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# Effect of Seed Tuber Suberization Methods on Growth and Yield of Potato under Kabul Climate Conditions


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**Abstract**

Potato (*Solanum tuberosum* L.) is an important food security crop in Afghanistan; however, low-quality seed tubers, poor agronomic practices, and disease incidence significantly limit productivity and tuber quality. Suberization plays a critical role in wound healing and seed tuber protection, yet its effectiveness under Kabul agro-climatic conditions remains insufficiently understood. Therefore, this study evaluated the effects of different suberization treatments on the growth and yield performance of the potato cultivar 'Cardinal' during the spring season of 2024 in Kabul, Afghanistan. The experiment was conducted using a randomized complete block design (RCBD) with six treatments: control ($T_1$), natural suberization ($T_2$), ash ($T_3$), talc ($T_4$), cement ($T_5$), and whole tuber planting ($T_6$), each replicated three times. Growth and yield parameters were recorded and statistically analyzed. The results demonstrated that different suberization treatments significantly improved vegetative growth and yield-related traits of potato. Talc treatment ($T_4$) and whole tuber planting ($T_6$) produced the highest tuber number (7.20 plant$^{-1}$), total yield (15.75- and 15.42-tons hectare$^{-1}$), sprouting percentage (97.83% and 98.61%), and tuber weight (119.88 and 114.12 g), respectively. Ash treatment ($T_3$) also increased tuber weight (130.13 g). LSD analysis grouped $T_3$, $T_4$, and $T_6$ as superior treatments. The findings indicate that effective suberization enhances wound healing, field establishment, and potato productivity under Kabul conditions. Based on overall performance, talc treatment ($T_4$) is recommended for potato production. Future studies should investigate the physiological and molecular mechanisms of suberization and its interaction with bio-stimulants and storage conditions.



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## Introduction

Potato (*Solanum tuberosum* L.) is an internationally important food crop, ranking fourth in production after rice, wheat, and maize (FAO, 2025; Li et al., 2025; OECD, 2022). It plays an essential role in human nourishment, providing substantial amounts of calories, proteins, vitamins- especially vitamin C and B-complex- and essential minerals, for example, potassium and magnesium (Burgos et al., 2020; Li et al., 2025; Sharma et al., 2020). Its adaptability to a


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varied range of agro-climatic conditions, high yield potential, and relatively short growth period make it an important crop for addressing food insecurity, supporting livelihoods, and sponsoring economic growth in both industrialized and developing countries (Biswal et al., 2025; Maniriho & Nkikabahizi, 2025; Placide et al., 2022).

Potatoes are cultivated not only for national consumption but also as a cash crop that supports millions of smallholder farmers globally. Furthermore, to support human consumption, potatoes serve as a raw material for processing and manufacturing, including products such as potato chips, fries, starch, and flour, which create substantial economic value (Bharathi et al., 2025; Hu et al., 2025). In developing countries, the crop plays a particularly critical role in rural livelihoods by providing income, reducing poverty, and stabilizing local economies (Bajracharya & Sapkota, 2017; Fang & Hong, 2025; Kalwar et al., 2024). In Afghanistan, potato is a key crop, especially in regions with favorable climatic conditions. Potato cultivation contributes to domestic food security and income generation, making it one of the most significant horticultural crops in the country (Helgilibrary, 2024; Potatopro, 2024; Salari et al., 2025). Despite its importance, the potato sector in Afghanistan faces numerous challenges, including low-quality seed tubers, limited access to qualified seed, suboptimal cultural practices, and vulnerability to disease and damage, which further decrease yield and marketable quality, limiting the overall yield of Afghan farmers (Hussainkhail et al., 2024).

Suberization is one of the critical physiological processes affecting potato tuber quality. Suberization is a natural wound-healing process in which a defensive coating of suberin, a hydrophobic biopolymer, is deposited on injured or cut surfaces of tubers. This layer or coating decreases water loss and protects against pathogen attack, enhancing tuber preservation and feasibility (Dogramaci et al., 2024; Han et al., 2024a; Zhu et al., 2023). Well-organized suberization also promotes uniform emergence and overall plant vigor, which are key factors for optimal growth and yield. Research has shown that non-natural or supported suberization techniques, such as the application of ash, talc, or cement dusts, can accelerate wound healing, improve sprouting rates, and enhance tuber yield under field and storage environments (Buckley et al., 2025; Villanueva et al., 2026; Yoldere, 2019). Appropriate suberization methods are particularly important in Afghanistan, where environmental stresses such as high temperatures, irregular rainfall, and limited storage facilities can affect the performance of seed potato tubers. Studies have shown that suberin deposition is regulated by complex biochemical pathways involving phenolic compounds, fatty acids, and polymerization enzymes, and its efficiency is influenced by both genotype and environmental conditions. Therefore, locally adapted strategies that combine suitable potato cultivars with effective suberization treatments can help improve potato production (Han et al., 2024b; Liu et al., 2023).

Potato farming in Afghanistan faces multiple challenges, including low-quality seed tubers, limited access to certified seeds, suboptimal agronomic practices, and disease pressures, all of which reduce yield and marketable quality. Suberization has the potential to improve tuber wound healing and enhance productivity, yet its application under local conditions remains largely unexplored.

This study aims to investigate the effects of different suberization methods on the growth and yield of the potato variety 'Cardinal', to provide practical, evidence-based strategies for Afghan farmers and to address the following research questions:

- How do different suberization treatments affect vegetative growth of 'Cardinal' potatoes?
- How do these treatments influence tuber yield and marketable quality?

## Methods and Materials

### Experimental Site and Climatic Conditions

The field experiment was conducted at the research farm of the Faculty of Agriculture, Kabul University, Kabul, Afghanistan, during the spring-to-summer (April-Oct) 2024 growing season. The climate of Kabul is classified as semi-arid, characterized by cool winters and relatively warm summers, with an average annual precipitation of approximately 327 mm and an elevation of about 1,790 m above sea level. During the cropping period, daily air temperatures ranged from 10 °C to 35 °C, while relative humidity fluctuated between 35% and 65%.

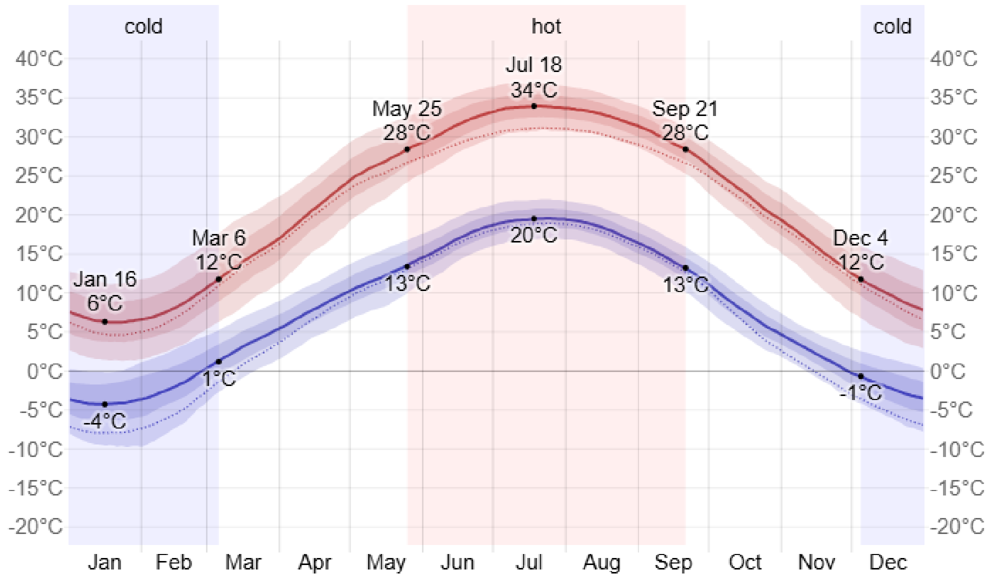


**Figure 1.** Monthly Average High and Low Temperature in Kabul (Weatherspark, 2024).

The soil at the experimental site was classified as sandy loam with a pH of8.1. Before planting, the field was plowed to a depth of 25–30 cm and subsequently leveled to facilitate uniform irrigation and proper field management (Raoufi et al., 2024).

### Plant Material and Treatments

The potato cultivar 'Cardinal', known for its high yield potential and adaptability to Kabul's agro-climatic conditions, was used in the present study. Seed tubers were obtained from reliable sources and carefully selected to ensure uniform size and freedom from visible defects or disease symptoms.

A total of six treatments were evaluated. $T_1$ (Control): fresh cut tubers planted directly in the field without any treatment. $T_2$ (Natural suberization): cut tubers allowed to undergo natural wound healing under ambient conditions for 48 hours (h) before planting. $T_3$ (Ash treatment): cut tubers coated with 5 kg/tons finely sieved wood ash and kept for 48 h before planting to enhance wound healing. $T_4$ (Talc treatment): cut tubers coated with 5 kg/tons pharmaceutical-grade talc and maintained for 48 h before planting. $T_5$ (Cement treatment): cut tubers treated with 5 kg/tons cement powder as a protective wound-covering material and kept for 48 h before planting. $T_6$ (Whole tuber planting): intact tubers weighing 45–60 g were planted directly in the field without cutting.

## Experimental Design and Plot Management

A randomized complete block design (RCBD) with three replications was employed to minimize variability arising from soil heterogeneity and microclimatic differences. Each experimental plot measured 3 × 4 m and consisted of four rows of potato plants, with a spacing of 75 cm between rows and 30 cm between plants within rows. A recommended fertilizer dose of 120 kg nitrogen (N), 60 kg phosphorus ($P_2O_5$), and 25t/ha of well-decomposed farmyard manure (FYM) per hectare was applied. Farmyard manure and phosphorus were incorporated into the soil as basal applications before planting. Nitrogen fertilizer was applied in split doses: half at planting and the remaining half at the earthing-up stage, following standard agronomic practices .Irrigation was provided via furrow irrigation at 6–12-day intervals, depending on soil moisture conditions and prevailing weather. Weed control was carried out manually during the early growth stages of the crop. Integrated pest management practices were implemented to reduce the incidence of common potato pests, particularly aphids and leafhoppers. No fungicides were applied during the experiment to avoid interference with the natural wound-healing and suberization processes of the tubers (Akkamis & Caliskan, 2023; Xu et al., 2025).

## Ethical and Safety Considerations

All treatments were carried out in accordance with institutional guidelines for field-based agricultural research. Talc, ash, and cement were applied using appropriate protective equipment, and necessary precautions were taken to minimize potential environmental impacts. No genetically modified organisms (GMOs) or hazardous chemicals were used during the experiment.

## Data collection

Vegetative growth parameters, including plant height (cm), number of main stems per plant, and number of secondary branches per main stem, were recorded at 60 and 90 days after planting (DAP). For these measurements, five plants were randomly selected from each plot. Tuber sprouting percentage was assessed 20 days after planting, where sprouting was defined as the visible emergence of a shoot ≥ 1 cm in length. For this assessment, ten tubers were randomly selected from each plot. At physiological maturity, tubers were harvested, and several yield-related parameters were evaluated. These included average tuber weight (g), calculated as the total tuber weight divided by the number of tubers; number of tubers per plant, recorded from each sampled plant; and total yield per hectare(tons), determined as the sum of marketable and non-marketable tubers. Marketable yield consisted of tubers weighing ≥ 50 g with no visible defects, whereas non-marketable yield included tubers weighing < 50 g, misshapen, or damaged tubers.

### Statistical Analysis

Data were analyzed using STAR software. ANOVA was conducted to detect significant differences among treatments, and mean separation was performed using the LSD test at a 0.05 or 0.01 probability level. The coefficient of variation (CV) was calculated to evaluate experimental precision, following standard protocols for potato field trials and suberization studies (Illarze et al., 2023; Phungula et al., 2025).

## Findings and Discussion

The effects of different suberization treatments on vegetative growth and tuber yield were carefully evaluated, and the results are presented in clear, easy-to-interpret tables. For clarity, the findings have been organized under two main categories—growth and yield—and discussed in the context of recent, peer-reviewed studies. This approach not only highlights the practical implications of the treatments but also situates our results within the broader scientific understanding of potato suberization and field performance.

### Effect of Suberization Treatments on Vegetative Growth and Sprouting

Vegetative growth and sprouting parameters were significantly influenced by suberization treatments ($p < 0.05$), as summarized in Table 1. The highest sprouting percentage was observed in whole-tuber planting (T6, 98.61%), followed closely by the talc treatment (T4, 97.83%), whereas the control treatment recorded a lower sprouting rate (94.44%). These findings suggest that treatments promoting effective suberization can enhance sprout emergence and uniformity, likely by accelerating wound periderm formation and reducing the risk of pathogen invasion. Previous studies have demonstrated that proper wound healing and suberin deposition at cut surfaces improve sprouting, crop stand establishment, and overall productivity of potato plants (Buckley et al., 2025; Han et al., 2024b; Zhu et al., 2023).

***Table 1.*** *Effect of suberization treatment on growth parameters of the potato variety Cardinal.*

| Treatment | Tuber Sprouting (%) | Plant Height (cm) | Main Stems/Plant | Secondary Branches/Main Stem | Primary Leaves/Main Stem | Main Stem Length (cm) | Secondary Leaves/ Primary Leaf |
|---|---|---|---|---|---|---|---|
| $T_1$ | 94.44 $^{b}$ | 53 | 2.67 $^{b}$ | 2.33 $^{b}$ | 13.10 $^{b}$ | 43.67 $^{abc}$ | 10.33 $^{bc}$ |
| $T_2$ | 95.83 $^{ab}$ | 53 | 4.33 $^{ab}$ | 2.33 $^{b}$ | 13.33 $^{b}$ | 44.00 $^{ab}$ | 11.00 $^{abc}$ |
| $T_3$ | 97.22 $^{ab}$ | 53 | 4.67 $^{a}$ | 3.00 $^{ab}$ | 13.33 $^{b}$ | 40.67 $^{c}$ | 10.33 $^{bc}$ |
| $T_4$ | 97.83 $^{a}$ | 55 | 5.33 $^{a}$ | 3.67 $^{a}$ | 13.00 $^{b}$ | 45.00 $^{ab}$ | 11.33 $^{ab}$ |
| $T_5$ | 94.45 $^{b}$ | 54 | 3.67 $^{ab}$ | 3.00 $^{ab}$ | 13.67 $^{b}$ | 43.00 $^{bc}$ | 10.00 $^{c}$ |
| $T_6$ | 98.61 $^{a}$ | 55 | 5.33 $^{a}$ | 3.67 $^{a}$ | 15.67 $^{a}$ | 46.33 $^{a}$ | 12.00 $^{a}$ |
| **LSD (0.05)** | 3.24 | - | 1.71 | 1.36 | 2.17 | 3.26 | 1.15 |
| **CV (%)** | 1.19 | - | 13.97 | 10.11 | 5.57 | 2.63 | 3.77 |
| **F-taste** | ** | ns | ** | * | * | ** | ** |

Plant height showed a slight increase under the talc treatment (T4) and whole tuber planting (T6), reaching 55 cm compared with 53 cm in the control, indicating improved vegetative vigor. Similarly, the number of main stems per plant and secondary branches per main stem was higher in T4 and T6 (5.33 main stems and 3.67 secondary branches) than in the control (2.67 main stems and 2.33 secondary branches), suggesting enhanced canopy development and potentially greater photosynthetic capacity. Leaf development was also positively influenced, with T6 producing the highest number of secondary leaves per primary leaf (12), which may contribute to increased assimilate production and improved yield potential. Enhanced wound healing and suberization of seed tubers likely contributed to stronger early plant growth and better canopy formation. A well-developed canopy improves light interception and assimilate accumulation, ultimately supporting tuber initiation and yield formation. Similar relationships between stem density, canopy expansion, and potato productivity have been reported in recent studies, emphasizing the importance of early plant vigor and uniform emergence for maximizing tuber yield (Buckley et al., 2025; Dhakal et al., 2024; Ye et al., 2024).

Talc treatment (T4) and whole tuber planting (T6) markedly enhanced vegetative growth, including sprouting uniformity, plant height, and branching, whereas ash treatment (T3) and natural suberization (T2) improved sprouting percentage but had a limited effect on canopy development. The control performed poorly across all traits, highlighting the importance of pre-planting treatments. Enhanced suberization and wound healing likely supported early establishment by forming a protective periderm that reduces pathogen invasion and water loss, promoting vigorous early growth. These results emphasize that targeted pre-planting interventions can effectively improve early potato growth and stand uniformity (Buckley et al., 2025; Zhu et al., 2023).

## Influence of Suberization Treatment on Potato Yield Components

Talc application (T4) and whole tuber planting (T6) significantly enhanced yield components of *Cardinal* potatoes under Kabul conditions ($p < 0.05$) Table 2.

***Table 2.*** *Effect of suberization treatments on tuber yield components of potato variety Cardinal.*

| Treatment | No. of Tubers/Plant | Total Yield (tons/hectare) | Marketable Yield (tons/hectare) | Non-marketable Yield (tons/hectare) | Tuber Weight (g) |
|---|---|---|---|---|---|
| $T_1$ | 5.81 $^{b}$ | 12.78 $^{c}$ | 11.19 $^{b}$ | 2.28 $^{a}$ | 119.52 $^{bc}$ |
| $T_2$ | 5.65 $^{b}$ | 13.56 $^{bc}$ | 11.75 $^{b}$ | 1.81 $^{b}$ | 129.40 $^{a}$ |
| $T_3$ | 6.11 $^{ab}$ | 14.78 $^{ab}$ | 13.00 $^{ab}$ | 1.78 $^{b}$ | 130.13 $^{a}$ |
| $T_4$ | 7.20 $^{a}$ | 15.75 $^{a}$ | 14.25 $^{a}$ | 1.50 $^{cd}$ | 119.88 $^{ab}$ |
| $T_5$ | 6.46 $^{ab}$ | 13.56 $^{bc}$ | 11.94 $^{b}$ | 1.61 $^{c}$ | 119.88 $^{ab}$ |
| $T_6$ | 7.20 $^{a}$ | 15.42 $^{a}$ | 14.00 $^{a}$ | 1.42 $^{d}$ | 114.12 $^{c}$ |
| **LSD (0.05)** | 1.09 | 1.57 | 4.91 | 4.91 | 7.26 |
| **CV (%)** | 6.02 | 4.57 | 8.05 | 2.60 | 3.10 |
| **F-taste** | ** | ** | ** | ** | ** |

These treatments produced the highest number of tubers per plant (7.20) and maximized total and marketable yields per plot (18.90 and 18.50 kg, respectively), compared to the control (T1:

5.81 tubers; 15.33 and 13.43 kg). Yields in T2 (natural suberization) and T5 (cement treatment) were intermediate. These findings indicate that targeted pre-planting suberization treatments can effectively improve tuber number and overall yield performance (Buckley et al., 2025; Han et al., 2024b; Wang et al., 2020; Zhu et al., 2023).

T2 (natural suberization, 129.40 g) and T3 (ash treatment, 130.13 g) produced the highest average tuber weights, with T4 (talc, 119.88 g) being statistically similar based on LSD analysis. The higher tuber weight observed in T2, T3, and T4 may be attributed to enhanced wound healing, reduced moisture loss, and improved protection against pathogen infection during suberization, which ultimately promoted better tuber development and assimilate accumulation. All yield components in T3 and T4 were grouped, indicating comparable effects on tuber weight, number, and total yield. Suberization and whole-tuber planting further enhanced tuber set and development, as reflected by the significantly higher tuber number per plant in T4 and T6 compared to the control, confirming that preplanting treatments effectively improve yield and marketable tuber quality (Buckley et al., 2025; Zhu et al., 2023).

The superior performance of talc treatment and whole-tuber planting observed in this study aligns with findings that enhanced wound-induced suberization improves tuber protection and healing responses, thereby reducing water loss and disease susceptibility. Moreover, planting wound-healed seed has been shown to increase yield and early crop establishment. Acceleration of wound periderm formation and suberin deposition through biotic elicitors has also been demonstrated to enhance tuber quality and storage performance. Additionally, seed tuber physical properties, including size and health status, are known to influence potato yield components and overall productivity (Buckley et al., 2025; Zhu et al., 2023).

## Conclusion

This study demonstrates that suberization treatments critically enhance growth, sprouting, and yield components of *Cardinal* potatoes under Kabul conditions. Talc application (T4) and whole tuber planting (T6) outperformed other treatments, while LSD analysis grouped T3 (ash treatment) with T4 and T6, indicating similar effects on tuber growth and yield. These results confirm that effective wound healing through artificial or assisted suberization improves field establishment and overall crop productivity. Talc treatment ($T_4$) is recommended for potato production. Future research should explore optimized treatment methods, combinations with bio-stimulants, and the underlying molecular and hormonal mechanisms to enhance tuber performance and storage quality further.

### Recommendations

Based on the results of this study, several practical and research-oriented recommendations can be proposed to enhance potato production, seed tuber quality, and crop establishment under similar climatic conditions:

- Adoption of effective suberization methods: Talc application (T4) and ash treatment (T3), along with whole tuber (non-cut) planting ($T_6$), were the most effective treatments in improving agronomic traits and yield components, particularly average tuber weight. Growers are strongly encouraged to incorporate these approaches into routine pre-planting seed tuber management to maximize potato productivity. Based on overall performance, talc treatment ($T_4$) is recommended for potato production.

- Standardization of care procedures: All potato varieties should receive consistent attention regarding application rates, treatment duration, and healing time. Further research is needed to optimize talc coating thickness and ash layer depth to maximize suberization while maintaining sprouting quality and tuber integrity.
- Research across agro-climatic zones: Additional field trials in diverse ecological zones are recommended to confirm the effectiveness of suberization techniques under varying soil types, temperatures, and humidity conditions.

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**Authors Contributions**

- Ahmad Jawid Zamany conceptualized and supervised the study.
- Ahmad Jawid Zamany, Mohammdullah Amin and Abdul Raziq Shinwari investigated and analyzed data.
- Mohammdullah Amin and Abdul Raziq Shinwari wrote the manuscript with input from all authors.
- All authors reviewed and approved the final version.

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