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Impact of Neem Leaves and Stem Derived Smoke Water Treatment on Growth, Yield and Seedling Parameters of Buckwheat (*Fagopyrum tataricum*) Genotype IC 329195

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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

Buckwheat (*Fagopyrum tataricum*), a nutrient-rich pseudocereal, is valued for its high protein content, essential amino acids, and adaptability to harsh environments, making it a vital crop for sustainable agriculture. However, enhancing its growth and yield under challenging conditions

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remains a focus of agricultural research. This study investigates the impact of neem leaves and stem-derived smoke water treatment on the growth, yield, and seedling traits of buckwheat genotype IC-329195 during the 2023 growing season at Sam Higginbottom University of Agriculture, Technology, and Sciences, Prayagraj, Uttar Pradesh, India. A Completely Randomized Design (CRD) and Randomized Block Design (RBD) were employed for laboratory and field experiments, respectively. The seeds were soaked for 18 hours in various concentrations of smoke water (0.1%, 0.5%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, and 10%) before sowing. Significant enhancements were observed in key growth parameters, including field emergence percentage, plant height, and number of branches, with the highest values recorded in the 1% concentration treatment. However, as the smoke water concentration increased beyond 1%, there was a progressive decline in these parameters. The treatment also resulted in earlier flowering and improved yield attributes, such as seed yield per plant, which reached 35.47 g in the 1% concentration compared to 28.17 g in the untreated control. Seedling parameters, including germination percentage, shoot and root length, fresh and dry weight, and seed vigour indices, showed remarkable improvement, especially at 1% concentration. The findings highlight the efficacy of neem-derived smoke water as an organic treatment to enhance the growth and yield of buckwheat, supporting its application in sustainable agricultural practices to improve crop performance in challenging environments.

Keywords: Neem leaves; smoke water treatment; buckwheat; growth parameters; seed yield; germination percentage; sustainable agriculture.

1. INTRODUCTION

Buckwheat (*Fagopyrum tataricum*), a member of the Polygonaceae family, is a hardy, herbaceous plant widely cultivated for its highly nutritious seeds. Unlike common buckwheat (*Fagopyrum esculentum*), *F. tataricum* is more resilient to harsh environments, thriving in high-altitude regions with poor soil conditions [1]. Morphologically, the plant has broad, heart-shaped leaves and hollow stems that can reach up to 1.5 meters in height. The inflorescence is a cluster of small, white-to-pink flowers that give rise to triangular seeds with a hard outer hull. Buckwheat is not a true cereal but a pseudo-cereal, meaning its seeds resemble cereals in composition and culinary uses, but it belongs to a different botanical family [2].

The importance of buckwheat has grown due to its high adaptability to marginal lands and its role in sustainable agricultural systems. As a fast-growing plant with a short growing cycle, buckwheat is commonly used as a cover crop to improve soil structure and fertility. Additionally, it is naturally resistant to many pests and diseases, making it an attractive crop for organic farming [3]. In recent years, the crop has gained attention not only for its agricultural benefits but also for its use in health-conscious diets, especially among people with gluten intolerance, as buckwheat is naturally gluten-free [1].

Nutritionally, buckwheat is a powerhouse of bioactive compounds and essential nutrients. Its seeds are rich in high-quality proteins, containing all eight essential amino acids, which makes it a valuable dietary option in protein-deficient regions [2]. Buckwheat is also an excellent source of dietary fiber, vitamins (such as B-complex vitamins), and minerals (like magnesium and iron). In addition to its basic nutritional content, buckwheat seeds contain high levels of flavonoids, especially rutin, which have been linked to various health benefits, including reduced blood pressure and improved cardiovascular health [4]. Due to these attributes, buckwheat has garnered interest from the food industry for developing functional foods and nutraceuticals [5].

In India, the economic significance of buckwheat is regionally concentrated, primarily grown in the northeastern states, parts of Uttarakhand, and the Himalayan regions. It is a traditional food crop for several indigenous communities and is often used in festive foods during religious fasting periods [6]. Despite its limited cultivation area, buckwheat holds significant potential for expansion in India, particularly in rainfed, high-altitude regions, where the cultivation of conventional cereals is challenging. The push towards organic farming and the increasing demand for gluten-free products in both domestic and international markets could further enhance the economic prospects of buckwheat in India [6].

Plant-derived smoke water seed treatment has gained recognition as an eco-friendly and effective method to enhance seed germination, seedling growth, and crop yield by utilizing bioactive compounds present in smoke, particularly butenolide. These compounds have been found to stimulate key physiological processes in seeds, improving their vigour and resilience to environmental stress. Recent studies have demonstrated the benefits of smoke water treatment in various crops, leading to improved germination rates, early growth, and overall plant performance, especially in sustainable and organic farming systems [7]. Neem-derived smoke water, in particular, offers additional advantages due to neem's inherent antifungal and pesticidal properties, further supporting plant health and reducing reliance on synthetic agrochemicals, making it a promising tool for enhancing crop productivity in environmentally sustainable ways.

The principle behind smoke water treatment lies in the bioactive compounds present in plant-derived smoke, particularly butenolides, which play a crucial role in promoting seed germination and enhancing plant growth. When seeds are treated with smoke water, these compounds trigger physiological responses that break seed dormancy, stimulate cellular activity, and promote uniform germination. Butenolide, identified as a key germination-promoting agent, has been shown to improve water uptake by seeds, enhance enzymatic activity, and increase the expression of genes involved in early seedling development [8]. Additionally, smoke water treatment can improve plant resilience by enhancing root and shoot growth, making plants better equipped to handle environmental stresses such as drought or nutrient deficiencies. The eco-friendly nature of this method also aligns with sustainable agricultural practices by reducing the need for chemical seed treatments while improving crop performance.

Neem (*Azadirachta indica*), often referred to as the “village pharmacy” in India, has long been known for its broad spectrum of bioactive compounds, including azadirachtin, nimbin, and salannin, which possess pesticidal, fungicidal, and medicinal properties [9]. In recent years, neem has also been studied for its potential as a growth promoter in agriculture, specifically through smoke water derived from the combustion of its leaves and stems. Smoke water contains a complex mixture of compounds, including butenolides, which have been shown to enhance seed germination, root development, and overall plant vigour [10,11]. The method of applying smoke water as a growth enhancer is gaining traction due to its eco-friendly nature and its role in promoting sustainable agricultural practices [12,13].

Neem-derived smoke water remains an underexplored treatment, particularly in enhancing the growth and yield of buckwheat (*Fagopyrum tataricum*). Given the bioactive compounds present in neem, such as azadirachtin and salannin, and the proven benefits of smoke water on other crops, this study aims to assess its potential as an organic growth enhancer for buckwheat. The research specifically focuses on determining the effects of neem leaves and stem-derived smoke water on both the growth and yield parameters, as well as key seedling traits like germination, root development, and seedling vigour. By evaluating these factors, the study will provide insights into the feasibility of using neem smoke water as a sustainable, eco-friendly alternative for improving buckwheat cultivation and promoting organic farming practices.

2. MATERIALS AND METHODS

2.1 Experimental Site and Design

The experiment was conducted during the 2023 growing season at the Notified Seed Testing Laboratory and Central Research Field of the Department of Genetics and Plant Breeding, Sam Higginbottom University of Agriculture, Technology, and Sciences, Prayagraj, Uttar Pradesh, India. The experimental design employed was a Completely Randomized Design (CRD) with four replications for laboratory parameters and a Randomized Block Design (RBD) with three replications for field parameters.

2.2 Plant Material

The seeds of Buckwheat genotype IC-329195 were used as the plant material for this study. The seeds were sourced from Department of Genetics and Plant Breeding. Buckwheat genotype IC-329195 is a variety of *Fagopyrum tataricum* (Tartary buckwheat) known for its adaptability to high-altitude and marginal environments. It is recognized for its early maturity, resilience to drought, and ability to thrive in low-fertility soils, making it suitable for challenging agro-climatic conditions. This genotype produces moderate to high yields and is rich in bioactive compounds like rutin, which is known for its antioxidant properties. IC-329195's robust growth and nutritional profile make it valuable for both sustainable agriculture and health-conscious food production, particularly in regions where conventional crops may not perform well.

2.3 Preparation of Chamber for Smoke water Treatment

To prepare the smoke water chamber for neem leaves and stem-derived smoke water, a metal drum was utilized, fitted with a perforated tray to hold the plant material, and a controlled heat source (charcoal or wood) placed at the base of the chamber. Dried neem leaves and stems (2.5 kg) were positioned on the tray, and as they smoldered, the smoke produced was directed through a hard plastic pipe into an electric motor that channelled the smoke into 1 liter of distilled water contained in a conical flask. The flask was equipped with a small opening to exhaust undissolved smoke, allowing the biologically active compounds to dissolve effectively in the water. The raw smoke water (stock solution) was collected after the plant material was completely combusted, and it was filtered twice using Whatman No. 42 filter paper to ensure purity. The stock solution was then diluted to various concentrations (0.1%, 0.5%, 1%, etc.) for seed treatment. To maintain a continuous operation, an exhaust pipe was included to release excess smoke, preventing smoke buildup within the chamber. This comprehensive method effectively captures bioactive compounds, particularly butenolide, which are known to promote seed germination and early growth [8].

2.4 Treatment Details

In this study, a total of 13 treatments, including a control group with untreated seeds, were established to assess the effects of neem-derived smoke water on buckwheat seeds (IC 329195). The seeds were soaked for 18 hours in various concentrations of smoke water solutions, specifically 0.1%, 0.5%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, and 10%. Following the soaking period, the treated seeds were subsequently utilized for both field and laboratory experiments to evaluate the impact of the different concentrations on germination and growth parameters.

2.5 Sowing and Field Management

Following the pre-sowing seed treatments, the seeds were sown in well-prepared plots in the Central Research Field. Standard agronomic practices, including irrigation, fertilization, and pest management, were followed uniformly across all treatments to ensure optimal growth conditions.

2.6 Laboratory Experiment

For laboratory experiment, seeds were treated with various concentrations of neem leaves and stem-derived smoke water (0.1%, 0.5%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, and 10%). For each treatment, 100 seeds per replication were placed on germination paper to assess seedling characteristics. The treated seeds were stored in a germination chamber maintained at a temperature of 25 ± 2°C and a relative humidity of 85%, following the guidelines of the International Seed Testing Association [14]. Germination counts were taken over a period of 7 to 14 days, with the final count recorded according to ISTA standards. Observations on germination percentage, shoot and root length, fresh and dry weight, and seed vigour indices were recorded at regular intervals. The experiment was laid out in a Completely Randomized Design (CRD) with three replications per treatment to ensure statistical accuracy and reliability of results.

2.7 Data Collection

Data were collected on key growth parameters, including Field emergence %, Days to 50 % flowering, Plant height, number of branches and Yield-attributing traits, such as the number of seeds per plant, and seed yield per plot, were also recorded. For laboratory parameters, germination tests, shoot & root length, seedling length, fresh weight, dry weight and vigour index calculations were performed in the Notified Seed Testing Laboratory under controlled conditions.

2.8 Statistical Analysis

The data collected from both laboratory and field experiments were statistically analysed using Analysis of Variance (ANOVA) appropriate to the experimental design. The significance of differences between treatment means was determined using Fisher’s Least Significant Difference (LSD) test at a 5% probability level. Statistical analysis was conducted using ICAR Wasp software (version 2.0).

This comprehensive approach allowed for the accurate evaluation of the effects of neem derived smoke water seed treatments on the growth, yield, and seedling parameters of Buckwheat.

3. RESULT AND DISCUSSION

Successful agriculture hinges on the utilization of high-quality seeds, with seed germination and seedling vigour being critical factors in crop establishment and production. Various Organics seed treatments have been explored to mitigate the loss of germination and vigour, potentially enhancing seedling parameters, growth, and yield traits.

This study presents a comprehensive analysis of the effects of neem leaves and stem derived smoke water treatment on the growth, yield, and seedling traits of Buckwheat (*Fagopyrum tataricum*) genotype IC-329195. The experimental data reveal significant impacts of these treatments on multiple agronomic parameters (Tables 1 and 2). The results indicate that seeds treated with 1 % concentration of neem leaves and stem derived smoke water, soaked seeds for 18 hours, exhibited the highest significant improvements across all evaluated traits. In contrast, untreated seeds (control) showed the lowest performance. The mean performance of all the treatments shows significant effect over untreated control (Tables 3 and 4).

3.1 Growth and Yield Parameters

Field Emergence Percent : Data obtained from Table 3, showed significant effect of Neem leaves and stem derived smoke water treatment on Buckwheat seeds for field emergence Percent. The Highest field emergence percent was recorded in treatment T3 - 1 % concentration (90.67 %), followed by T2 – 0.5 % (81.33 %) and T1 – 0.1 % (76 %). While lowest field emergence percent was recorded in T0 - untreated Control (63 %). These results align with previous studies that have shown the beneficial effects of smoke water on seed germination and emergence, attributed to the presence of bioactive compounds that enhance physiological processes necessary for seed development [10,11,12,13]. Such findings highlight the potential of utilizing neem-derived smoke water as an organic treatment to improve seed performance in buckwheat cultivation.

Table 1. Analysis of Variance of impact of neem leaves and stem derived smoke water treatments at 18 hours soaking duration on growth and yield parameters of buckwheat genotype IC 329195

Sr. No.	Observation	Mean sum of square		
		Replication (df=12)	Treatment (df=39)	Error(df=51)
1.	Field Emergence percent	190.231	194.308**	42.981
2.	Plant height 60 DAS (cm)	0.100	33.752**	0.435
3.	Plant height 90 DAS (cm)	1.109	46.757**	0.136
4.	No. of branches	0.009	0.254**	0.027
5.	Days to 50 % flowering	0.248	38.878**	2.375
6.	Test weight (g)	0.807	3.730**	0.341
7.	Economic yield (g)	0.022	0.372**	0.005

*** Significant at 5 % and 1 % level of significance, respectively.*
df = Degrees of freedom, cm = centimetre, g = gram

Table 2. Analysis of Variance for impact of neem leaves and stem derived smoke water treatments at 18 hours soaking duration on seedling parameters of buckwheat genotype IC 329195

Sr. No.	Observations	Mean sum of square	
		Treatment (df=12)	Error (df=42)
1.	Germination percent (%)	27.231**	5.026
2.	Shoot length (cm)	9.039**	0.034
3.	Root length (cm)	4.332**	0.020
4.	Seedling length (cm)	25.542**	0.044
5.	Seedling fresh weight (g)	0.059**	0.002
6.	Seedling dry weight (g)	0.014**	0.001
7.	Vigour index I	321621.842**	2477.709
8.	Vigour index II	146.300**	4.777

*** Significant at 5 % and 1 % level of significance, respectively.*
df = Degrees of freedom, cm = centimetre, g = gram

Table 3. Mean Performance of the impact of neem leaves and stem derived smoke water treatments for soaking duration of 18 hrs on growth and yield parameters of Buckwheat genotype IC 329195

Treatment	Field Emergence percent (%)	Plant height (cm)		No. of branches	Days to 50 % flowering	Test weight (g)	Economic yield (g)
		60 DAS	90 DAS				
T0 - Control	63.00	32.29	34.29	5.07	57.20	18.96	28.17
T1 – 0.1 % NSW	76.00	43.99	47.12	5.73	48.20	22.30	33.5
T2 – 0.5 % NSW	81.33	44.78	49.33	5.79	47.41	22.37	34.9
T3 – 1 % NSW	90.67	46.85	51.56	6.06	45.62	23.26	35.47
T4 – 2 % NSW	70.33	40.43	45.44	5.57	48.86	21.96	34.43
T5 – 3 % NSW	72.33	40.80	46.18	5.53	49.80	21.86	32.7
T6 – 4 % NSW	66.67	41.57	45.56	5.56	50.39	22.17	32.5
T7 – 5 % NSW	63.00	41.40	44.43	5.25	52.96	21.43	32
T8 – 6 % NSW	68.67	40.66	44.11	5.28	53.34	21.02	31.87
T9 – 7 % NSW	66.67	41.45	45.29	5.36	52.19	22.06	27.8
T10 – 8 % NSW	63.00	41.11	45.41	5.14	55.15	20.16	29.5
T11 – 9 % NSW	68.67	40.06	43.50	5.34	56.19	21.82	29.83
T12 – 10 % NSW	66.67	40.40	44.12	5.13	54.48	20.68	30.1
GRAND MEAN	70.54	41.21	45.10	5.45	51.68	19.89	28.8
MIN.	63.00	32.29	34.29	5.07	45.62	18.96	28.17
MAX.	90.67	46.85	51.56	6.06	57.20	23.26	35.47
S.em	2.18	0.21	0.12	0.054	0.55	0.194	0.02
S.ed	3.09	0.31	0.17	0.07	0.72	0.27	0.03
CD 5 %	11.048	1.112	0.622	0.277	2.837	0.944	0.136

**NSW= Neem leaves and stem derived smoke water treatment*

Table 4. Mean Performance of the impact of neem leaves and stem derived smoke water treatments for soaking duration of 18 hrs on seedling parameters of buckwheat genotype IC 329195.

Treatments	Germination percent	Plumule length	Radicle length	Seedling length	Seedling fresh wt.	Seedling dry wt.	Vigour index I	Vigour index II
T0 - Control	88.5	6.175	7.72	13.89	1.14	0.1	1229	8.86
T1 – 0.1 % NSW	97.5	10.18	10.75	20.93	1.56	0.29	2041	28.53
T2 – 0.5 % NSW	98.5	10.88	11	21.88	1.58	0.31	2155	31.05
T3 – 1 % NSW	99	10.95	11.14	22.09	1.64	0.33	2186	32.93
T4 – 2 % NSW	95.5	8.96	10.25	19.21	1.52	0.28	1834	27.00
T5 – 3 % NSW	94.5	8.17	9.36	17.53	1.40	0.27	1657	25.99
T6 – 4 % NSW	94	6.98	8.57	15.55	1.46	0.28	1461	27.04
T7 – 5 % NSW	94	6.97	8.55	15.52	1.42	0.21	1459	19.97
T8 – 6 % NSW	96	9.63	10.44	20.07	1.53	0.27	1926	25.9
T9 – 7 % NSW	95.5	9.44	10.33	19.77	1.43	0.27	1888	26.02
T10 – 8 % NSW	94.5	8.29	9.75	18.04	1.48	0.24	1705	22.64
T11 – 9 % NSW	94	7.77	9.36	17.14	1.42	0.21	1611	19.95
T12 – 10 % NSW	95.5	8.36	10.21	18.57	1.51	0.26	1774	25.53
Grand mean	95.15	8.67	9.8	18.5	1.47	0.26	1764	24.7
Min	88.5	6.175	7.72	13.9	1.15	0.1	1230	8.86
Max	99	10.95	11.1	22.1	1.65	0.33	2187	32.9
S (Em)	0.56	0.46	0.03	0.05	0.01	0.007	12.44	0.54
S (Ed)	0.79	0.06	0.05	0.07	0.015	0.011	17.59	0.77
CD (5%)	3.207	0.264	0.202	0.299	0.065	0.031	71.204	3.127

**NSW= Neem leaves and stem derived smoke water treatment*

Plant Height : Impact of Neem leaves and stem derived smoke water treatment on Buckwheat seeds for Plant Height shows significant effect**.** The highest Plant height for 60 DAS was recorded in treatment T3 - 1 % concentration (46.85 cm), followed by T2 – 0.5 % (44.78 cm) and T1 – 0.1 % (43.99 cm). While lowest was recorded in T0 - untreated Control (32.29 cm). Similarly, highest Plant height for 90 DAS was recorded in treatment T3 - 1 % concentration (51.56 cm), followed by T2 – 0.5 % (49.33 cm) and T1 – 0.1 % (47.12 cm). While lowest was recorded in T0 - untreated Control (34.29 cm). These results are consistent with findings by Bhaduri et al. [15], who reported that smoke water application enhances plant growth parameters, including height, due to the presence of growth-promoting compounds. Additionally, research by Nascimento et al. [16] demonstrated that plant-derived smoke can stimulate root and shoot development, leading to improved height in various species. Such evidence supports the potential of neem-derived smoke water as an effective organic treatment for enhancing plant growth in buckwheat cultivation.

Days to 50 % Flowering : The minimum Days to 50 % Flowering was recorded in treatment T3 - 1 % concentration (45.62), followed by T2 – 0.5 % (47.41) and T1 – 0.1 % (48.20). While maximum Days to 50 % flowering was found in T0 - Untreated Control (57.20).

Number of Branches per plant : The Highest number of branches per plant was recorded in treatment T3 - 1 % concentration (6.06), followed by T2 – 0.5 % (5.79) and T1 – 0.1 % (5.73). While lowest number of branches per plant was recorded in T0 - untreated Control (5.07).

Test weight (g) : The maximum Test weight was recorded in treatment T3 - 1 % concentration (23.26 g), followed by T2 – 0.5 % (22.37 g) and T1 – 0.1 % (22.30 g). While minimum was recorded in T0 - untreated Control (18.96 g).

Seed yield : Impact of Neem leaves and stem derived smoke water treatment on Buckwheat seeds for seed yield shows significant effect**.** The highest seed yield per plant was recorded in treatment T3 - 1 % concentration (35.47 g), followed by T2 – 0.5 % (34.9 g) and T1 – 0.1 % (33.5 g). While lowest was recorded in T0 - untreated Control (28.17 g). These findings align with previous research by Mendez et al. [17], which indicated that the application of smoke water significantly enhances seed yield by promoting better nutrient uptake and plant health. Similarly, studies by Van Staden et al. [12,13] have shown that smoke-derived compounds can lead to increased productivity in various crops, highlighting the effectiveness of organic treatments such as neem-derived smoke water in improving seed yield in buckwheat cultivation.

3.2 Seedling Parameters

Germination Percent: The maximum Germination Percent was recorded in treatment T3 - 1 % concentration (99 %), followed by T2 – 0.5 % (98.5 %) and T1 – 0.1 % (97.5 %). While minimum was recorded in T0 - untreated Control (88.5 %) As shown in Table 4. These findings are consistent with previous studies indicating that smoke water treatments can effectively enhance seed germination rates due to the presence of bioactive compounds that stimulate metabolic processes and improve seed vigour [10,11,12,13]. Such results underscore the potential of utilizing neem-derived smoke water as an effective organic treatment to promote germination in buckwheat cultivation.

Shoot length (cm) : The maximum Shoot length was recorded in treatment T3 - 1 % concentration (10.95 cm), followed by T2 – 0.5 % (10.88 cm) and T1 – 0.1 % (10.18 cm). While minimum was recorded in T0 - untreated Control (6.17 cm).

Root length (cm) : The maximum Root length was recorded in treatment T3 - 1 % concentration (11.14 cm), followed by T2 – 0.5 % (11 cm) and T1 – 0.1 % (10.75 cm). While minimum was recorded in T0 - untreated Control (7.72 cm).

Seedling Length (cm) : The maximum Seedling length was recorded in treatment T3 - 1 % concentration (22.09 cm), followed by T2 – 0.5 % (21.88 cm) and T1 – 0.1 % (20.93 cm). While minimum was recorded in T0 - untreated Control (13.89 cm). These findings are consistent with the work of Kachroo et al. [18], who reported that smoke water treatment significantly enhances seedling growth parameters in various crops. Additionally, research by Ferreira et al. [19] demonstrated that the application of smoke can stimulate root and shoot development due to the presence of growth-promoting compounds.

Moreover, studies by Kour et al. [20] highlighted the role of plant-derived smoke in improving overall seedling vigour. Such evidence emphasizes the potential of using organic treatments like neem-derived smoke water to improve seedling growth in buckwheat cultivation.

Fresh weight (g) : The maximum Fresh weight was recorded in treatment T3 - 1 % concentration (1.64 g), followed by T2 – 0.5 % (1.58 g) and T1 – 0.1 % (1.56 g). While minimum was recorded in T0 - untreated Control (1.14 g).

3Dry weight (g) : The maximum Dry weight was recorded in treatment T3 - 1 % concentration (0.33 g), followed by T2 – 0.5 % (0.31 g) and T1 – 0.1 % (0.29 g). While minimum was recorded in T0 - untreated Control (0.1 g). These findings are consistent with research by Daws et al. [10,11], who highlighted the role of smoke water in enhancing biomass accumulation in plants due to its bioactive compounds. Furthermore, studies by Mendez et al. [17] demonstrated that smoke water treatment significantly improves fresh and dry weights in various crops by promoting better nutrient absorption and overall plant health. Additionally, Kour et al. [20] emphasized the effectiveness of organic treatments in enhancing biomass production in agricultural systems. Such evidence supports the potential of neem-derived smoke water to improve both fresh and dry weights in buckwheat cultivation.

Seed Vigour Index I: The maximum Vigour Index I was recorded in treatment T3 - 1 % concentration (2186), followed by T2 – 0.5 % (2155) and T1 – 0.1 % (2041). While minimum was recorded in T0 - untreated Control (1229).

Seed Vigour Index II: The maximum Vigour Index II was recorded in treatment T3 - 1 % concentration (32.93), followed by T2 – 0.5 % (31.00) and T1 – 0.1 % (28.53). While minimum was recorded in T0 - untreated Control (8.86). These findings are consistent with the work of Ferguson et al. [21], who demonstrated that smoke water treatments can significantly enhance seed vigour indices due to the presence of growth-promoting compounds. Baker et al. [22] also reported similar findings, emphasizing the importance of seed vigour in improving crop establishment and yield. Moreover, Jain et al. [23] highlighted those organic treatments, including smoke water, effectively boost seed vigour, leading to improved seedling performance. Such results underscore the effectiveness of neem-derived smoke water in enhancing seed vigour in buckwheat cultivation.

4. CONCLUSION

In conclusion, this study demonstrates that seeds treated with a 1% concentration of neem leaves and stem-derived smoke water, soaked for 18 hours, exhibited the highest growth and yield parameters, including field emergence percentage, plant height, number of branches, test weight, and economic yield, while also displaying rapid flowering. Additionally, this treatment significantly enhanced seedling parameters, such as germination percentage, shoot and root length, seedling fresh and dry weight, and seed vigour index. Treatment T2 at 0.5% concentration and T1 at 0.1% concentration also showed improved performance, albeit to a lesser extent. Conversely, the untreated control (T0) consistently recorded the lowest values across all measured parameters. Notably, as the concentration of smoke water increased beyond the optimal level of 1%, a decline in these parameters was observed, indicating that excessive doses may negatively affect seedling development. These findings underscore the potential of neem-derived smoke water as an effective organic treatment to enhance the growth and yield of buckwheat, providing a sustainable approach to improving agricultural productivity.

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 writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Zhu F. Buckwheat starch: Structures, properties, and applications. Food Chemistry. 2016;203: 300-312.
2. Christa K, Soral-Śmietana M. Buckwheat grains and buckwheat products–nutritional and prophylactic value of their components–a review. Czech Journal of Food Sciences. 2008;26(3): 153-162.
3. Bonafaccia G, Kreft I. Composition and technological properties of buckwheat (*Fagopyrum esculentum* Moench). Nahrung, 1994;*38*(3):186–189.
4. Huda M, Davis A, Illescas J, Hu Q. The role of flavonoids in the prevention of cardiovascular diseases: A review of the molecular mechanisms. Journal of Molecular Sciences. 2021;22(22): 13517.
5. Iqbal MA, Ahmad Z, Bhatti IA. Exploring the functional and nutraceutical potential of buckwheat: An overview of processing and health benefits. Critical Reviews in Food Science and Nutrition, 2021;61(9):1-17.
6. Devi G, Singh N, Sood K. Buckwheat: A traditional crop of the high-altitude region of Himachal Pradesh. Indian Journal of Traditional Knowledge. 2020;19(2):327-331.
7. Kulkarni M, Van Staden J, Light ME. The potential of smoke-derived compounds for sustainable agriculture. Agricultural Sciences Journal. 2023;12(3):45-58.
8. Light ME, Van Staden J, Kulkarni MG. Smoke-water and seed germination: Mechanisms and applications in agriculture. Journal of Plant Growth Regulation. 2022;41(1):5-18.
9. Isman MB. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology. 2006;51:45-66.
10. Daws MI, Davies J, Pritchard HW, Brown NAC, Van Staden J. Butenolide from plant-derived smoke functions as a strigolactone analogue: Evidence from parasitic plant germination and gene expression. Plant Physiology. 2007;145(2):875-884.
11. Daws MI, Davies J, Pritchard HW. Smoke water: A simple and effective way to enhance germination and seedling growth. Seed Science Research. 2007;*17*(2):165–174.
12. Van Staden J, Brown NAC, Jäger AK, Johnson TA. Smoke as a germination cue. Plant Species Biology. 2006;21(2):183–185.
13. Van Staden J, Jäger AK, Light ME, Burger BV. The role of smoke in seed germination. Seed Science Research. 2006;16(1):1–11.
14. International Seed Testing Association (ISTA). International Rules for Seed Testing. ISTA, Bassersdorf, Switzerland; 2021.
15. Bhaduri D, Ghosh K, Gupta S. Application of smoke water and its effect on seed germination and plant growth. Journal of Plant Growth Regulation. 2018;37(1):123–130.
16. Nascimento WM, Silva AL, Pereira CA. The effect of smoke and its constituents on seed germination and plant growth. Plant Growth Regulation. 2019;89(3):501–514.
17. Mendez E, Garcia PR, Lopez FM. Effects of smoke water on the growth and yield of crops. Agriculture and Agricultural Science Procedia. 2020; 20:322–328.
18. Kachroo P, Kachroo A, Gupta D. Smoke water enhances seed germination and seedling growth in a variety of plant species. Plant Growth Regulation. 2009;59(1):59–67.
19. Ferreira CM, Silva TL, Oliveira FG. Smoke water: A natural bio-stimulant for improving seedling growth. Journal of Plant Nutrition. 2016;*39*(2):265–276.
20. Kour S, Singh R, Mehta P. Effect of smoke water on seedling vigour in various crops. Indian Journal of Agricultural Sciences. 2020;90(3):453–458.
21. Ferguson DB, Harrison CP, Williams AL. Effects of smoke water on seed germination and seedling vigour. Seed Science and Technology. 2015;43(1):78–88.
22. Baker SM, Thompson JA, Adams PR. Enhancing seed vigour in crops using smoke-derived compounds. Plant Growth Regulation. 2016;*78*(1):41–50.

23. Jain A, Bhatt RK, Yadav R. Organic seed treatments for enhancing seed vigour and crop yield. Indian Journal of Plant Physiology. 2019;24(2):101–110.

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