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Impact of Gibberellic Acid and Potassium Nitrate Pre-Sowing Treatments on True Potato Seed Germination and Early Growth: A Comparative Analysis

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study aimed to evaluate the effects of various pre-sowing chemical treatments on True Potato Seed (TPS) germination and early growth to identify optimal treatments that enhance seedling vigor and productivity in Dolakha, Nepal. The experiment was conducted from April to June 2023 in Charikot, Dolakha district (27.669518° N, 86.051006° E). It used a Completely Randomized Design (CRD) with eight treatments, each replicated three times. Treatments included hot water, gibberellic acid (GA3) at concentrations of 1000, 1500, and 2000 ppm, and potassium nitrate (KNO3) at 0.2%,

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0.4%, and 0.6%. These are applied for 24 hours in the dark, followed by shade drying. Key metrics recorded were germination percentage, shoot length, root length, leaf number, and seedling vigor. Data analysis was conducted using ANOVA in R-Studio and the results were presented via MS Excel. The findings revealed that seeds treated with 2000 ppm GA3 had the highest germination rate at 86.34%, compared to the control group (59.72%). This concentration also produced the longest shoot length (11.92 cm) and the highest seedling vigor index (1.01). The Variations in the relative growth rates for shoot, root lengths, and the number of leaves were not statistically significant across treatments. In conclusion, the study demonstrated that higher concentrations of GA3 (2000 ppm) and KNO3 (0.6%) significantly improved TPS germination and seedling vigor. These findings suggest that these treatments can benefit potato cultivation by enhancing seedling quality and reducing dependence on seed tubers. Further research is recommended to explore the long-term impacts on crop yield and broader applicability.

Keywords: True potato seed (TPS); gibberellic acid (GA3); potassium nitrate (KNO3); seed germination; seedling vigor.

1. INTRODUCTION

Potato (Solanum tuberosum L) is native to South America [1]. It is a major food source in Nepal and is cultivated from 100m in southern Terai to 4000m in the northern range [2]. Potatoes are grown on 198,256 hectares of land in Nepal, with a total production of 3,410,829 mt. In Dolakha district, 55,948 mt of potatoes were harvested in the fiscal year 2021/22, achieving a productivity of 18.17 mt per hectare [3]. Despite this significant production, the high demand and export potential are not fully met. This is due to shortages and quality issues with seed tubers. True Potato Seed (TPS) provides a good solution to these challenges.

The vast majority of cultivated potatoes are vegetatively propagated; however, the practices of TPS are popular [4]. True Potato Seed (TPS) is primarily used for sexual propagation by planting small, black seeds from potato berries, which can yield table potatoes when seedlings are transplanted from protected environments [5]. Nevertheless, TPS is also used to produce seedlings or mini tubers for vegetative propagation. Challenges like dormancy, which are influenced by temperature and seed age, can affect germination rates and timing [6].

In addition, the factors affecting the germination of True Potato Seed (TPS) include the age of the berry, mode of extraction, media for germination, light, moisture content, and seed size [7,8]. Dormancy in TPS can be reduced using various methods, such as soaking seeds in gibberellic acid (GA3) or potassium nitrate solutions [9]. Mixing the seeds for too long during extraction can lower germination rates. Fermenting the gelatinous seed layer can make the seeds germinate faster [10].

The main purpose of studying the effect of different doses of commercially available chemicals on True Potato Seed (TPS) germination is to increase the productivity of potato farmers in Dolakha district, Nepal. This research aims to identify the optimal chemical and physical treatments to improve TPS germination and seedling vigor. Farmers can achieve higher yields and reduce their dependence on costly and labor-intensive seed tubers by increasing the germination percentage and overall plant health.

2. METHODS AND METHODOLOGY

2.1 Experimental Site

The experiment was conducted in the shade room at Charikot, Dolakha district, Nepal (27.669518° N, 86.051006° E), where indirect sunlight was present. The site experiences a sub-temperate climate with average annual maximum temperatures of 19°C and minimum temperatures of 8°C, along with an average annual rainfall of 2043.5 mm. The duration of the experiment was from April to June 2023.

2.2 Experimental Design

The research was conducted using a Completely Randomized Design (CRD). There were eight different treatments, and each was tested three times. The hormonal priming of seeds was performed in the dark for 24 hours, followed by shade drying to remove excess moisture. The treatments included: T1 as the control, T2 with hot water treatment, T3 with 1000 ppm GA, T4 with 1500 ppm GA, T5 with 2000 ppm GA, T6 with 0.2% KNO3, T7 with 0.4% KNO3, and T8 with 0.6% KNO3. The design and field layout are shown in Figs. 1 & 2.

2.3 Design and Field Layout

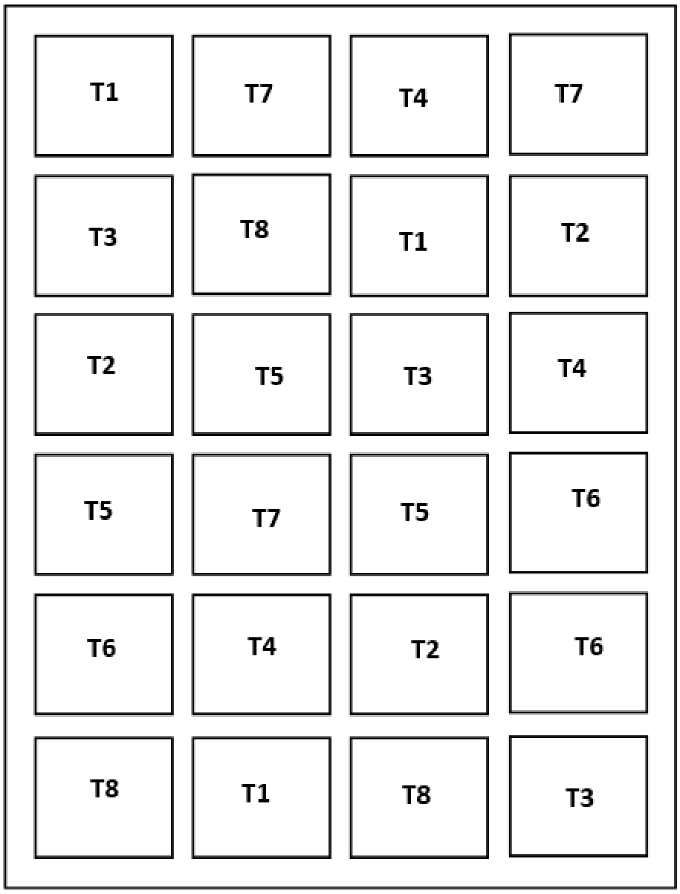

Fig. 1. Layout of design

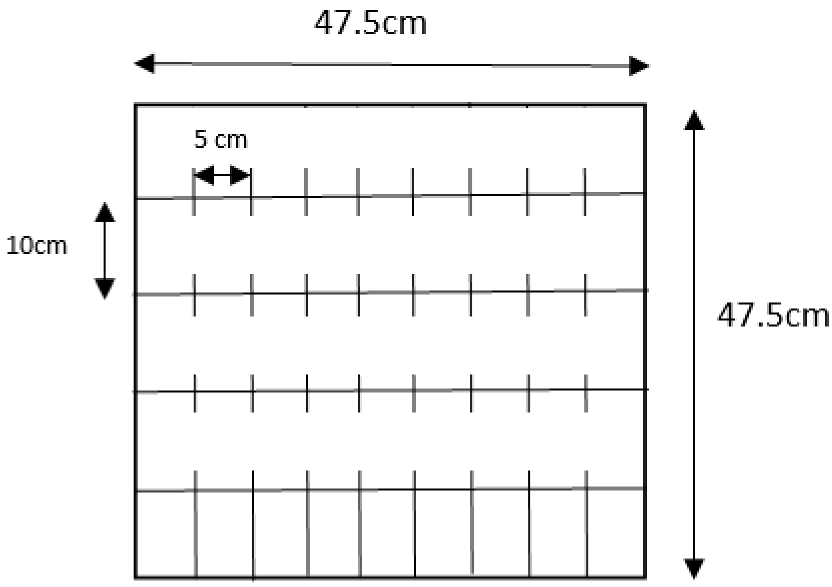

Fig. 2. Nursery tray

2.4 Operational Activities

Seeds were treated with GA3 and KNO3 and placed in shaded areas for 24 hours before being directly sown into plastic trays. Each treatment involved sowing 4 to 5 seeds in 32 hills, totaling 144 seeds per treatment. Thinning was performed 15 days later to maintain 1-2 seedlings per hill. Data collection on various growth parameters began from the first observed germination and continued regularly for 30 days. The relative growth rate was calculated by dividing the increase in shoot or root length by the initial length and then by the period [11]. Additionally, data were collected on shoot length, root length, and leaf numbers to provide comprehensive insights into the seedlings' growth and development. In addition, germination percentage and seedling vigor were calculated using the following formulas.

Germination % = $\frac{\text{Number of seeds germinated}}{\text{number of seed sown}}$ [12]

Seedling vigor = $\frac{(\text{shoot length}+\text{root length})*\text{germination }\%}{100}$ [13]

2.5 Data Analysis

The collected data was recorded by using the MS-Excel and analyzed by the R-studio statistical for CRD (Complete Randomize Design) at a 5% level of significance. Graphs and tables were constructed by using MS Excel.

3. RESULTS AND DISCUSSION

The study showed that different pre-sowing treatments had a statistically significant effect ($P<0.001$) on germination percentage, shoot length, root length, and seedling vigor. However, the number of leaves and relative growth rate did not show statistically significant differences (Tables 1 & 2)

Seed germination is influenced by seed treatment and growth medium, enhancing water absorption, soil texture, nutrient availability, and oxygen supply [14]. The results showed that a higher percentage of germination was observed in seeds treated with 2000 ppm GA (86.34) and the lowest germination percentage was found in seeds treated with control solution (59.72). The higher the concentration of GA3 and KNO3 the higher the germination percentage. The same results were found by Dev et al. [15]. Seed treated with distilled water for 24 hours at alternating temperatures of 20 ℃ for 17 hours and 30 ℃ for 7 hours each day shows 25% germination in soil and 64% in petri dishes. In similar conditions, Seeds treated with 0.2% KNO3 showed 33% germination in soil and 75% in petri dishes. Similar results were reported by Clarke & Stevenson [16]. The difference in results in the germination may be due to the way of extracting seed from the berry [17]. Seed treated with 1500 ppm GA3 for 24 hours sown in plots with temperatures fluctuating between 13-22℃ had germination percentages ranging from 85% to 98% after 5 and 10 days. A similar result was reported by Wiersema [18]. Normal water resulted in 76% variation in germination while, seeds treated with 0.2% KNO3 resulted in 90% variation, 0.5% KNO3 showed 85%, and 1% KNO3 showed 76% variation in germination percentages [19]. Successful germination of 100% was observed in potato seeds treated with 2000 ppm of GA3 after 4 weeks of sowing [20]. Fermented seeds soaked in 1000 ppm and 2000 ppm GA3 solutions showed 95% and 92% germination after 19 days at 18℃ to 23℃ [21]. La Molina and San Ramon seeds treated with 1500 ppm GA3 which were sowed in the plastic tray at 0.5 cm depth for 24 hours showcased 91.9% and 94.5% germination [22].

The effect of different pre-sowing treatments on the shoot length of TPS was found more significant at 30 DAS than at 15 DAS (Table 1). The mean length was found 5.94 cm and 10.83 cm at 15 and 30 DAS respectively. The data observed at 15 DAS show that the longest shoot length (7.05 cm) was found on seedlings treated with 2000 ppm GA3 followed by seeds treated with 1500 ppm GA3 (7.03 cm). Control seedlings treated with normal water had the shortest length i.e. 4.67cm. Similarly, at 30 DAS, seedlings treated with 2000ppm GA3 had the longest shoot length (11.92 cm), followed by seedlings treated with 0.6% KNO3 i.e. (11.55 cm.) Control seedlings had the shortest length at 9.22cm. Other treatment has more or less similar results. Seedlings that grow from the seed treated with potassium nitrate solution were noticeably larger than those of the water series even when the germination percentage was the same [23]. Gibberellic acid promotes seedling stem elongation and growth by stimulating cell division, and elongation in the internodes of the stem resulting in increased shoot length compared to treatment with KNO3 as it gives potassium and nitrogen only for proper growth and development of seedlings [24].

The mean Root length was 1.93 cm and 2.72 cm on 15 DAS and 30 DAS. The root length of 15

DAS was found more significant than that of 30 DAS. The mean Root length is found at 15 DAS, the maximum root length (2.57 cm) was observed with 2000 ppm GA3 followed by 2.43 cm of the seedling treated with 1500 ppm GA3. The minimum length (1.19cm) was found in seedlings treated with 0.2% KNO3. Similarly, at 30DAS, the maximum root length (3.27 cm) was reported with 0.6% KNO3 followed by 3.10 cm of the seedling treated with 1500 ppm GA3. The minimum length of 2.17cm was found in seedlings treated with 0.2% KNO3. Other treatments have comparable results. Gibberellic acid breaks dormancy, promotes cell elongation and the proper growth of embryonic roots. However, KNO3 promotes growth by providing essential nutrients (potassium and nitrogen), contributing to various physiological processes: osmoregulation, enzyme activation, and the maintenance of turgor pressure [25]. The plants treated with gibberellic acid showed longer root lengths compared to those treated with KNO3 solutions, a result that is consistent with findings by Singh [26].

The application of different pre-sowing treatments did not affect the leaves per plant (Table 2). At 15 DAS, the number of leaves ranged from 1.93 in seedlings treated with 0.2% KNO3 to 2.40 in seedlings treated with 1000 ppm GA. By 30 DAS, the number of leaves ranged from 4.00 in control and 0.2% KNO3 treatments to 4.53 in seedlings treated with 2000 ppm GA and 0.6% KNO3. The numbers of leaves per plant were recorded highest after 30 days of sowing in plants treated with 2000ppm GA3 (11.92) and 0.6% KNO3 (11.55). This is because the application of GA3 increases the height due to stimulation of cell division and elongation and KNO3 promotes growth by supplying essential nutrients. The higher the GA3 and KNO3 application higher the leaf number**.** The TPS seedlings are transplanted when it range from 3/4 leaves stage after 21 to 28 days of sowing. The seedling growth set back due to thinning of seedlings at 15 DAS which retard the growth of seedlings. So, the leaf number of the seedlings remains more or less similar irrespective of different pre-sowing treatments [27].

Seedling vigor was found highest in seeds treated with 2000 ppm GA3 (0.96 & 1.01) and 0.6% KNO3 (0.9 & 0.96) in both 15 DAS and 30 DAS. However, the lowest seedling vigor was found in control treatments (0.66 & 0.72) in both 15 DAS and 30 DAS (Table 2). At 15 DAS, seedling vigor ranged from 0.66 in the control group to 0.96 in seedlings treated with 2000 ppm GA. At 30 DAS, seedling vigor ranged from 0.72 in the control group to 1.01 in seedlings treated with 2000 ppm GA. The data indicate that higher concentrations of GA3 and KNO3 resulted in increased seedling vigor. This is due to higher concentrations of GA3 and KNO3 application fostering the chance of germination and growth of seedlings as both act as a stimulatory agent providing higher competitive ability and reducing the chance of mortality [28]. The decreased seedling vigor in control and hot water treatment may be due to over-exposure of seedlings to pre-sowing treatments. The results conform with N. E. Pallais et.al. [29].

The RGR of shoot length varied among treatments, with the highest rate observed in seedlings treated with 0.4% KNO3 (0.38) and the lowest in seedlings treated with 1500 ppm GA (0.29). Despite these variations, the differences were not statistically significant ($P>0.05$) as shown in Table 2. The general trend indicates that while KNO3 treatments provided a slightly higher RGR, indicating potentially more efficient shoot elongation, the overall impact of GA treatments on shoot RGR was comparable to other treatments. This finding suggests that while KNO3 may enhance shoot growth slightly, the effect of GA on shoot growth is consistent but not as pronounced. For root length, RGR values were notably higher in treatments with 0.2% KNO3 and 0.6% KNO3 (0.06), compared to other treatments. The RGR for root length was also not statistically significant ($P>0.05$), but the trend suggests that KNO3 treatments could enhance root growth more effectively than GA treatments. This is consistent with the role of potassium nitrate in improving nutrient uptake and osmoregulation, which are crucial for root development. The lower RGR values in GA-treated seedlings could be attributed to the focus of GA3 on promoting shoot elongation rather than root growth, as GA3 primarily affects stem elongation and cell division in the shoots.

According to Dev et al, after a certain phase, the effect of gibberellin and KNO3 decreases and the growth of seedlings can be seen at a more or less constant rate [15]. This can explain the non-significant result on the relative growth rate of root length and shoot length of seedlings. The relative growth rate at the beginning was found to be greater than the later stage due to transplanting shock which retard the growth of the seedling [30].

Table 1. Germination Percentage, shoot length, and root length influenced by different pre-sowing treatments on TPS

Treatments	Germination Percentage	Shoot Length @ 15DAS (cm)	Shoot Length @ 30 DAS (cm)	Root Length @ 15 DAS (cm)	Root Length @30 DAS (cm)
Control	59.72^{c}	4.67^{d}	9.22^{c}	1.42^{cd}	2.59^{bc}
Hot water treatment	63.42^{c}	5.42^{bcd}	10.23^{b}	1.54^{cd}	2.43^{c}
1000ppm GA	75.69^{b}	6.43^{ab}	11.06^{ab}	1.82^{bc}	2.43^{c}
1500ppm GA	80.09^{b}	7.03^{a}	11.49^{a}	2.43^{a}	3.10^{ab}
2000ppm GA	86.34^{a}	7.05^{a}	11.92^{ab}	2.57^{a}	3.05^{ab}
0.2% KNO3	61.10^{c}	5.49^{bcd}	10.12^{bc}	1.19^{d}	2.17^{c}
0.4% KNO3	78.93^{b}	5.21^{cd}	11.02^{ab}	2.11^{ab}	2.75^{abc}
0.6% KNO3	81.25^{ab}	6.27^{abc}	11.55^{a}	2.37^{a}	3.27^{a}
LSD(0.05)	5.69	1.05	0.91	0.52	0.57
SEm (+-)	0.67	0.124318	0.108388	0.061907	0.068075
F- Probability	<0.001***	<0.01	<0.001	<0.001	<0.01
CV (%)	4.48	10.24	4.90	15.68	12.23
Grand Mean	73.32	5.94	10.83	1.93	2.72

*The column with the same letter(s) in superscript indicates no significant difference between treatments. '***' significant at 0.001 Level of significance, '**' significant at 0.01 Level of Significance, '* 'Significant at 0.05 Level of Significance.*

Table 2. Leaf numbers, seedling vigor, and relative growth rate influenced by different pre-showing treatments on TPS

Treatments	Leaf Number @ 15 DAS	Leaf Number @ 30 DAS	Seedling Vigor @ 15 DAS	Seedling Vigor@ 30 DAS	Relative Growth Rate of Shoot Length	Relative Growth Rate of Root Length
Control	2.27	4.00	0.66[c]	0.72[d]	0.30[a]	0.08[a]
Hot water treatment	2.13	4.00	0.70[c]	0.76[d]	0.32[a]	0.06[ab]
1000ppm GA	2.40	4.13	0.84[b]	0.89[c]	0.30[a]	0.04[ab]
1500ppm GA	2.26	4.27	0.90[b]	0.94[bc]	0.29[a]	0.04[ab]
2000ppm GA	2.13	4.53	0.96[a]	1.01[a]	0.32[a]	0.03[b]
0.2% KNO3	1.93	4.00	0.68[c]	0.73[d]	0.30[a]	0.06[ab]
0.4% KNO3	2.00	4.27	0.86[b]	0.92[bc]	0.38[a]	0.04[ab]
0.6% KNO3	2.00	4.53	0.90[b]	0.96[ab]	0.35[a]	0.06[ab]
LSD(0.05)	0.667	0.468	0.059	0.060	0.094	0.039
SEm (+-)	0.078616	0.055277	0.006913	0.007156	0.011038	0.004657
F- Probability	ns	ns	<0.001	<0.001	ns	ns
CV (%)	17.98	6.42	4.17	4.04	16.61	43.27
Grand Mean	2.14	4.21	0.81	0.87	0.33	0.053

*The column with the same letter(s) in superscript indicates no significant difference between treatments. '***' significant at 0.001 Level of significance, '**' significant at 0.01 Level of Significance, '* 'Significant at 0.05 Level of Significance.*

4. CONCLUSION

This study showed that 2000 ppm gibberellic acid (GA3) significantly improves the germination rate and growth of True Potato Seed (TPS) compared to other treatments and controls. This finding is crucial as it suggests that GA3 can aid potato farmers in Dolakha in cultivating healthier plants and achieving higher yields. The key insight is the particular efficacy of GA3 in improving TPS performance, which could potentially revolutionize local farming practices. Although this study was limited to one location and a short duration, future research should evaluate these treatments across various geographic regions and longer periods to verify and expand upon these findings.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of manuscripts.

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

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