

# Original Research Article

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

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### ABSTRACT

**Aims:** This study investigates the effects of various pre-sowing chemical treatments on the germination and early growth of True Potato Seed (TPS) to identify optimal treatments that enhance seedling vigor and productivity in Dolakha, Nepal.

**Study Design:** A Completely Randomized Design (CRD) was utilized with eight treatments, each replicated three times.

**Place and Duration of Study:** The experiment took place in a shaded room at Charikot, Dolakha district, Nepal (27.669518° N, 86.051006° E) from April to June 2024.

**Methodology:** TPS seeds were treated with different chemicals including hot water, gibberellic acid (GA3) at 1000, 1500, and 2000 ppm, and potassium nitrate (KNO3) at 0.2%, 0.4%, and 0.6%. Treatments were applied for 24 hours in the dark, followed by shade drying. Key metrics such as germination percentage, shoot length, root length, leaf number, and seedling vigor were recorded. Data were analyzed using ANOVA in R-Studio and presented using MS Excel.

**Results:** Seeds treated with 2000 ppm GA3 exhibited the highest germination rate (86.34%), compared to 59.72% in the control. The longest shoot length (11.92 cm) and highest seedling vigor (1.01) were also observed with 2000 ppm GA3. Root length measurements were most significant at 15 DAS for GA3 and at 30 DAS for KNO3 treatments. No significant differences were found in leaf number among treatments. Relative growth rates for both shoot and root lengths varied but were not statistically significant.

**Conclusion:** Higher concentrations of GA3 (2000 ppm) and KNO3 (0.6%) significantly improved TPS germination and seedling vigor. These treatments can enhance potato cultivation by increasing seedling quality and reducing dependence on seed tubers, suggesting practical benefits for potato farmers in Dolakha. Further studies could explore the long-term impact 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]. Potatoes are a major food source in Nepal, and they are cultivated from 100m in southern Terai to 4000m in the northern range[2]. It is cultivated on 198,256 hectares of land in Nepal, with a total production of 3,410,829 mt[3]. In Dolakha district alone, 55,948 mt. of potatoes were harvested in the fiscal year 2021/22, achieving a productivity of 18.17 mt. per hectare (Ministry of Agriculture and Livestock Development [3]) Despite this significant production, a high demand and export potential are not fully met due to shortages and quality issues with seed tubers. True Potato Seed (TPS) provides a promising 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]. However, TPS is also employed to produce seedling tubers or mini tubers for vegetative propagation, though challenges such as dormancy, 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]. Dormancy in TPS can be mitigated using various methods, such as soaking seeds in gibberellic acid (GA3) or potassium nitrate solutions, which enhances germination by breaking dormancy[8]&[9]. Blending the seeds for too long during extraction can reduce germination rates, while methods like fermenting the gelatinous seed layer improve the speed of germination [10].

The main purpose of studying the effect of different doses of commercially available chemicals on True Potato Seed (TPS) germination is to enhance 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. By increasing the germination percentage and overall plant health, farmers can achieve higher yields and reduce their dependence on costly and labor-intensive seed tubers.

## 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 2024.

### 2.2 Design of Experiment

The research was conducted using a Completely Randomized Design (CRD) with eight treatments, each replicated 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% KNO<sub>3</sub>, T7 with 0.4% KNO<sub>3</sub>, and T8 with 0.6% KNO<sub>3</sub>. The design and field layout are depicted in Figures 1 & 2.

### 2.3 Design and Field Layout

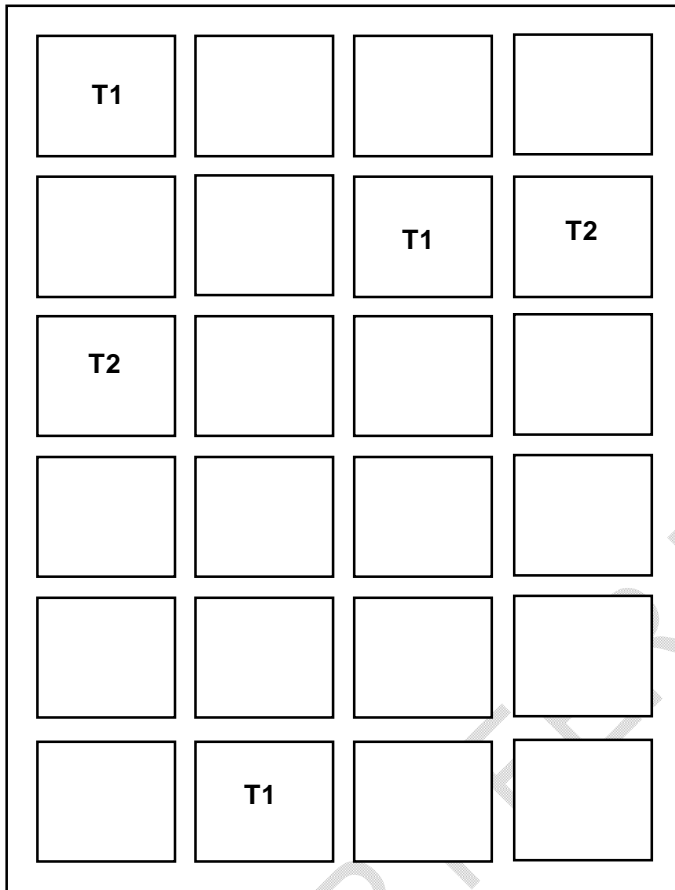


Figure 2: Layout of Design

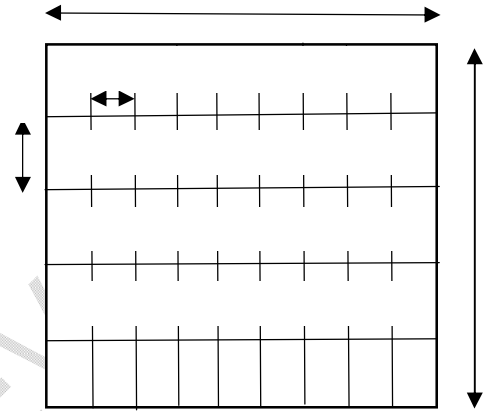


Figure 1: Nursery Tray

### 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 commenced 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.

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

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

## 2.5 Data analysis

The collected data was compiled by using the ms-excel program and subjected to analysis of variance as per the procedures given in the r-studio statistical computer package 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 revealed 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 as shown in table 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 revealed 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 forwarded by Dev et al.[15]. Seed treated with distilled water for 24 hours at alternating temperatures of 20 °C for 17 hours and 30 °C 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°C had germination percentages ranging from 85% to 98% after 5 and 10 days. A similar result was put forward 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°C to 23°C[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 to be 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 GA<sub>3</sub> (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 GA<sub>3</sub> had the longest shoot length (11.92 cm), followed by seedlings treated with 0.6% KNO<sub>3</sub> 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 KNO<sub>3</sub> as it gives potassium and nitrogen only for proper growth and development of seedling [24].

The mean Root length is found to be 1.93 cm and 2.72 cm on 15 DAS and 30 DAS. The root length of 15 DAS is found to be more significant than of 30 DAS. The mean Root length is found at 15 DAS, the maximum root length was found to be 2.57 cm treated with 2000ppm GA<sub>3</sub> followed by 2.43 cm of the seedling treated with 1500 ppm GA<sub>3</sub>. The minimum length of 1.19cm was found in seedlings treated with 0.2% KNO<sub>3</sub>. Similarly, at 30DAS, the maximum root length was found to be 3.27 cm treated with 0.6% KNO<sub>3</sub> followed by 3.10 cm of the seedling treated with 1500ppm GA<sub>3</sub>. The minimum length of 2.17cm was found in seedlings treated with 0.2% KNO<sub>3</sub>. Other treatments have comparable results. Gibberellic acid breaks dormancy and also promotes cell elongation and enhances nutrient uptake which help in the proper growth of embryonic root but KNO<sub>3</sub> promote growth by providing essential nutrients (potassium and nitrogen), contributing to various physiological processes including osmoregulation, enzyme activation, and the maintenance of turgor pressure [25]. The plants treated with gibberellic acid showed the longest root length to seeds treated with KNO<sub>3</sub> solutions was a similar result found by Singh[26].

The effect of different pre-sowing treatments on leaf number was found to be non-significant (Table 2). The application of different pre-sowing treatments did not affect the leaves per plant. At 15 DAS, the number of leaves ranged from 1.93 in seedlings treated with 0.2% KNO<sub>3</sub> 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% KNO<sub>3</sub> treatments to 4.53 in seedlings treated with 2000 ppm GA and 0.6% KNO<sub>3</sub>. The numbers of leaves per plant were recorded highest after 30 days of sowing in plants treated with 2000ppm GA<sub>3</sub> (11.92) and 0.6% KNO<sub>3</sub> (11.55). This is because the application of GA<sub>3</sub> increases the height due to stimulation of cell division and elongation and KNO<sub>3</sub> promotes growth by supplying essential nutrients. The higher the GA<sub>3</sub> and KNO<sub>3</sub> application higher the leaf number. The TPS seedlings are transplanted when it ranges 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% KNO<sub>3</sub> (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 KNO<sub>3</sub> resulted in increased seedling vigor. This is due to higher concentrations of GA3 and KNO<sub>3</sub> application foster the chance of germination and growth of seedlings as both acts 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 [29].

The RGR of shoot length varied among treatments, with the highest rate observed in seedlings treated with 0.4% KNO<sub>3</sub> (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 KNO<sub>3</sub> 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 KNO<sub>3</sub> 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% KNO<sub>3</sub> and 0.6% KNO<sub>3</sub> (0.06), compared to other treatments. The RGR for root length was also not statistically significant ( $P > 0.05$ ), but the trend suggests that KNO<sub>3</sub> 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 KNO<sub>3</sub> decreases and the growth of seedlings can be seen in the 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 <sup>c</sup>	4.67 <sup>d</sup>	9.22 <sup>c</sup>	1.42 <sup>cd</sup>	2.59 <sup>bc</sup>
Hot water treatment	63.42 <sup>c</sup>	5.42 <sup>bcd</sup>	10.23 <sup>b</sup>	1.54 <sup>cd</sup>	2.43 <sup>c</sup>
1000ppm GA	75.69 <sup>b</sup>	6.43 <sup>ab</sup>	11.06 <sup>ab</sup>	1.82 <sup>bc</sup>	2.43 <sup>c</sup>
1500ppm GA	80.09 <sup>b</sup>	7.03 <sup>a</sup>	11.49 <sup>a</sup>	2.43 <sup>a</sup>	3.10 <sup>ab</sup>
2000ppm GA	86.34 <sup>a</sup>	7.05 <sup>a</sup>	11.92 <sup>ab</sup>	2.57 <sup>a</sup>	3.05 <sup>ab</sup>
0.2% KNO3	61.10 <sup>c</sup>	5.49 <sup>bcd</sup>	10.12 <sup>bc</sup>	1.19 <sup>d</sup>	2.17 <sup>c</sup>
0.4% KNO3	78.93 <sup>b</sup>	5.21 <sup>cd</sup>	11.02 <sup>ab</sup>	2.11 <sup>ab</sup>	2.75 <sup>abc</sup>
0.6% KNO3	81.25 <sup>ab</sup>	6.27 <sup>abc</sup>	11.55 <sup>a</sup>	2.37 <sup>a</sup>	3.27 <sup>a</sup>
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-sowing treatments on TPS**

Treatments	Leaf Number @	Leaf Number @	Seedling Vigor @ 15	Seedling Vigor @ 30	Relative Growth Rate of	Relative Growth Rate of

	15 DAS	30 DAS	DAS	DAS	Shoot Length	Length
Control	2.27	4.00	0.66 <sup>c</sup>	0.72 <sup>d</sup>	0.30 <sup>a</sup>	0.08 <sup>a</sup>
Hot water treatment	2.13	4.00	0.70 <sup>c</sup>	0.76 <sup>d</sup>	0.32 <sup>a</sup>	0.06 <sup>ab</sup>
1000ppm GA	2.40	4.13	0.84 <sup>b</sup>	0.89 <sup>c</sup>	0.30 <sup>a</sup>	0.04 <sup>ab</sup>
1500ppm GA	2.26	4.27	0.90 <sup>b</sup>	0.94 <sup>bc</sup>	0.29 <sup>a</sup>	0.04 <sup>ab</sup>
2000ppm GA	2.13	4.53	0.96 <sup>a</sup>	1.01 <sup>a</sup>	0.32 <sup>a</sup>	0.03 <sup>b</sup>
0.2% KNO <sub>3</sub>	1.93	4.00	0.68 <sup>c</sup>	0.73 <sup>d</sup>	0.30 <sup>a</sup>	0.06 <sup>ab</sup>
0.4% KNO <sub>3</sub>	2.00	4.27	0.86 <sup>b</sup>	0.92 <sup>bc</sup>	0.38 <sup>a</sup>	0.04 <sup>ab</sup>
0.6% KNO <sub>3</sub>	2.00	4.53	0.90 <sup>b</sup>	0.96 <sup>ab</sup>	0.35 <sup>a</sup>	0.06 <sup>ab</sup>
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 shows that using 2000 ppm gibberellic acid (GA3) greatly improves the germination rate and growth of True Potato Seed (TPS), more so than other treatments or no treatment at all. This finding is important because it means GA3 can help potato farmers in Dolakha grow healthier plants and get better yields. The new insight here is that GA3 is particularly effective for improving TPS, which could be a game-changer for local farming. Although the study was limited to one location and a short timeframe, future research should test these treatments in different places and for longer periods to confirm and expand on these results.

## REFERENCES

- [1] P. M. Harris, *The potato crop: The scientific basis for improvement*, 2nd ed., vol. 1. Springer Science & Business Media, 1992.
- [2] D. Ghimire, G. Lamsal, B. Paudel, S. Khatri, and B. Bhusal, "Analysis of trend in area, production and yield of major vegetables of Nepal," *Trends in Horticulture*, vol. 1, no. 2, Sep. 2018, doi: 10.24294/th.v1i2.914.
- [3] Ministry of Agriculture and Livestock Development (MoALD), "Statistical-Information-on-Nepalese-Agriculture," 2023.
- [4] N. W. Simmonds, "A review of potato propagation by means of seed, as distinct from clonal propagation by tubers," *Potato Res*, vol. 40, no. 2, pp. 191–214, 1997, doi: 10.1007/BF02358245.
- [5] P. Malagamba, "Potato Production from True Seed in Tropical Climates."
- [6] N. Pallais, N. Fong, R. Garcia, and J. Santos-Rojas, "Factors affecting seedling vigor in potatoes: II. Genotype, dormancy, and pre-sowing treatments," *Am Potato J*, vol. 67, no. 2, pp. 109–119, 1990, doi: 10.1007/BF02990960.
- [7] N. W. Simmonds, "Experiments on the germination of potato seeds. I," *European Potato Journal*, vol. 6, no. 1, pp. 45–60, 1963, doi: 10.1007/BF02364634.
- [8] P. B. Spicer and L. E. O. A. Dionne, "Use of gibberellin to hasten germination of *Solanum* seed," *Nature*, vol. 189, no. 4761, pp. 327–328, 1961, doi: 10.1038/189327a0.
- [9] A. Alexopoulos, I. Karapanos, K. Akoumianakis, and H. Passam, "Effect of gibberellic acid on the growth rate and physiological age of tubers cultivated from True Potato Seed," *J Plant Growth Regul*, vol. 36, Mar. 2017, doi: 10.1007/s00344-016-9616-z.
- [10] F. I. Lauer, R. Mullin, and A. W. Blomquist, "Potato seed germination as influenced by food blender injury, gibberellic acid, thiram and fermentation," *Am Potato J*, vol. 42, no. 3, pp. 71–75, 1965, doi: 10.1007/BF02862431.
- [11] J. & van L. H. H. Goudriaan, *Modelling potential crop growth processes: textbook with exercises*. Kluwer Academic Publishers., 1994.
- [12] ISTA., "International rules for seed testing," *Seed Science and Technology*, vol. 27, pp. 155–199, 1999.
- [13] P. Dhakal and R. Subedi, "Influence of mannitol priming on maize seeds under induced water stress," *Journal of Agriculture and Crops*, no. 63, pp. 27–31, Mar. 2020, doi: 10.32861/jac.63.27.31.
- [14] S. Gautam, N. Sarma, G. Sarma, and U. Borthakur, "Effects of soil pH stress on plant development: From seed germination to early seedling growth internal factors," *African Journal of Biological Science*, vol. 7, no. 6, pp. 3461–3473, 2024, doi: 10.48047/AFJBS.6.7.2024.3462-Seed.
- [15] R. Dev, D. Dayal, and M. Sureshkumar, "Gibberellic Acid and Potassium Nitrate Promote Seed Germination and Growth of Grey-leaved Saucer-berry (*Cordia*

- Sinensis Lam.) Seedlings," *International Journal of Fruit Science*, vol. 20, no. S2, pp. 937–954, 2020, doi: 10.1080/15538362.2020.1774465.
- [16] A. E. Clarke and F. J. Stevenson, "Factors influencing the germination of seeds of the potato," *Am Potato J*, vol. 20, no. 9, pp. 247–258, 1943, doi: 10.1007/BF02881698.
- [17] D. T. P. Gallagher and M. N. Nabi, "Extraction and germination of true potato seed," *New Zealand Journal of Experimental Agriculture*, vol. 12, no. 2, pp. 151–154, 1984, doi: 10.1080/03015521.1984.10421425.
- [18] S. G. Wiersema, "A method of producing seed tubers from true potato seed," *Potato Res*, vol. 29, no. 2, pp. 225–237, 1986, doi: 10.1007/BF02357653.
- [19] G. P. Steinbauer, "Interaction of temperature and moistening agents in the germination and early development of potato seedlings," *Am Potato J*, vol. 34, no. 4, pp. 89–93, 1957, doi: 10.1007/BF02852230.
- [20] J. B. Bamberg, "Germination of gibberellin sensitive *Solanum* (potato) botanical seeds soaked in GA3 and re-dried," *American Journal of Potato Research*, vol. 77, no. 3, pp. 201–202, 2000, doi: 10.1007/BF02853945.
- [21] M. W. Martin, "Techniques for successful field seeding of true potato seed," *Am Potato J*, vol. 60, no. 4, pp. 245–259, 1983, doi: 10.1007/BF02854275.
- [22] A. Ierna and J. Tenorio, "Effects of pre-sowing treatment on plant emergence and seedling vigour in true potato seed," *Journal of Horticultural Science and Biotechnology*, vol. 86, no. 5, pp. 467–472, 2011, doi: 10.1080/14620316.2011.11512790.
- [23] S. I. Shim, J.-C. Moon, C. S. Jang, P. Raymer, and W. Kim, "Effect of potassium nitrate priming on seed germination of seashore paspalum," 2008.
- [24] L. Tapfumaneyi, P. Dube, S. Mavengahama, and W. Ngezimana, "Effects of different levels of gibberellic acid and potassium nitrate solutions on the emergence and seedling vigor of amaranth and *Cleome gynandra*," *Agrosystems, Geosciences and Environment*, vol. 7, no. 1, pp. 1–12, 2024, doi: 10.1002/agg2.20464.
- [25] M. Kazemi, "Effect of Gibberellic Acid and Potassium Nitrate Spray on Vegetative Growth and Reproductive Characteristics of Tomato," *J. Biol. Environ. Sci*, vol. 8, no. 22, pp. 1–9, 2014.
- [26] P. Singh, "Impact of potassium nitrate (KNO<sub>3</sub>) and gibberellic acid (GA<sub>3</sub>) on germination and growth of aonla (*Emblica officinalis* L.)," *Int J Chem Stud*, vol. 8, no. 2, pp. 1379–1381, 2020, doi: 10.22271/chemi.2020.v8.i2u.8955.
- [27] M. A. Zainaldeen and I. J. Abdul Rasool, "Response of Growth and Yield of True Potato Seed Plants to Foliar Application with Organic Nutrients," *IOP Conf Ser Earth Environ Sci*, vol. 1158, no. 4, pp. 1–6, 2023, doi: 10.1088/1755-1315/1158/4/042047.
- [28] N. G. Tzortzakis, "Effect of pre-sowing treatment on seed germination and seedling vigour in endive and chicory," *Horticultural Science*, vol. 36, no. 3, pp. 117–125, 2009, doi: 10.17221/28/2008-hortsci.
- [29] N. E. Pallais, N. Y. Espinola, R. M. Falcon, and R. S. Garcia, "Improving Seedling Vigor in Sexual Seeds of Potato Under High Temperature," *HortScience*, vol. 26, no. 3, pp. 296–299, 2019, doi: 10.21273/hortsci.26.3.296.
- [30] L. C. M. van Dijk, O. C. Kacheyo, M. E. de Vries, W. J. M. Lommen, and P. C. Struik, "Crop Cycle Length Determines Optimal Transplanting Date for Seedlings from Hybrid True Potato Seeds," *Potato Res*, vol. 65, no. 2, pp. 435–460, 2022, doi: 10.1007/s11540-021-09524-x.