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Effect of Seed Priming on Germination and Seedling Growth of Cucumber (*Cucumis sativus* cv. Bhaktapur Local) in Syangja, Nepal

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Abstract Cucumber (*Cucumis sativus* L.) is high-value vegetable in Nepal, known for its high nutritive value, high water and fiber content. However, cucumber faces low and inconsistent germination rates and poor seedling growth. Seed priming is a viable option to address these issues. Hence, an experiment was conducted from March to July, 2024 in Syangja, Nepal to analyse the effect of seed priming on germination and seedling growth of cucumber under high-tech polyhouse condition. The experiment was laid out in Completely Randomized Design (CRD) with ten treatments i.e. T_1: Control, T_2: Hot water (45 °C for 5 minutes), T_3: GA_3 100 ppm, T_4: GA_3 200 ppm, T_5: KNO_3 1%, T_6: KNO_3 3%, T_7: Cow urine 5%, T_8: Cow urine 10%, T_9: Vermiwash 10%, and T_{10}: Vermiwash 20%, each replicated three times. The results revealed that significantly the highest germination percentage (88%), seed vigour index-I (2,643.83), seed vigour index-II (22,555.33), fresh root weight (0.51 g) and earliest days to 50% germination (6 days) were recorded from the seed primed with hot water (45 °C for 5 minutes). Significantly the earliest mean germination time (6.06 days), highest speed of germination (0.49) and highest dry shoot weight (240 mg) were recorded in KNO_3 1%, while dry root weight was maximum in GA_3 200 ppm (46.00 mg). Hot water significantly enhanced germination percentage and overall seed vigour; KNO_3 1% reduced MGT and improved germination speed; GA_3 200 ppm promoted root dry matter accumulation. In practical applications, the choice of priming method should be based on target trait, as well as cost and availability considerations.
Keywords Cucumber (*Cucumis sativus* L.); Germination; Hot water; Potassium nitrate; Seed priming

1 Introduction

Cucumber (*Cucumis sativus* L.) is one of the economically important cucurbits grown during summer season in hills and terai region of Nepal. Cucumber is low in calories and contains soluble fiber, high level of vitamins like C, K, other traces of minerals and antioxidants (Murad and Nyc, 2016). The nutritive value of 100 g of edible cucumber contains 12 calories of energy, 0.6 g of protein, 0.1 g of fat, 2.2-3.6 g of carbohydrates, 0.5 g of dietary fiber, 14 mg of Ca, 15 mg of Mg, 124 mg of K, 24 mg of P (Shakuntala et al., 2020).

Seed priming is a pre-sowing strategy for influencing seedling development by modulating pre-germination metabolic activity prior to the emergence of radicle and generally enhance rapid, uniform emergence and plant development to achieve higher yield (Black and Bewley, 2000). It is a technique to elevate the germination percentage and reduce the time of seedling emergence along with improvement in uniformity of germination and emergence in field condition (Dhal et al., 2022). Hydro-priming enhance the seed germination, growth and uniform seedling growth in the field in various crops (Adebisi et al., 2012), and increases the speed of germination, decreases mean germination time (MGT), increases seed vigour index (SVI) (Shakuntala et al., 2020). GA_3 play essential role in plant growth and development (Bai et al., 2016), chlorophyll biosynthesis, carbohydrate metabolism (Varier et al., 2010), and increases germination by 30.56% (Behera, 2016). KNO_3 improves seed parameters of cucumber and other vegetables (Ghassemi-Golezani and Esmaeilpour, 2008). Cow urine 10% shows positive influence in capsicum due to presence of physiologically active substances (Ambika and Balakrishnan, 2015). Vermiwash priming increases the first and final count germination compared to control (Sowmya et al., 2022). Fathima and Sekar (2014) revealed that vermiwash treatment was most effective in promoting seedling growth, including maximum hypocotyl and radicle length.

Poor germination and erratic seedling growth were major factors to obstruct the seedling emergence and lower production of cucumber respectively. Effective results of seed priming on germination and seedling growth may be useful in making cucumber growers aware about the benefits of seed priming. Hence, the experiment was conducted to assess the effect of seed priming on germination and seedling growth of cucumber.

2 Materials and Methods

2.1 Experimental site

The study was conducted in high-tech polyhouse at the demonstration site of Agriculture Knowledge Center (AKC) Office, Putalibazar, Syangja from March to July, 2024. Syangja district lies in mid-hill region at altitude 300-2,266 masl. It lies at latitude 28º4'6"N and longitude 83º52'0"E.

The morning temperature at 6:00 am remained relatively stable (20 °C–23 °C) (Figure 1). The afternoon temperature at 2:00 pm consistently recorded the highest values (35 °C–40 °C), while the evening temperature at 6:00 pm was moderate (30 °C–35 °C). This pattern indicates a clear diurnal fluctuation, with peak temperatures occurring in the afternoon and minimum values in the early morning.

Relative humidity was highest during the morning (80%–100%), lowest in the afternoon (25%–35%), and moderate in the evening (35%–50%) (Figure 2). An inverse relationship between temperature and relative humidity was evident, with higher daytime temperatures corresponding to lower humidity levels.

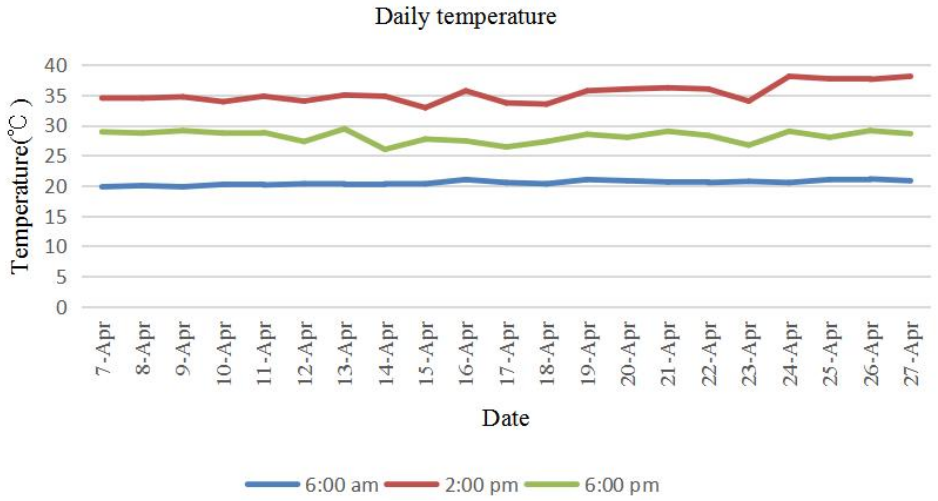


Figure 1 Daily temperature of the high-tech polyhouse during experimental period

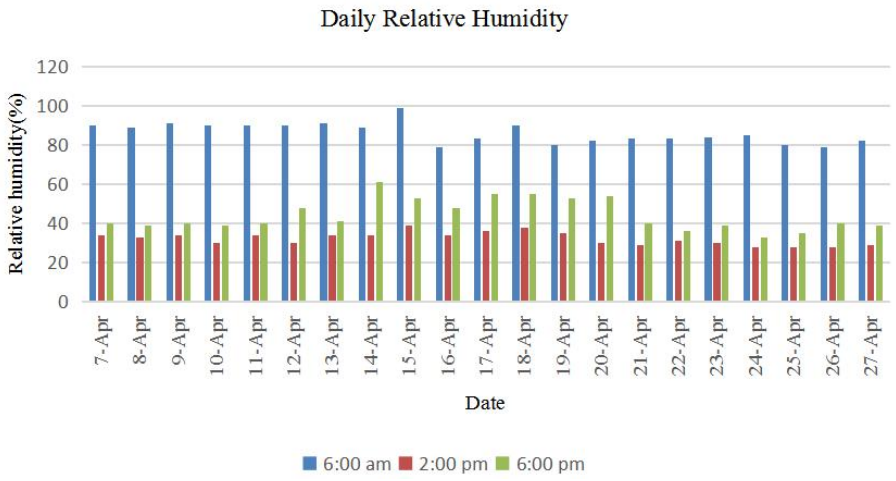


Figure 2 Daily relative humidity of the high-tech polyhouse during experimental period

2.2 Plant material and seed source

The seeds were purchased from Agrovet and produced by Muktinath Krishi Company. The packet included following labellings:

- Variety name: Bhaktapur Local
- Moisture content: 6%
- Thousand-seed weight: 32 g

2.3 Seed priming treatments

Ten different types of treatments and concentrations were evaluated for an experiment. Control, Hot water, Gibberellic acid (GA_3), Potassium nitrate (KNO_3), Cow urine and Vermiwash were used with selective concentration (Table 1).

Table 1 Details of the treatments evaluated in the experiment

Treatments	Details
T_1	Control (unsoaked)
T_2	Hot water (45 °C for 5 minutes)
T_3	GA_3 100 ppm
T_4	GA_3 200 ppm
T_5	KNO_3 1%
T_6	KNO_3 3%
T_7	Cow urine 5%
T_8	Cow urine 10%
T_9	Vermiwash 10%
T_{10}	Vermiwash 20%

Note: GA_3- gibberellic acid; KNO_3- potassium nitrate; ppm- parts per million

2.4 Procedure of seed priming

Seeds were primed for 24 hours in priming solution of KNO_3, GA_3, Cow urine and Vermiwash. Similarly, hot water (45 °C) priming of seed was done for 5 minutes. Seeds were soaked in 100 mL priming solutions of the respective treatment solutions. Then the seeds were re-dried to near original moisture level at room temperature for 24 hrs. For control, seeds were not treated and it were used as in the original condition.

For priming with GA_3, 1 g of GA_3 was taken in a test tube and 3 mL of 70% ethyl alcohol was added and it was shaked with low heat. The heated solution of the test tube was diluted with distilled water to make 1,000 ppm of 1 litre stock solution of GA_3. Finally, it was diluted with distilled water to prepare 100 ppm and 200 ppm GA_3 solutions. For the preparation of KNO_3 1% solution, 1 g of KNO_3 was taken and diluted with distilled water to make 100 mL solution and 3 g of KNO_3 was taken and diluted with distilled water to make 100 mL solution of KNO_3 3%.

2.5 Experimental design and layout

The experiment was laid out in Completely Randomized Design (CRD) with ten treatments and three replications. “Each treatment consisted 50 seeds, with 3 replications, resulting in total sample size of 150 seeds per treatment.” For seedling measurements, the 10 sample plants were randomly selected from each tray, and then tray mean were calculated. Subsequently, ANOVA were performed using the tray as an experimental unit (n=3).

2.6 Germination assessment

Among 50 seeds sown in each tray, the number of seed got emerged were only taken for an assessment considering 50 as a whole. Observation was done on daily basis in the morning time and data were recorded according to the data observed. Calculation of germination parameters are given below:

Number of normal seedlings from each replication were counted and germination percentage was calculated by using formula given by Piri et al. (2009):

$$\text{Seed germination percentage} = \frac{\text{Number of normal seedlings}}{\text{Total number of seeds}} \times 100\%$$

Mean germination time (MGT) was the time taken for a lot to germinate. The lower the MGT the faster the population of seeds were germinated (Dhakal and Subedi, 2020):

$$\text{MGT} = \frac{\sum (D*n)}{\sum n}$$

Where, D =the number of days counted from the beginning of germination, n = number of seed germinated on each day.

Seedling Vigour Index (SVI) was calculated by using following formula (Dhakal and Subedi, 2020):

SVI-I = Germination percentage × Total seedling length (cm)
SVI-II = Germination percentage × seedling dry weight (mg)

Where, SVI-I indicates vigour of seed in relation with length of seedling while SVI-II indicates vigour of seed in relation with dry matter accumulates of seedling.

Days to 50% germination was the time taken to get 50% germination of final germination percentages (Coolber et al., 1990).

Speed of germination (BRI) was calculated by using following formula (Bartlett, 1937):

$$\text{BRI} = \frac{p1+(p1+p2)+(p1+p2+p3)+\ldots+(p1+p2+p3+\ldots+pn}{N(p1+p2+\ldots+pn)}$$

Where, $p1+p2+p3+\ldots$and pn are the germination (%) at 1st, 2nd, 3rd and nth day, respectively and 'N' is the total number of days taken for germination.

2.7 Seedling growth measurement

Seedling growth was evaluated by sampling plants at 21 days after sowing. The sampled seedlings were carefully uprooted to avoid damaging the roots. After collection, the roots were separated from the stem portions and different growth parameters were measured. For each treatment, ten representative seedlings were selected, and the mean values were calculated and recorded for further analysis.

Root length was measured after the seedlings were uprooted. The measurement was taken from the tip of the root apex to the base of the root system at 21 days after sowing, following the method described by Dhakal and Subedi (2020). Shoot length was determined by measuring the distance from the base of the growing medium to the tip of the shoot apex.

For fresh weight determination, sample plants from each experimental unit were collected and separated into root and shoot portions by cutting with a knife. The stem portion was weighed using a weighing machine to determine shoot fresh weight, and the values were recorded in grams. Similarly, the root portion was weighed separately to obtain root fresh weight, and the average values were calculated for each treatment.

To determine dry weight, the shoot portions were first weighed to obtain fresh weight and then placed in envelopes. These samples were dried in a hot air oven at 105 °C for 24 hours and then allowed to cool as described by Khatiwada and Adhikari (2020). After drying, the shoot samples were weighed and the shoot dry weight was recorded in milligrams. The same procedure was followed for the root portions: after measuring fresh weight, the root samples were packed in envelopes, dried in a hot air oven at 105 °C for 24 hours, cooled, and then weighed to obtain root dry weight in milligrams. The average values were calculated for analysis.

2.8 Statistical analysis

All the recorded data were arranged systematically treatment wise under three replications using Microsoft Excel version 16.89.1. To determine the significant result between the treatments, Analysis of variance (ANOVA) was carried out using R studio version 4.4.1 and DMRT was used for mean separation at 5% level of significance (p<0.05).

3 Results and Analysis

3.1 Germination percentage, mean germination time (MGT) and days to 50% germination (T_{50})

The results on germination percentage, mean germination time (MGT) and days to 50% germination (T_{50}) affected by different seed priming method are presented in Table 2. Germination percentage, mean germination time, and days to 50% germination were significantly affected by different seed priming techniques.

Table 2 Effect of seed priming on germination percentage, mean germination time (MGT) and days to 50 % germination (T_{50}) of cucumber (*Cucumis sativus* cv. Bhaktapur Local) in Syangja, Nepal, 2024

Treatments	Germination parameters		
	Germination percentage	MGT (Days)	T_{50} (Days)
Control	73.34^{c}	6.90^{a}	6.83^{a}
Hot water (45 °C for 5 minutes)	88.00^{a}	6.30^{b}	6.00^{b}
GA_3 100 ppm	84.00^{ab}	6.22^{bc}	6.00^{b}
GA_3 200 ppm	81.34^{abc}	6.34^{bc}	6.00^{b}
KNO_3 1%	80.67^{abc}	6.06^{c}	6.00^{b}
KNO_3 3%	80.00^{abc}	6.19^{bc}	6.00^{b}
Cow urine 5%	77.34^{bc}	6.27^{bc}	6.00^{b}
Cow urine 10%	80.00^{abc}	6.26^{bc}	6.00^{b}
Vermiwash 10%	76.67^{bc}	6.17^{bc}	6.00^{b}
Vermiwash 20%	80.67^{abc}	6.41^{b}	6.00^{b}
CV (%)	5.52	1.98	0.75
$LSD_{0.05}$	7.54	0.21	0.07
Grand mean	80.20	6.31	6.08
SEm (±)	2.55	0.07	0.02
F-test	*	***	***

Note: Mean within the column followed by the same letter/s are not significantly different at 5% level of significance by DMRT. * Significant at 5% (p<0.05), ** Significant at 1% (p<0.01), *** Significant at 0.1% (p<0.001), NS= non-significant at 5% (p>0.05), SEm= Standard Error of mean, LSD= Least significant difference, CV= Coefficient of variance, MGT= Mean germination time and T_{50}= Days to 50% germination

Significantly the highest germination percentage (88.00%) was found in hot water (45 °C for 5 minutes). GA_3 100 ppm (84.00%), GA_3 200 ppm (81.34%), KNO_3 1% (80.67%), Vermiwash 20% (80.67%), KNO_3 3% (80.67%) and Cow urine 10% (80.00%), also showed increased germination percentage but were non-significant among themselves (LSD=7.54), while the lowest germination percentage (73.34%) was observed in control.

Significantly the highest mean germination time was recorded in control (6.90 days), while the lowest MGT was found in KNO_3 1% (6.06 days), which was not significantly different from Vermiwash 10% (6.17 days), KNO_3 3% (6.19 days), $GA_3$100 ppm (6.22 days), Cow urine 10% (6.26 days), Cow urine 5% (6.27 days) and GA_3 200 ppm (6.34 days). Significantly the highest T_{50} (6.83 days) was found in control and the lowest T_{50} was found in hot water (6.00 days) which was not significantly different from Vermiwash 10% and 20%, Cow urine 5% and 10%, KNO_3 1% and 3%, GA_3 100 ppm and 200 ppm.

3.2 Seed vigour index (SVI-I and SVI-II) and speed of germination (BRI)

The results on Seed vigour index I (SVI-I), Seed vigour index II (SVI-II) and speed of germination (BRI) are presented in Table 3. Significantly the highest SVI-I (2,643.83) was found in hot water (45 °C for 5 minutes)

which was not significantly different from KNO_3 1% (2,506.23) and GA_3 200 ppm (2,502.24), while the lowest SVI-I (1,828.13) was found in control.

Table 3 Effect of seed priming on seed vigour index and speed of germination of cucumber (*Cucumis sativus* cv. Bhaktapur Local) in Syangja, Nepal, 2024

Treatments	Seed vigour index (SVI)		Speed of germination
	SVI-I	SVI-II	BRI
Control	1,828.13^{d}	16,823.33^{d}	0.40^{d}
Hot water (45 °C for 5 minutes)	2,643.83^{a}	22,555.33^{a}	0.46^{bc}
GA_3 100 ppm	2,202.97^{bcd}	21,026.00^{ab}	0.47^{abc}
GA_3 200 ppm	2,502.24^{ab}	21,933.33^{ab}	0.46^{bc}
KNO_3 1%	2,306.23^{abc}	22,006.67^{ab}	0.49^{a}
KNO_3 3%	2,031.86^{cd}	17,776.00^{cd}	0.48^{abc}
Cow urine 5%	2,044.51^{cd}	19,702.67^{bc}	0.47^{abc}
Cow urine 10%	2,167.02^{bcd}	20,877.33^{ab}	0.47^{abc}
Vermiwash 10%	1,966.06^{cd}	17,946.00^{cd}	0.48^{ab}
Vermiwash 20%	2,106.60^{cd}	19,580.67^{bc}	0.45^{c}
CV (%)	9.40	6.41	0.46
$LSD_{0.05}$	349.07	2,188.86	0.02
Grand mean	2,179.94	20,022.73	0.46
SEm (±)	118.30	741.98	0.00
F-test	**	***	***

Note: Mean within the column followed by the same letter/s are not significantly different at 5% level of significance by DMRT. * Significant at 5% (p<0.05), ** Significant at 1% (p<0.01), *** Significant at 0.1% (p<0.001), NS= non-significant at 5% (p>0.05), SEm= Standard Error of mean, LSD= Least significant difference, CV= Coefficient of variance, SVI-I= Seed vigour index-I, SVI-II= Seed vigour index-II and BRI= Speed of germination

Significantly the highest SVI-II (22,555.33) was found in hot water which was not significantly different from KNO_3 1% (22006.67), GA_3 200 ppm (21,933.33), GA_3 100 ppm (21,026.00) and Cow urine 10% (20,877.33), while the lowest SVI-II (16,823.33) was found in control. This finding was also supported by Sowmya et al. (2013), where KNO_3 1% had highest SVI-II.

Significantly the highest BRI (0.49) was found in KNO_3 1% which was not significantly different from KNO_3 3% and Vermiwash 10% (0.48), Cow urine 5% and 10% (0.47), GA_3 100 ppm (0.47), while the lowest BRI (0.40) was found in control.

3.3 Shoot length and root length (cm)

The results on shoot length and root length are presented in Table 4. The effect of different seed priming treatments on shoot length did not show significant differences. Similar finding was reported by Al Sahil (2016).

Root length was highly significant for different seed priming techniques. Significantly, the highest root length was found in GA_3 200 ppm (21.15 cm) which did not differ significantly from the hot water (20.09 cm) treatment, while the lowest root length was found in control (15.49 cm). Vermiwash 10% (15.75 cm), Cow urine 5% (16.56 cm), Vermiwash 20% (16.62 cm), KNO_3 3% (16.67 cm), GA_3 100 ppm (17.08 cm), Cow urine 10% (17.26 cm) and KNO_3 1% (17.76 cm) also showed lower root length but were non-significant among themselves.

3.4 Fresh shoot weight and fresh root weight (g)

The results on fresh shoot and fresh root weight are presented in Table 5. The effect of different seed priming treatments on fresh shoot weight did not show significant differences. According to Farooq et al. (2007), Osmo-priming or chemo-priming did not improve the seedling fresh weight in melon. Seed pre-soaking treatments were recorded non-significant for seedling fresh weight in cucumber (Al Sahil, 2016).

Table 4 Effect of seed priming on shoot length and root length of cucumber (*Cucumis sativus* cv. Bhaktapur Local) in Syangja, Nepal, 2024

Treatments	Shoot length (cm)	Root length (cm)
Control	9.42	15.49^{c}
Hot water (45 °C for 5 minutes)	9.91	20.09^{ab}
GA_3 100 ppm	9.14	17.08^{bc}
GA_3 200 ppm	9.56	21.15^{a}
KNO_3 1%	10.81	17.76^{bc}
KNO_3 3%	8.79	16.67^{c}
Cow urine 5%	9.89	16.56^{c}
Cow urine 10%	9.75	17.26^{bc}
Vermiwash 10%	9.85	15.75^{c}
Vermiwash 20%	9.53	16.62^{c}
CV (%)	6.36	9.57
$LSD_{0.05}$	1.04	2.84
Grand mean	9.66	17.44
SEm (±)	0.35	0.96
F-test	NS	**

Note: Mean within the column followed by the same letter/s are not significantly different at 5% level of significance by DMRT. * Significant at 5% (p<0.05), ** Significant at 1% (p<0.01), *** Significant at 0.1% (p<0.001), NS= non-significant at 5% (p>0.05), SEm= Standard Error of mean, LSD= Least significant difference, CV= Coefficient of variance

Table 5 Effect of seed priming on fresh shoot and fresh root weight per seedling of cucumber (*Cucumis sativus* cv. Bhaktapur Local) in Syangja, Nepal, 2024

Treatments	Fresh shoot weight (g)	Fresh root weight (g)
Control	2.79	0.35^{b}
Hot water (45 °C for 5 minutes)	2.84	0.51^{a}
GA_3 100 ppm	2.79	0.30^{bc}
GA_3 200 ppm	2.76	0.35^{b}
KNO_3 1%	3.11	0.30^{bc}
KNO_3 3%	2.58	0.37^{b}
Cow urine 5%	3.09	0.50^{a}
Cow urine 10%	3.01	0.45^{a}
Vermiwash 10%	2.52	0.25^{cd}
Vermiwash 20%	2.62	0.21^{d}
CV (%)	10.95	11.06
$LSD_{0.05}$	0.52	0.06
Grand mean	2.81	0.36
SEm (±)	0.17	0.02
F-test	NS	***

Note: Mean within the column followed by the same letter/s are not significantly different at 5% level of significance by DMRT. * Significant at 5% (p<0.05), ** Significant at 1% (p<0.01), *** Significant at 0.1% (p<0.001), NS= non-significant at 5% (p>0.05), SEm= Standard Error of mean, LSD= Least significant difference, CV= Coefficient of variance

Fresh root weight was very highly significant for different priming techniques. Significantly, the highest fresh root weight (0.51 g) was found in hot water which was not significantly different from Cow urine 5% (0.50 g) and Cow urine 10% (0.45 g), while the lowest fresh root weight was found in Vermiwash 20% (0.21 g). Similar finding was reported by Tania et al. (2019). Rehydration causes early emergence by influencing pre-germinative process for germination (Tania et al., 2019).

3.5 Dry shoot weight and dry root weight (mg)

The results on dry shoot weight and dry root weight are presented in Table 6. Dry shoot weight and root weight were very highly significant for different priming treatments. Significantly, the highest dry shoot weight was found in KNO_3 1% (240.00 mg), while the lowest dry shoot weight was found in KNO_3 3% (194.67 mg) which was not significantly different from control (197.34 mg), Vermiwash 10% (204.00 mg) and Vermiwash 20% (209.67 mg).

Significantly the highest dry root weight (46.00 mg) was found in GA_3 200 ppm, while the lowest dry root weight was found in KNO_3 3% (27.34 mg) which was not significantly different from GA_3 100 ppm (30.00 mg), Vermiwash 10% (31.34 mg), control (32.00 mg) Vermiwash 20% (32.67 mg) and KNO_3 1% (32.67 mg).

Table 6 Effect of seed priming on dry shoot weight and dry root weight per seedling of cucumber (*Cucumis sativus* cv. Bhaktapur Local) in Syangja, Nepal, 2024

Treatments	Dry shoot weight (mg)	Dry root weight (mg)
Control	197.34^{d}	32.00^{cd}
Hot water (45 °C for 5 minutes)	218.34^{bc}	38.00^{b}
GA_3 100 ppm	220.34^{bc}	30.00^{d}
GA_3 200 ppm	223.67^{b}	46.00^{a}
KNO_3 1%	240.00^{a}	32.67^{cd}
KNO_3 3%	194.67^{d}	27.34^{d}
Cow urine 5%	218.67^{bc}	36.00^{bc}
Cow urine 10%	222.00^{bc}	39.34^{b}
Vermiwash 10%	204.00^{cd}	31.34^{cd}
Vermiwash 20%	209.67^{d}	32.67^{cd}
CV (%)	4.4	8.37
$LSD_{0.05}$	16.20	4.92
Grand mean	214.86	34.53
SEm (±)	5.49	1.67
F-test	***	***

Note: Mean within the column followed by the same letter/s are not significantly different at 5% level of significance by DMRT. * Significant at 5% (p<0.05), ** Significant at 1% (p<0.01), *** Significant at 0.1% (p<0.001), NS= non-significant at 5% (p>0.05), SEm= Standard Error of mean, LSD= Least significant difference, CV= Coefficient of variance

4 Discussion

Germination behavior and seedling growth of cucumber were significantly influenced by seed priming. Among the treatments, hot water (45 °C) priming showed superior performance in germination percentage and seed vigour indices, while KNO_3 1% outperformed in speed of germination. GA_3 200 ppm showed comparatively better dry matter accumulation. In contrast, control showed inferior performance across all parameters.

Hot water treatment enhances imbibition and stimulates several germination related-process, including the synthesis of GA_3, RNA, protein synthesis and DNA replication. This in turn may have weakened the endosperm, thereby promoting increased germination rate (Black and Bewley, 2000). KNO_3 Priming improved emergence and its time significantly in both carrot seed and *Clonostachys rosea* cv. IK726 (Bennett et al., 2009). Similar results were reported by Tania et al. (2019) in bitter gourd. Faster germination in seed priming with KNO_3 1%, than non-priming is likely due to its stimulation of metabolic processes during imbibition, which prepare seed for root emergence (Sowmya et al., 2013). This reduces mean germination time (Sowmya et al., 2022) and days to 50% germination. Similar finding was reported by Shim et al. (2009), where seed priming improves days to 50% germination than non- primed seed. According to Singh et al. (2019), seed soaked at (50-52) °C exhibited the highest seedling vigour index-I indicating that this temperature range significantly enhance seedling vigour. KNO_3 1% also recorded to show similar result (Sowmya et al., 2013). GA_3 200 ppm recorded higher SVI-I which was in accordance with Badu et al. (2022).

GA_3 200 ppm priming showed significant effect on root length and root dry matter accumulation of cucumber promoting root development through active stimulation of enzyme synthesis (hydrolytic enzyme) and enhanced cell elongation in the radicle region leading to highest root length. The results were observed for root length as earlier found by Badu et al. (2022). GA_3 priming showed improved assimilate partitioning toward root tissues and increased root sink strength for carbohydrate and other structural compounds leading to dry matter accumulation. Singh (1984), reported that GA_3 significantly increased dry root weight in seedling. KNO_3 1% showed best result in shoot dry matter accumulation because KNO_3 supports in supply of readily available nitrogen promoting protein synthesis and more efficient reserve mobilization and assimilation during early growth. Similar finding was reported by Farooq et al. (2007), where improvement in seedling dry weight was observed from seed primed with KNO_3 1% solution.

Distinct advantages can be revealed from comprehensive comparison among treatments. Hot water priming results in higher and uniform germination, making it beneficial for nursery establishment. For rapid and synchronized emergence of seedling, KNO_3 1% could be beneficial, while GA_3 200 ppm showed higher root dry matter biomass leads to potential improvement in transplant establishment. These trade-offs highlight the importance of selecting proper seed priming methods based on production objectives.

Beside of positive outcomes, the experiment was limited to single location and inside polyhouse condition. Absence of field validation restrict broader generalization. More studies are required under large and open field condition for better conformity.

5 Conclusion

Priming cucumber seed with hot water (45 °C for 5 minutes) proved to be effective for highest germination percentage. However, it was not significantly different from GA_3 100 ppm, and GA_3 200 ppm. Similarly, hot water was found to decrease days to 50% germination, increase seed vigour index-I, seed vigour index-II and have better effect on root length and fresh root weight. Mean germination time was decreased and the highest speed of germination was found in KNO_3 1%. Dry shoot weight was significantly affected by KNO_3 1% while GA_3 200 ppm showed significant effect on dry root weight. Control treatment consistently produced the lowest result in most of the parameters. Hence, in practical applications, the choice of priming method should be based on target trait, as well as cost and availability considerations to enhance most of the germination and seedling growth parameters of cucumber.

Authors' contributions

Saroj Yadav is the principal researcher who conceptualized the idea, collected and analysed the data, and prepared the manuscript. Bibas Chaulagai and Promise Shrestha helped Saroj Yadav in data collection, analysis, editing and proofreading of manuscript. Ganesh Lamsal helped in conceptualizing the idea, data analysis and proofreading of the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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