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Effects of different seed priming techniques on growth, yield and profitability of Onion cultivars

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Abstract
In a meticulously conducted experiment at the Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, during the *Rabi* season of 2022-23, a Factorial Randomized Block Design (FRBD) was utilized to explore the impact of twelve distinct seed priming treatments on onion cultivation. These treatments included two varieties of onion *viz.*, Phule Samarth and B780 seeds of which were primed with KNO_3 at 2%, TiO_2 at 500ppm, PEG at 1MPa, Salicylic acid at 50ppm, *Pseudomonas* at 1%, and a control group using water. Each treatment was replicated three times to ensure result reliability. In terms of growth parameters, the combination of KNO_3 at 2% and B780 variety led to the highest plant height, Salicylic acid at 50ppm combined with B780 resulted in the highest number of leaves and longest leaf length, and B5A2 (*Pseudomonas* at 1% + B780) exhibited the maximum leaf width. Furthermore, B2A1 (TiO_2 at 500ppm + Phule Samarth) Resulted in the early maturity. In terms of yield parameters, the highest polar diameter was observed for treatment PEG at 1MPa + B780, the highest equatorial diameter for Salicylic acid at 50ppm + B780 and the highest bulb weight for Salicylic acid + B780. The combination of Salicylic acid at 50ppm + B780 also resulted in the highest yield per plot and the maximum marketable yield quantal per hectare. Economically, the data underscored the efficiency of KNO_3 at 2% and Salicylic acid at 50ppm treatments, particularly for the B780 variety, with a Benefit-to-Cost Ratio (B:C) of 2.21. These findings emphasize the potential seed priming for optimizing growth and yield in onion.

Keywords: Seed priming, onion cultivation, factorial randomized block design (FRBD), kno_3 treatment, salicylic acid, b780 onion variety, growth parameters, yield optimization, benefit-to-cost ratio (B:C), onion marketable yield

Introduction
Onion (*Allium cepa* L.) holds global significance as both a culinary spice and staple vegetable. Notably, India ranks second in global onion production, reflecting the increasing demand driven by its culinary importance and export potential. This surge underscores the importance of improving seed quality and ensuring successful crop establishment (Thejeshwini *et al*., 2019) [12]. Typically grown as an annual plant, onions yield their distinctive bulbs from the flattened bases of hollow, waxy-textured leaves. Beyond their culinary and economic importance, onions are rich in essential vitamins and minerals, making them a valuable dietary addition. They have also been treasured for their therapeutic properties, including use in traditional folk medicine for treating pulmonary diseases and potentially aiding in lowering blood sugar and blood pressure (Tadimalla, 2017) [11]. In the domain of onion cultivation, seed priming has emerged as a promising technique for enhancing seed vigour, quality and crop yield. This encompasses various methods, such as hydropriming, Osmo priming, biopriming, and nano priming. Effective seed priming, achieved by managing moisture content and temperature, promotes rapid and uniform germination, resulting in robust crop establishment and increased agricultural productivity. However, it's crucial to recognize that the response to seed priming may vary among different onion varieties, based on their initial quality. Therefore, comprehensive research is necessary to determine the most effective priming techniques for specific onion varieties (Rana *et al*., 2022) [8]. Afzal *et al*. (2006) [1] evaluated the effect of hormonal priming with ABA, salicylic acid, or ascorbic acid on Wheat germination and seedling growth under normal and saline conditions.

Bahrani and Pourreza, (2012) [3] studied the Gibberellic Acid and Salicylic Acid effects on seed germination and seedlings growth of wheat (*Triticum aestivum* L.) under salt stress conditions. Selvarani and Umarani (2011) [10] found that onion could benefited from priming with KNO_3 for 12 h, but still there have been no detailed studies carried out to identify the optimum priming duration and concentration of KNO_3 for better seedling performance, yield and yield related traits of the crop. Therefore, the present study was planned and conducted to access the effect of different priming agents and varieties on growth, yield and quality of onion.

Materials and Methods

The current experiment was conducted at Vegetable Research Centre, Maharajpur, Department of Horticulture, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. The study took place during the *Rabi* season of 2022-23. The experiment involving Onion crop (*Allium cepa* L.) was conducted using a Factorial Randomized Block Design (FRBD). Factor A, which represents "Variety," *viz*., Phule Samarth and B 780 and Factor B comprised of Seed priming Agents *viz*., KNO_3 @ 2%, TiO_2 @ 500ppm, PEG -1Mpa, Salicylic acid @ 50ppm, Pseudomonas @1% and Control (Water). The experiment included 3 replications and 12 treatments. The crop was grown with a row spacing of 20 cm and a plant to plant spacing of 15 cm. These varieties offer diverse characteristics and benefits, each suited to specific growing conditions or desired outcomes.

Seeds of cv Phule Samarth and B780 was received from Tamil Nadu were used for the priming experiments. Seeds of B780 and Phule Samarth were subjected to each priming agents *viz;* KNO_3 @ 2%, TiO_2 @ 500ppm, Salicylic acid @ 50ppm, PEG @ -1Mpa and *Pseudomonas* @1%. The solution was prepared by mixing of 2g of KNO_3, 50mg of TiO_2, 5mg of Salicylic acid, 27.3g of PEG and 1g of *Pseudomonas* in 100ml of distilled water separately in beaker. The seeds were soaked in solutions for 24 h for each treatment. After completion of soaking seeds were washed thoroughly with distilled water followed by drying of seeds in shade for 24 h to bring the seeds to original moisture content.

Results and Discussion

Effect on growth and yield attributes

Table 1 provides a detailed explanation of the evaluation of priming agent, variety, and their interaction on onion development characteristics. First, in terms of variety (Factor A), Phule Samarth (A1) and B 780 (A2) showed mean plant heights of 41.04 cm and 43.14 cm, respectively. These results suggest that, in the current conditions, B 780 tends to be slightly taller on average than Phule Samarth. Second, KNO_3 at 2% treatment produced the highest mean plant height at 43.54 cm, closely followed by salicylic acid at 50 ppm with 43.40 cm, while water treatment produced the lowest height at 38.84 cm when assessing the effect of seed priming agents (Factor B). These differences highlight how significantly seed priming chemicals affect plant height. Furthermore, an examination of the interaction effect between seed priming agents and variety revealed notable disparities, with the combination of KNO_3 at 2% and B780 (B1A2) producing the highest height at 45.03 cm, emphasizing the synergistic impact of seed priming agents and variety. Conversely, the lowest height of 38.67 cm was observed for the Water treatment in combination with Phule Samarth (B6A1). This analysis provides valuable insights for optimizing onion crop management strategies, considering both variety and seed priming agents as critical determinants of plant height. The choice of seed priming techniques and onion variety selection holds immense influence over plant growth, particularly in terms of height. This study explores these effects on Phule Samarth and B 780 onion varieties. Significantly divergent mean plant heights across various seed priming agents underscore the critical role these treatments play in early plant growth stages. KNO_3 at 2% priming exhibited superior results, suggesting the potential benefits of potassium nitrate in enhancing germination vigour and consequently, plant height. In contrast, water, serving as the control, recorded the least impact on plant height, serving as a reference point for evaluating the efficacy of other treatments. Variances in plant height between Phule Samarth and B 780 highlight the varietal differences, a common occurrence in crop varieties due to their genetic makeup. Greater responsiveness was observed in B 780, suggesting that it may have genetic benefits or be more adaptable to the seed priming procedures that were investigated. The combination of onion type and seed priming chemicals can have a considerable impact on plant height through subtle interaction effects, which presents prospects for optimal agricultural techniques. The B1A2 combination (KNO_3 at 2% + B780) produced the tallest plants, demonstrating the potential of customized methods to improve crop yield. The similar result was found by Karami *et al*. 2020 and Thejashwini *et al*. 2019 [6, 12].

Examining the data on the number of leaves per onion plant, it was found that Phule Samarth and B780 showed marginal varietal differences in the variety (Factor A), with Phule Samarth recording an average of 11.98 leaves per plant and B780 recording a slightly superior mean of 12.4 leaves per plant. This suggests that B780 has the innate genetic potential to enhance foliar proliferation. However, there was a noticeable difference when analysing the effect of seed priming agents (Factor B). Salicylic acid at 50 ppm was the most effective seed priming agent, resulting in the highest mean number of leaves per plant at 13.72, closely followed by *Pseudomonas* at 1%, which produced an average of 13.35 leaves per plant. On the other hand, seeds soaked in water alone showed the lowest mean number of leaves at 10.7, emphasizing the substantial influence of seed priming agents on foliar development. Furthermore, an exploration of the interaction effect (Factor A × Factor B) revealed a complex relationship, with combinations like B4A2 (Salicylic acid at 50 ppm + B780) achieving the highest number of leaves per plant at 13.97, while B6A1 (Water + Phule Samarth) had the lowest at 10.53. This comprehensive analysis underscores the intricate dynamics of variety and seed priming agents on onion plant leaf development, providing valuable insights for crop management strategies. Our results highlight how important seed priming compounds are for the foliar growth of onion plants. The significant agent salicylic acid @ 50 ppm jumps out, indicating its function in encouraging leaf growth. *Pseudomonas* @ 1% has significant promise in this area as well. The process of seed priming, which aims to improve the vigour of seedlings and synchronize germination, is crucial in establishing how many leaves a plant produces. However, there is no denying that the onion seed variety plays a crucial role in this process. The modest advantage that B780 has over Phule Samarth is indicative of the fine balance that exists between genetic potential and outside interventions. Interaction effects between variety and priming agent underscore the complexity of plant development, with the combination of Salicylic acid @ 50ppm and B780 yielding the highest number of leaves per plant. Similar results were reported by Thejashwini *et al*. 2019 [12].

Our findings show that seed priming chemicals have a major impact on onion leaf length, which is a crucial predictor of plant vigour and prospective production. With an average leaf length of 34.29 cm, variety A2 (B780) performed marginally better than variety A1 (Phule Samarth), indicating that B780 may have a genetic advantage in vegetative growth. Breeding choices must be carefully considered in light of this subtle difference, which has ramifications for productivity and adaptability. Second, when factor B the effect of seed priming agents was considered, salicylic acid at 50 ppm was shown to be the most advantageous treatment, producing an average leaf length of 34.93 cm. In contrast, PEG - 1MPa was found to be the least advantageous, producing an average leaf length of 29.56 cm. The interaction effect (Factor A × B) indicated a moderate interactive influence, with the highest leaf length observed for B4A2 (Salicylic acid at 50 ppm + B780) at 36.19 cm and the lowest for B3A2 (PEG - 1MPa + B780) at 28.17 cm. This analysis provides valuable insights for optimizing onion crop management, considering both variety and seed priming agents as crucial determinants of leaf length in onion plants. Salicylic acid is well-known for encouraging development and exhibiting stress tolerance, making it a crucial component in increasing leaf length. On the other hand, PEG - 1MPa, which acts as an osmoticum, can prevent growth because of possible water stress circumstances. Variations in leaf length can also be attributed to varietal genetics, where B780 routinely outperforms Phule Samarth. The relationship between priming agents and variety helps to clarify the intricate interactions between genetics and outside treatments; according to Karami *et al*. 2020 [5], the combination of salicylic acid @ 50ppm and B780 produced the longest leaves.

However, in case of Leaf width in onion plants variety B780 consistently demonstrated a higher mean across various seed priming treatments, averaging 0.93 cm, while variety Phule Samarth exhibited a slightly lower mean of 0.85 cm, indicating the greater responsiveness of the latter variety to seed priming treatments for enhanced foliar development. With regards to the influence of seed priming agents (Factor B), notable variations were observed, with the highest mean leaf width resulting from the *Pseudomonas* at 1% treatment at 0.96 cm, followed closely by Salicylic acid at 50 ppm with a mean of 0.93 cm. Furthermore, the interaction effect analysis (Factor A × B) revealed a critical difference (C.D.) at the 5% level of 0.15, suggesting a moderate interactive influence between varieties and seed priming agents. The maximum leaf width was observed for B5A2 (*Pseudomonas* at 1% + B780) at 1.02 cm, followed by B4A2 (Salicylic acid at 50 ppm + B780) at 0.98 cm, while the minimum leaf width was found for the combination B2A1 (TiO_2 at 500 ppm + Phule Samarth) at 0.77 cm. This analysis provides valuable insights for optimizing onion crop management, considering both variety and seed priming agents as crucial determinants of leaf width in onion plants. The purpose of the onion seed priming experiment was to evaluate the effects of several priming agents on leaf breadth, a critical growth potential measure. The greatest increase in leaf width was obtained with *pseudomonas* @1% seed priming, demonstrating the efficiency of *pseudomonas* as a priming agent. On the other hand, the Phule Samarth variety's TiO_2 @ 500ppm treatment showed the lowest mean, suggesting a less favourable reaction to this particular combination. Across all priming treatments, the B780 variety consistently outperformed Phule Samarth. The largest leaf width was obtained by combining B780 and *pseudomonas* at 1%, according to an investigation of interaction effects. This is consistent with the 2007 onion crop findings reported by Amin *et al*. [2]

Onion types' days to maturity showed a small variation; the B780 variety took an average of 127.67 days, which was marginally longer than the Phule Samarth variety's 126.67 days. This discrepancy emphasizes how innate genetic variables affect how long maturation takes. TiO_2 at 500 ppm produced the shortest days to maturity (123.5 days) of the seed priming agents examined, indicating a faster maturation process. On the other hand, priming with water and PEG-1MPa took the longest, average 129.50 days. These differing reactions demonstrate how various seed priming chemicals might affect how long onion plants take to mature. The results of the interaction effect between seed priming agents and onion varieties showed that, at 130 days, combinations B6A1 (Water + Phule Samarth) and B3A2 (PEG 1MPa + B780) had the longest days to maturity, while B2A1 (TiO_2 @ 500 ppm + Phule Samarth) had the shortest. These findings provide important insights into the interactions between variety and seed priming agents on onion maturation. Onion maturity is essential to marketability and when to harvest. The information emphasizes how varietal characteristics and seed priming chemicals affect onion maturation. TiO_2 at 500 ppm produces the shortest maturation period. Variations in maturation days among seed priming treatments highlight the importance of early seed treatments in regulating plant growth. Differences between the Phule Samarth and B780 varieties underscore the genetic factors at play. The interactive effects reveal the need for tailored approaches, with B2A1 (TiO_2 @ 500ppm + Phule Samarth) resulting in the shortest maturation period. Selvarani and Umarani 2011 [10] found same result.

Table 1: Evaluation of Variety, Priming agent and their interaction on growth parameters of onion (*Allium cepa* L.)

S. No.	Priming	Plant height (cm)			Number of leaves per plant			Leaf length (cm)			Leaf width (cm)			Days to maturity		
		A1 (Phule Samarth)	A2 (B780)	Mean B	A1 (Phule Samarth)	A2 (B780)	Mean B	A1 (Phule Samarth)	A2 (B780)	Mean B	A1 (Phule Samarth)	A2 (B780)	Mean B	A1 (Phule Samarth)	A2 (B780)	Mean B
1	B1 (KNO_3 @ 2%)	42.04	45.03	43.54	11.67	13.17	12.42	32.13	34.82	33.48	0.86	0.85	0.86	125	127	126
2	B2 (TiO_2 @ 500ppm)	40.17	44.37	42.27	11.33	12.5	11.92	30.34	35.7	33.02	0.77	0.87	0.82	123	124	123.5
3	B3 (PEG - 1MPa)	40.28	42.57	41.43	11.25	10.77	11.01	30.94	28.17	29.56	0.84	0.92	0.88	129	130	129.5
4	B4 (Salicylic acid @ 50ppm)	42.89	43.91	43.4	13.47	13.97	13.72	33.67	36.19	34.93	0.87	0.98	0.93	126	128	127

5	B5 (*Pseudomonas* @ 1%)	42.18	43.97	43.08	13.6	13.1	13.35	31.46	35.55	33.51	0.89	1.02	0.96	127	128	127.5
6	B6 (Water)	38.67	39.01	38.84	10.53	10.87	10.7	31.67	35.32	33.5	0.88	0.91	0.9	130	129	129.5
	Mean A	41.04	43.14		11.98	12.4		31.7	34.29		0.85	0.93		126.67	127.67	
	C.D. @ 1% level	0.45	0.77	1.1	0.6	1.05	1.49	0.48	1.19	0.84	0.06	NS	0.15	0.6	1.05	1.49
	S.E.(m)	0.15	0.26	0.37	0.2	0.35	0.5	0.16	0.4	0.28	0.02	0.03	0.05	0.2	0.35	0.5

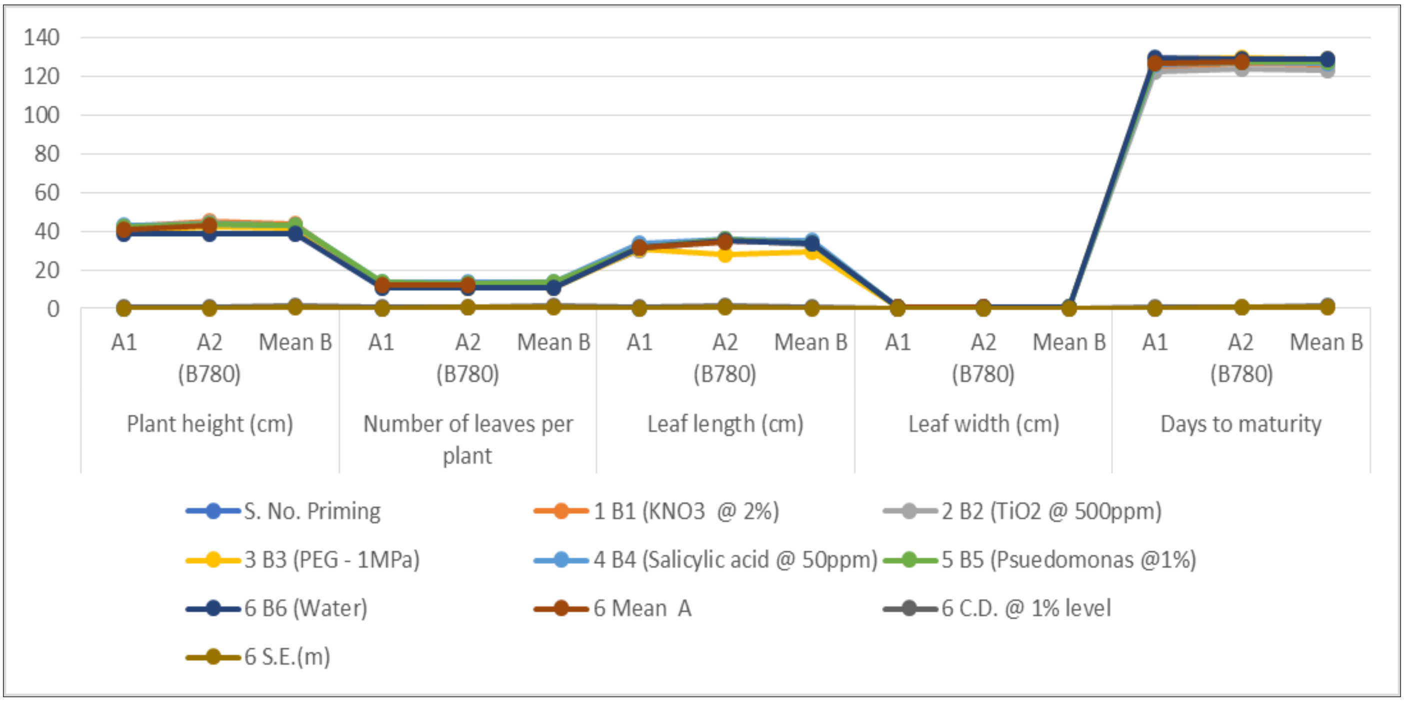

Fig 1: The influence of seed priming on onion plant height (cm), the count of leaves per plant, leaf length (cm), leaf width (cm) and days to maturity

Table 2 shows the assessment of variety, priming agent, and their interaction on yield and its contributing features. Onion polar diameter study highlights varietal differences in onion size by revealing innate genetic contributions to this characteristic. Compared to Phule Samarth, which had an average polar diameter of 4.49 cm, variety B780 regularly recorded a higher polar diameter, averaging 4.76 cm. These varietal differences highlight how important genetic factors are in determining onion morphology and how breeding and genetic factors, independent of outside treatments, have a major impact on onion size. Additionally, the effect of several seed priming treatments on polar diameter was noticeable, suggesting that priming chemicals had an impact on onion morphology. Salicylic acid at 50 ppm exhibited the most substantial impact, resulting in an average polar diameter of 4.88 cm, significantly higher than other treatments. Conversely, water as a priming agent produced the smallest average polar diameter at 4.29 cm. Other treatments, such as TiO_2 at 500 ppm, KNO_3 at 2%, and PEG - 1MPa, manifested intermediary effects. The examination of interactive effects between seed priming agents and varieties revealed that the highest polar diameter was observed for B3A2 (PEG - 1MPa + B780) at 5.04 cm, followed by B4A2 (Salicylic acid at 50 ppm + B780) at 4.97 cm, while the minimum polar diameter was found for B6A1 (Water + Phule Samarth) at 4.17 cm. This thorough examination emphasizes how genetics, seed priming chemicals, and variety interact to determine onion polar diameter. Onion polar diameter is an important morphological property that is controlled by both varietal characteristics and seed priming agents. Water, as a basic hydration agent, proved less effective than PEG -1MPa, which had a considerable impact on polar diameter with its osmotic modifications. Different reactions between Phule Samarth and B780 demonstrate how genetics plays a part in determining polar diameter. The interaction effects highlight the complex interaction between heredity and environmental factors; the largest polar diameter is produced by B3A2 (PEG -1MPa + B780).

When onion varieties were evaluated for equatorial diameter, minor variations were found. For example, A2 (B780) had an average equatorial diameter of 5.16 cm, which was slightly greater than A1 (Phule Samarth) at 5.14 cm. These little differences indicate that both onion cultivars have similar intrinsic capacity for growing bulbs in the equatorial regions, independent of seed priming. Significant differences in equatorial diameter were noted amongst seed priming treatments; salicylic acid at 50 ppm produced the largest average equatorial diameter of 5.26 cm, suggesting that it may be useful in encouraging bulb expansion in this area. The Water treatment, on the other hand, produced the lowest average diameter (4.89 cm), indicating that it was less effective in promoting bulb growth. The intermediate results were observed for TiO_2 at 500 ppm and *Pseudomonas* at 1%, with average diameters around 5.25 cm and 5.21 cm, respectively. Further exploration of the interaction effect between onion varieties and seed priming agents showed the highest equatorial diameter for B2A2 (Salicylic acid at 50 ppm + B780) at 5.41 cm, followed by B2A2 (TiO_2 at 500 ppm + B780) and B3A1 (PEG 1MPa + Phule Samarth) at 5.31 cm for both, while the minimum diameter was found for B6A2 (Water + B780) at 4.87 cm. This analysis highlights the nuanced interplay of variety, seed priming agents, and their combined influence on onion equatorial diameter. Seed priming techniques affect onion bulb equatorial diameter, an important yield and storage metric. Water priming is less successful than salicylic acid at 50 ppm in increasing equatorial diameter, probably through encouraging cellular development. A1 and A2 differ little from one another, suggesting genetic involvement. The interaction between variety and priming agents is suggested by interaction effects. The largest equatorial diameter was obtained with B2A2 (salicylic acid @ 50 ppm + B780), which is comparable to the results reported by Thejashwini *et al*. in 2019 [12].

In terms of Bulb weight in onion varieties, A1 (Phule Samarth) and A2 (B780) recorded comparable mean values of 55.10g and 56.90g, respectively, but a closer examination revealed A2's greater responsiveness to specific priming agents, notably Salicylic acid at 50 ppm, where it reached a peak bulb weight of 63.50g. This suggests genetic factors influencing A2's adaptability to certain treatments. Different seed priming agents exhibited diverse effects on bulb weight, with Salicylic acid at 50 ppm resulting in the highest average weight of 59.3g, followed by PEG-1MPa at 56.7g, while water had the least impact at 51.4g. The interaction effect between seed priming agents and onion varieties underscored the importance of selecting the right priming agent for each variety. The highest bulb weight was achieved by B4A2 (Salicylic acid + B780) at 63.50g, followed by B3A1 (PEG-1MPa + Phule Samarth) at 58.40g, while the minimum weight was recorded for B6A1 (Water + Phule Samarth) at 48.90g. This analysis provides valuable insights into the interplay of genetic factors, seed priming agents, and variety in influencing onion bulb weight. The study using a factorial randomized block design highlights the significant impact of seed priming agents on onion bulb weights. Salicylic acid @ 50ppm, especially in the A2 (B780) variety, stands out for its influence on bulb weight, possibly linked to enhanced seed vigour and germination rate. Variances in adaptability between A1 (Phule Samarth) and A2 (B780) underscore genetic differences in onion types' responsiveness to priming agents. This interaction between genetic predisposition and priming agent highlights the potential for improved growth outcomes. The highest bulb weight was observed for B4A2 (Salicylic acid + B780). These results are similar to that reported by Amin *et al*. 2007 [2].

Varietal disparities play a significant role in onion crop performance, and the data analysis underscores this fact. A2 (B780) consistently outperforms A1 (Phule Samarth) across all seed priming treatments, with an average yield of 258.45q compared to 233.95q, highlighting A2's potentially superior genetic attributes or heightened responsiveness to seed conditioning treatments. Furthermore, the choice of seed priming agents (Factor B) significantly impacts onion yield per hectare. Salicylic acid at 50ppm proves to be the most effective, yielding the highest average of 263.37q, emphasizing its pivotal role in optimizing seed germination and growth. Conversely, water, serving as a control, results in the lowest yield at 228.07q, underscoring the influence of priming agents on seed development. The interaction effect between seed priming agents and onion varieties reveals the highest yield per hectare for B4A2 (Salicylic acid at 50ppm + B780) at 268.62q, followed by B1A2 (KNO_3 at 2% + B780) at 266.06q, while the minimum is observed for B6A1 (Water + Phule Samarth) at 210.39q. This comprehensive analysis provides valuable insights for optimizing onion crop management strategies to achieve higher yields, accounting for varietal differences and the choice of seed priming agents. Seed priming is a foundational agricultural practice significantly influencing crop yield. In this study, priming agents accelerate germination and enhance seed vigour, resulting in higher yield. Salicylic acid @ 50ppm emerged as the most efficient agent. Differences in performance between onion varieties (A1 Phule Samarth and A2 B780) highlight genetic variations that make certain varieties more responsive to priming. Interaction effects suggest customized approaches are needed, rather than a one-size-fits-all solution. The highest yield per hectare was observed for B4A2 (Salicylic acid @ 50ppm + B780). Heidari *et al*. 2015 found same result [4].

In the evaluation of marketable yield, A2 (B780) consistently outperformed A1 (Phule Samarth) across all seed priming treatments, with an average marketable yield of 251.66 q compared to 227.02 q, highlighting the inherent robustness and yield potential of the A2 variety under the experimental conditions. Additionally, the choice of seed priming agents (Factor B) significantly impacted marketable yield. Salicylic acid at 50ppm proved to be the most effective, resulting in the highest marketable yield at 256.67 q, while water, serving as a control or basic priming agent, yielded the least at 220.74 q. The order of priming agents in terms of enhancing marketable yield was as follows: Salicylic acid at 50ppm > KNO_3 at 2% > PEG-1MPa > Pseudomonas at 1% > TiO_2 at 500ppm > Water. Furthermore, the interaction effect between onion variety and seed priming agents unveiled intricate dynamics, with A2 consistently outperforming A1, although the extent of superiority varied with the priming agent. The maximum marketable yield per hectare was observed for B4A2 (Salicylic acid at 50ppm + B780) at 261.78 q/ha, followed by B1A2 (KNO_3 at 2% + B780) at 259.59 q/ha, while the minimum was recorded for B6A1 (Water + Phule Samarth) at 203.49 q/ha. This comprehensive analysis provides insights into optimizing onion crop management strategies to maximize marketable yield, considering both varietal differences and the choice of seed priming agents. The marketable yield of onions significantly depends on both the variety and seed priming agents used. Salicylic acid @ 50ppm, an effective priming agent, enhances yields, in line with its known benefits for plant growth and stress tolerance. Water, as a priming agent, falls short, emphasizing the advantages of specialized agents. Genetic differences between onion varieties contribute to yield variations, with A2 (B780) consistently outperforming A1 (Phule Samarth). The interaction between priming agents and varieties adds complexity to optimizing onion yield, with the highest marketable yield observed for B4A2 (Salicylic acid @ 50ppm + B780). Pak Mehr *et al*. 2011 found same result [7].

Table 2: Evaluation of Variety, Priming agent and their interaction on yield and its attributing parameters of onion (*Allium cepa* L.)

S. No.	Priming	Polar diameter (cm)			Equatorial diameter (cm)			Bulb weight (g)			Yield per hectare (q)			Marketable yield (q)		
		A1 (Phule Samarth)	A2 (B780)	Mean B	A1 (Phule Samarth)	A2 (B780)	Mean B	A1 (Phule Samarth)	A2 (B780)	Mean B	A1 (Phule Samarth)	A2 (B780)	Mean B	A1 (Phule Samarth)	A2 (B780)	Mean B
1	B1 (KNO_3 @ 2%)	4.45	4.8	4.63	5.16	5.01	5.09	56.5	57.3	56.9	238.43	266.06	252.25	230.97	259.59	245.28
2	B2 (TiO_2 @ 500ppm)	4.61	4.7	4.66	5.19	5.31	5.25	57.3	54.2	55.8	224.63	255.9	240.27	218.21	249.25	233.73
3	B3 (PEG - 1MPa)	4.53	5.04	4.79	5.31	5.08	5.2	58.4	55	56.7	237.77	259.23	248.5	230.39	252.23	241.31
4	B4 (Salicylic acid @ 50ppm)	4.78	4.97	4.88	5.11	5.41	5.26	55.2	63.5	59.3	258.12	268.62	263.37	251.56	261.78	256.67
5	B5 (*Pseudomonas* @1%)	4.39	4.63	4.51	5.14	5.28	5.21	54.3	57.8	56.1	234.35	255.12	244.74	227.52	249.12	238.32
6	B6 (Water)	4.17	4.41	4.29	4.9	4.87	4.89	48.9	53.8	51.4	210.39	245.74	228.07	203.49	237.98	220.74
	Mean A	4.49	4.76		5.14	5.16		55.1	56.9		233.95	258.45		227.02	251.66	
	C.D. @ 1% level	0.03	0.05	0.07	0.03	0.06	0.08	1.25	2.17	3.07	2.63	4.55	6.44	2.73	4.73	6.69
	S.E.(m)	0.01	0.01	0.02	0.01	0.02	0.02	0.42	0.73	1.04	0.89	1.54	2.18	0.92	1.60	2.26

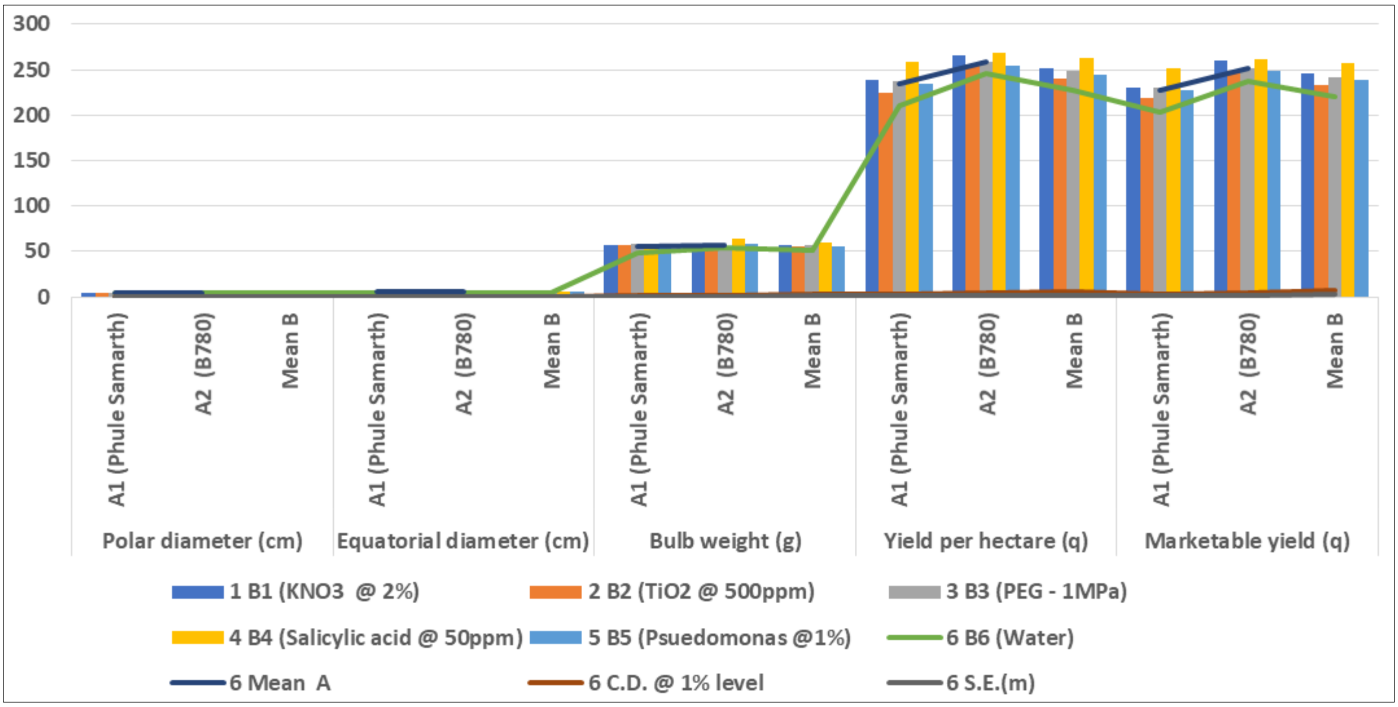

Fig 2: The effect of seed priming on onion polar and equatorial diameters (cm), Bulb Weight (g), yield per heactare (q) and marketable yield per (q)

Economics parameter

Several economic factors were evaluated in the factorial randomized block design analysis of onion farming, with a focus on the Phule Samarth and B 780 varieties that were treated to different seed priming treatments (Table 3 and Figure 3). With only minimal differences, the cost of cultivation was found to be largely constant across treatments. PEG -1MPa exhibited somewhat greater expenditure, which might be attributed to the associated expenses of administering or sourcing the treatment. Salicylic acid at 50 ppm (for T_4 and T_{10}) and KNO3 at 2% (for T_7) yielded the highest gross returns, whereas plain water (T_6) produced the lowest returns. These findings demonstrate the advantages of use priming agents to increase onion productivity and marketability. The highest net returns were observed for Salicylic acid at 50ppm treatment (T_4) for Phule Samarth and the same treatment for B 780 (T_{10}), underscoring the economic advantages of this priming agent. Conversely, plain water for Phule Samarth (T_6) yielded the least net returns, indicating missed opportunities for improved yields and profitability through seed priming. The benefit-to-cost ratios revealed that KNO_3 at 2% for B 780 (T_7) and Salicylic acid at 50ppm for B 780 (T_{10}) had the highest ratios at 2.21, signifying that every rupee spent on cultivation could yield a return of Rs/-2.21. On the other hand, plain water as a priming agent for Phule Samarth (T_6) had the lowest B:C ratio of 1.5, reinforcing the economic advantages of employing priming treatments in onion cultivation. The financial analysis of growing onions demonstrates how important variety and seed priming treatments are to the benefit-to-cost ratio. Treatments using salicylic acid at 50 ppm and KNO_3 at 2% stand out for having favourable ratios. The importance of various treatments, especially salicylic acid @ 50 ppm, which enhances germination, seedling vigour and stress resistance, is highlighted by the constancy in cultivation expenses. Conversely, water doesn't have these advantages, which means that returns are smaller. With a B:C ratio of 2.21, KNO_3 @ 2% and salicylic acid @ 50 ppm treatments, particularly for the B 780 variant, demonstrate economic efficacy. Similar results were reported by Kumari *et al.* (2017) [6].

Table 3: Effect of seed priming on economic parameters of onion (*Allium cepa* L.)

S. No.	Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
T1	Phule Samarth + KNO_3 @ 2%	122260	346452	224192	1.83
T2	Phule Samarth + TiO_2 @500 ppm	122164	327315	205151	1.68
T3	Phule Samarth + PEG -1MPa	123831	345590	221759	1.79
T4	Phule Samarth + Salicylic acid 50ppm	122141	377345	255204	2.09
T5	Phule Samarth + *Pseudomonas* @ 1%	122143	341280	219137	1.79
T6	Phule Samarth + Water	122136	305235	183099	1.5
T7	B 780 + KNO_3 @ 2%	122260	392385	270125	2.21
T8	B 780 + TiO_2 @500 ppm	122164	373880	251716	2.06
T9	B 780 + PEG -1MPa	123831	378350	254519	2.06
T10	B 780 + Salicylic acid 50ppm	122141	392665	270524	2.21
T11	B 780 + *Pseudomonas* @ 1%	122143	373685	251542	2.06
T12	B 780 + Water	122136	356970	234834	1.92

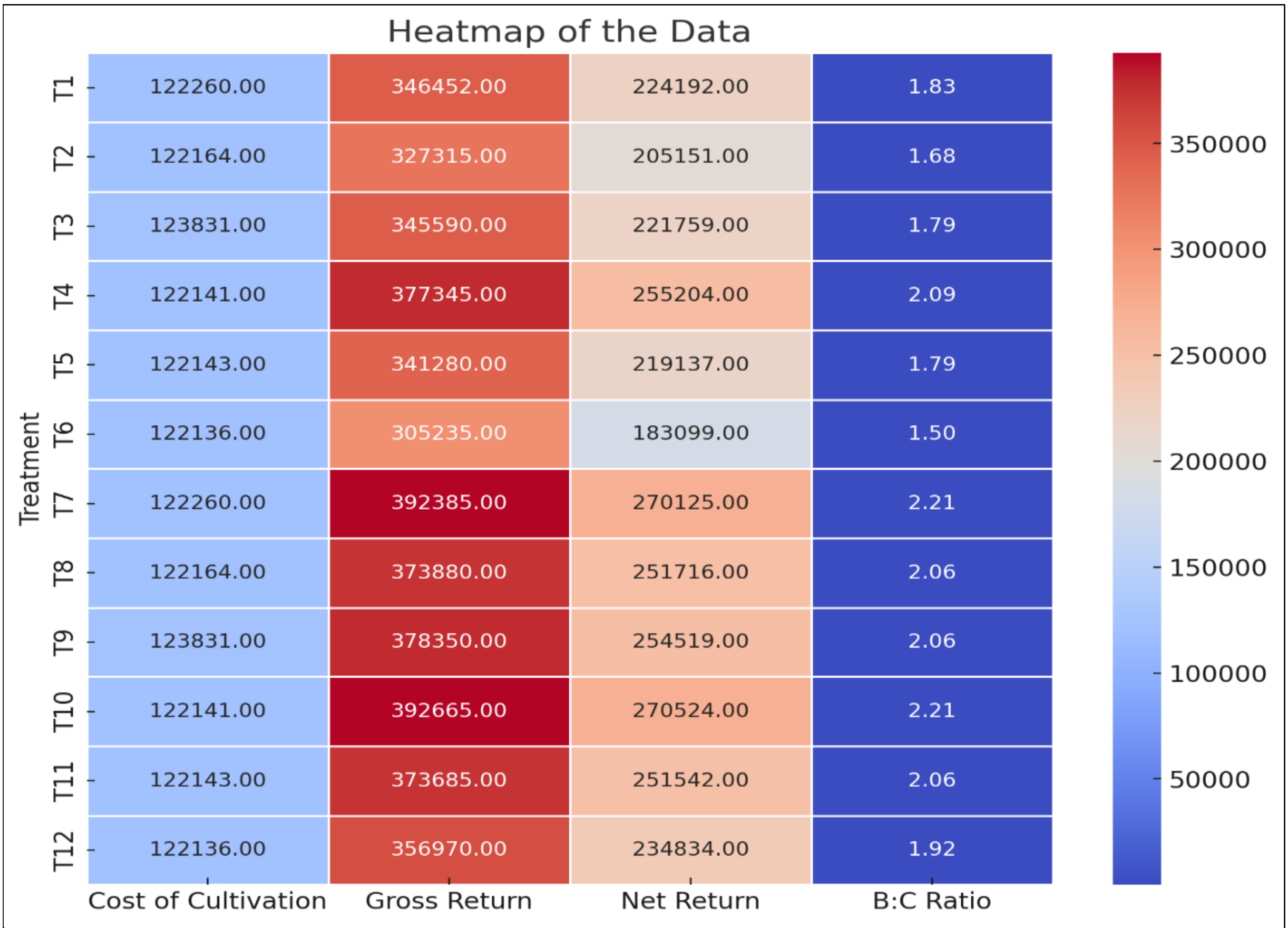

Fig 3: Investigation of Seed Priming's Impact Mediated by Factor A, Factor B, and Interaction on Cost of cultivation in Onion

Conclusion

It can be concluded from the present study that Salicylic acid exhibited a significant influence on multiple bulb characteristics, yield metrics, leaf attributes, and the number of leaves per plant. KNO_3 @ 2% proved effective in enhancing plant height, while the use of Pseudomonas improved leaf width, and PEG – 1MPa notably optimized polar diameter. In a comprehensive economic analysis of seed priming's impact on onion cultivation, both KNO_3 @ 2% and Salicylic acid @ 50 ppm emerged as pivotal priming agents, excelling in essential economic parameters such as cost of cultivation per hectare, gross monetary returns per hectare, net monetary returns per hectare, and the overall benefit-cost ratio. This underscores the economic viability and advantage of incorporating KNO_3 @ 2% and Salicylic acid @ 50ppm in seed priming practices, potentially leading to enhanced profitability for onion growers. These findings emphasize the potential of tailored seed priming strategies to drive targeted improvements in onion cultivation and yield.

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