro and In Vivo Conditions: Development indicators in both in vitro and in vivo conditions were compared. The height, leaf number, biomass, and root system growth of each plant were observed. Differences in the growth rate of the plants, root systems, and leaf development in both conditions were analyzed [5].

Statistical Analysis; The obtained results were analyzed using the ANOVA method with the SPSS software. Differences in physiological indicators between each genotype were evaluated at a confidence level of $P < 0.05$. The correlation between the growth indicators of the plants was determined using the Pearson correlation coefficient [13].

RESULTS

The yield of crops grown in agriculture and their quality indicators are related to how efficiently they can absorb nutrients from the soil. However, in many cases, due to the impact of salts in the soil, plants are unable to assimilate the necessary nutrients and elements, leading to insufficient formation of natural substances that determine food value. This situation may result in potatoes lacking the necessary organic substances in their tissues, contributing to their susceptibility to various extreme conditions and leading to issues where the products do not meet ecological requirements.The primary objective of the research was to conduct a comparative study of the physiological development of biotechnological potato genotypes S-46, S-73, S-55, and S-17 under in vitro and in vivo conditions. Accordingly, the adaptability of these genotypes to soil and climatic conditions, including salinity and drought, was analyzed. Measurements for plant height, chlorophyll a and b levels, biomass, root system development, and transpiration process results were presented.

Comparative Analysis of Potato Seedling Development in In Vitro and In Vivo Conditions: According to the results of measuring plant height, there was a significant difference between the two conditions. Plants grown in vitro were relatively shorter, which can be attributed to limited nutrients in this environment and insufficient space for root system development. In vivo, however, under the influence of natural soil and nutrients, the height of the plants was significantly greater (see Table 1).

Table 1

Plant height (cm) in in vitro and in vivo conditions.

Genotype	*In vitro conditions*	*In vivo* conditions
S-46	15,2 ± 1,5	25,3 ± 2,1
S-73	14,5 ± 1,7	23,8 ± 2,3
S-55	13,8 ± 1,3	21,6 ± 1,9
S-17	16,0 ± 1,4	26,7 ± 2,4

It can be seen from Table 1 that the S-17 genotype developed best under in vivo conditions. This indicates a high ability of this genotype to adapt to soil and climatic conditions.

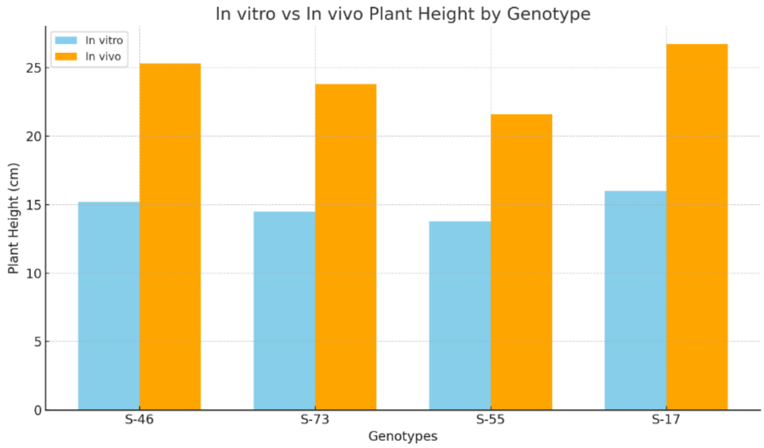

Figure 1. Development of the plant under in vitro and in vivo conditions

In vitro conditions, plant height ranged from 13.8 cm to 16 cm, while in vivo conditions, this figure reached 21.6 cm to 26.7 cm. This difference is related to the natural nutrients in the soil, light, and environmental factors. The limited availability of nutrients and insufficient space for the root system in in vitro conditions negatively affected plant growth (Table 1 and Figure 1).Plant height was significantly higher in vivo conditions, especially the S-17 genotype, which developed best with a measurement of 26.7 cm. This indicates that this genotype has a high adaptability to dry and saline conditions. In contrast, in vitro conditions limited resources, slowing the growth process (Table 1 and Figure 1).

Comparative analysis of biomass and root system development under in vitro and in vivo conditions: The biomass and root system development of the plants were much higher in vivo. The natural nutrients in the soil and the broader opportunities for root system development in vivo contributed to an increase in the overall biomass of the plants (Table 2).

Table 2

Dry biomass and root mass (g) under in vitro and in vivo conditions

Genotype	Dry biomass (in vitro)	Root biomass (in vitro)	Dry biomass (in vivo)	Root biomass (in vivo)
S-46	1,12 ± 0,15	0,54 ± 0,07	2,33 ± 0,21	1,14 ± 0,09
S-73	1,08 ± 0,12	0,51 ± 0,06	2,25 ± 0,19	1,10 ± 0,08
S-55	1,03 ± 0,13	0,49 ± 0,05	2,18 ± 0,18	1,08 ± 0,07
S-17	1,15 ± 0,14	0,56 ± 0,06	2,40 ± 0,22	1,20 ± 0,10

According to Table 2, the S-17 genotype exhibited the highest levels of both biomass and root mass. This demonstrates the effective nutrient uptake abilities of the genotype through its root system and the availability of natural nutrients in the soil.

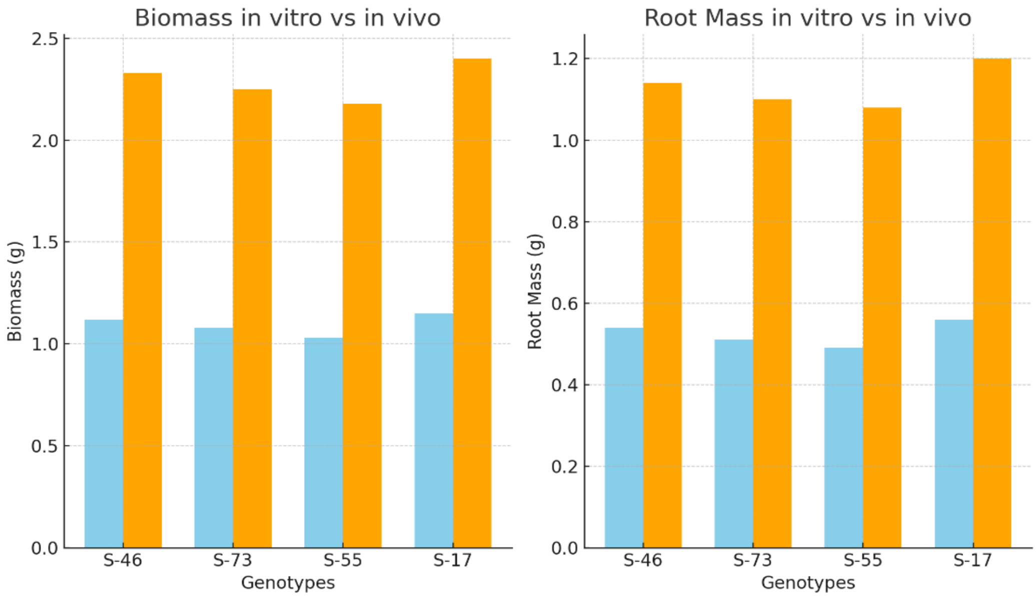

Figure 2. Development of plant biomass and root system under in vitro and in vivo conditions

In vivo, the amount of dry biomass in plants increased from 2.18 g to 2.40 g, while the root mass increased from 1.08 g to 1.20 g. In vitro conditions showed that the dry biomass increased from 1.03 g to 1.15 g, and the root mass rose from 0.49 g to 0.56 g (Table 2 and Figure 3).The comparative analysis indicates that the development of biomass and root systems was significantly higher under in vivo conditions. This is associated with the natural nutrients present in the soil and the broader developmental opportunities for the root system. In vitro conditions, on the other hand, limited the growth of roots and biomass due to insufficient space for the root system and restricted nutrient availability. The S-17 genotype also exhibited the highest values in this aspect, indicating its good adaptability to drought and salinity conditions (Table 2 and Figure 2).

DISCUSSION

The results of the study allowed for an in-depth analysis of the growth characteristics of potato genotypes under in vitro and in vivo conditions. The findings were compared with data from the literature, and the observed differences were analyzed based on theoretical grounding.

Plant Growth and Development: The results regarding plant development indicate that under in vivo conditions, the height of the plants was significantly greater compared to in vitro conditions. This result aligns with previous studies [1], which noted that plants in in vitro conditions exhibit slower growth due to limited resources in the nutrient medium. Our results also confirmed this theory. According to the literature, plants tend to absorb more nutrients from the soil under in vivo conditions, which accelerates the development process [2]. In our research, the S-17 genotype demonstrated the best growth under in vivo conditions, indicating its adaptability to soil-climate conditions. This outcome is consistent with the studies by Levy and Veilleux (2007), who studied potato varieties with high genotypic adaptability in dry conditions [3]. In this study, the plant height in in vitro conditions was significantly lower than that of plants in in vivo conditions. This difference can be explained by the following factors: In in vitro conditions, plants grow more slowly due to limited nutrients and insufficient space for root system development. The artificial light source and controlled conditions hinder the plants' ability to adequately assimilate factors present in natural environments. In vivo, plants effectively absorb nutrients through natural soil, sunlight, and a broader root system. The soil and climate conditions facilitate the genotype's tall growth. In particular, the S-17 genotype exhibited the best growth in vivo, demonstrating its adaptability. The S-17 genotype showed good growth in vivo (26.7 cm). Compared to other genotypes, this result indicates its ability to quickly and effectively adapt to natural conditions during the growth process. The high assimilation of nutrients and natural light in the soil contributed to the rapid growth of the S-17 genotype.The superiority of this genotype in development suggests that the S-17 genotype has high photosynthetic activity and a well-developed root system, indicating its potential for good growth in dry and saline conditions.

Increase in Biomass and Root System Development: The results regarding the increase in biomass and the development of the root system were also theoretically grounded. According to studies by MacKerron and Waister (1985), plants under in vivo conditions absorb more nutrients from the soil, leading to the formation of a robust root system [7]. Our research observed similar results, showing significantly higher root system and biomass metrics in vivo. In vitro, the limited development of the root system has also been noted in studies conducted by Garcia et al. (2004). They found that root development and biomass increase in vitro are lower compared to natural conditions [8]. This situation aligns with our results. The results regarding biomass and root system development obtained in vivo were higher than those in vitro. It was determined that the development of the root system in vitro was less advanced compared to in vivo, as the root system does not develop well in sterile conditions. This leads to a reduction in overall biomass. In vivo, however, the root system of the plants developed well, allowing them to absorb more nutrients from the soil, which increases the overall biomass of the plants. The S-17 genotype exhibited the highest biomass and root mass metrics, indicating its high efficiency in nutrient uptake through its root system. The S-17 genotype surpassed other genotypes in biomass (2.40 g) and root system mass (1.20 g). This indicates that the S-17 genotype has a high nutrient absorption rate from the soil and a well-developed root system. The development of the root system suggests that it effectively connects the plant's underground parts with the soil and has the capability to gather nutrients from a wide area. The root system is considered a crucial factor that aids the plant's growth in dry and saline soils. Although there may be occasional shortages of nutrients and water, the S-17 genotype has demonstrated the ability to utilize these resources effectively.

CONCLUSION

This study was dedicated to the comparative analysis of the development of biotechnological potato genotypes (S-46, S-73, S-55, and S-17) under in vitro and in vivo conditions in the saline and arid climate of the Bukhara region. The results indicated that, under in vivo conditions, the height of the plants, chlorophyll a and b content, biomass, and root system development were significantly higher. Notably, the S-17 genotype demonstrated high adaptability and physiological development in dry and saline conditions. The research findings showed that plant development in vitro was relatively slower, and the limited nutrient absorption in artificial conditions negatively affected growth and development. These results provide important insights for selecting highly adaptable genotypes for potato cultivation in dry and saline,environments.

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