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Effect of Nano DAP on Germination and Seedling Growth of Different Crops

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ABSTRACT: Lab experiment was conducted in the Department of Agronomy in the year 2023 to study the effect of seed treatment with nano DAP on germination and seedling growth of seven crops *viz*., rice, wheat, maize, oats, soybean, mustard and gram. The experiment consisted of seven treatments which were tested incompletely randomized design with three replications. Germination percentage and seedling growth indices varied significantly with seeds treated with nano DAP@ 5ml/litre resulted in maximum germination percentage, higher seedling length as well as seedling dry weight and were found at par with nano DAP @ 2.5 ml/litre and significantly higher over other treatments. On the basis of this study it can be concluded that nano DAP has great potential in improving germination, emergence and seedling vigour. Treating seeds with nano DAP @ 2.5 ml/litre or 5 ml/litre enhanced seed germination, seedling indices and seedling vigour index but further increase in nano DAP concentration beyond 5 ml/litre might have adverse effect on plant growth.

Keywords: nano DAP, germination, seedling vigour, field crops.

INTRODUCTION

With global food demand escalating due to population growth, increasing food grain production in a sustainable manner is essential. However, with soil health deteriorating and input costs rising, enhancing production must be achieved in a way that preserves soil integrity and minimizes environmental impact. Uniform and timely seed germination is a fundamental step that ensures consistent plant stands, which ultimately contributes to higher yields. Pre-sowing seed treatments are routinely applied to control pathogens and promote growth and yield. Seed soaking, in particular, disrupts natural dormancy barriers, facilitating more rapid germination by initiating key metabolic pathways.

Nanoparticles-Atomic and Molecular aggregates in the nanoscale range of 1–100 nm (Rai and Ingle 2012) offer innovative solutions in agriculture. Nanoparticles of elements such as gold, silver, zinc, zinc oxide, copper, aluminum, silica, cesium oxide, titanium dioxide, and magnetized iron have been extensively studied for agricultural applications (Zhang and Webster 2009). Nano particles can efficiently penetrate the seed coat and outermost tissue layers and deliver priming chemicals straight to the embryo because of their tiny size and large surface area (Singh *et al*., 2023).

Their unique properties, including high reactivity, enhanced solubility, and mobility, enable nanoparticles to target and modify specific physiological and biochemical pathways within plants (Kumari *et al*., 2023). The hydrolytic enzymes, such as lipases, α-amylase, and proteases, which break down stored macromolecules into smaller molecules needed for energy and biosynthesis, can be activated by nano-primers acting as cofactors or catalysts once they have entered the plant body (Kaur *et al*., 2024). By altering hormone-signaling pathways and the production of reactive oxygen species (ROS) within cells, nano-priming also affects the quantity and activity of phytohormones such gibberellins and abscisic acid, which facilitate the shift from dormancy to active growth (Lee and Kasote 2024). Simpler molecules are necessary to meet the energy and biosynthetic needs of developing embryos. Furthermore, more ATP and other high-energy molecules required for germination and early seedling growth are synthesized as a result of the increased activity of dehydrogenases engaged in glycolysis and the citric acid cycle. Nano-priming stimulates the synthesis of proteins and nucleic acids required for cell division and growth by facilitating the delivery of nutrients and growth regulators to cells (Li *et al*., 2022).

Nano fertilizers are envisioned to reduce the requirement of conventional chemical fertilizerby 50%, with over 15-30% increase in crop production, improvement in soil health, reduction in the emission of greenhouse gases. Nano – DAP is one such fertilizer that supplies two of the primary nutrients (nitrogen and phosphorus) with the objective of improving the use efficiencies of both these nutrients. This product has been recently developed by IFFCO Ltd and is expected to improve the crop yields with higher use efficiency. However very little information is available with regards to efficacy of this nano fertilizer (Nano – DAP) in improving germination and seedling vigour indices of different crops.

MATERIALS AND METHODS

A lab experiment was conducted in the department of Agronomy, college of Agriculture, CSK HPKV, Palampur in the year 2023. The experiment consisted of seven treatments *viz.,* T1: Control (seeds were soaked in tap water), T2: nano DAP @ 2.5 ml/litre, T3: nano DAP @ 5 ml/litre, T4: nano DAP @ 7.5 ml/litre, T5: nano DAP @ 10 ml/litre, T6: nano DAP @ 12.5 ml/litre, T7: nano DAP @ 15 ml/litre. The treatments were tested incompletely randomized design with three replications. A stock solution of 20 ml/litre was prepared using 20 ml nano DAP per litre of distilled water. Using this stock solution, different concentration were prepared using formula $C_1V_1= C_2V_2$. After this, 100 healthy seeds were soaked in100ml solution of different concentrations as per the treatment for four hours followed by air drying.

The germination test was carried out in three replications of 100 seeds each using Top paper method (suitable for small-sized seeds *viz*., rice, wheat, mustard and oats) and between paper method (suitable for large-sized seeds *viz*., maize, soybean and gram) as described by ISTA (Anonymous, 2015). In top paper methods, soaked and air dried seeds were arranged in perti plates containing filter paper wetted with water. The petri dishes were kept in an incubator set at 25±1°C for8 days, whereas, in between paper method, seeds were placed on the germination sheet, which was then covered with another layer of germination sheet before being rolled. The rolled blotter paper were placed in the germinator in an upright position. During the germination test, the RH was maintained at 90 per cent and the temperature was around 25±1°C for 8 days. The petri plates and germination sheets were inspected daily for any fungal attack. Water was sprinkled over the seeds as and when required. The first count was taken on 5th day and the final count was taken on the 8th day of the germination test.

Percent germination was calculated using the following formula

$$\text{Germination \%} = \frac{\text{number of normal seedlings}}{\text{total number of seeds sown}} \times 100$$

Seedling growth parameters were recorded at the end of germination period (8th day). Ten random seedlings were selected for taking observations. The length of each seedling was measured from tip of the primary leaf to the root tip. The average length was calculated and expressed in centimetres. The ten normal seedlings used for measuring seedling length were wrapped in butter paper and kept in hot air oven at 80 deg c for 17 hours. After 17 hours, the dry weight of the seedlings was recorded. The average dry weight of a seedling was worked out in milligrams.

Seedling vigour index-I (SVI-I) and Seedling vigour index-II (SVI-II) were computed using formula suggested by Abdul Baki and Anderson(1973).

SVI-I = Germination percentage × seedling length(cm/seedling)

SVI-II = Germination percentage × seedling dry weight (mg/seedling)

RESULTS AND DISCUSSION

Germination percentage. The germination percentage in all the crops presented in Table 1-7 was significantly influenced by different treatments. Significantly higher germination percentage in all the tested crops was observed when the seeds were treated with nano DAP @ 5 ml/litre or 5 ml/litre though the treatment was at par with the seed treatment done with lowest dose of 2.5 ml/litre or 2.5 ml/litre seed. A close perusal of the data further revealed that increasing the concentration of nano DAP in solution used for seed treatment above 5 ml/litre lowered the germination percentage with the highest concentration of 15 ml/litre recorded lowest germination percentage in all the crops.

Seedling vigour indices. Significantly higher seedling length, seedling dry weight as well as seedling vigour index I and seedling vigour index II (Table 1-7) were recorded with treatment in which seeds were treated with nano DAP @ 5 ml/litre seed though this treatment was at par with nano DAP @ 2.5 ml/litre seed in five crops *i.e.,* wheat, maize, oats, gram and soybean, while in rice and mustard, significantly higher seedling length, seedling dry weight as well as seedling vigour index I and seedling vigour index II was recorded with treatment in which seeds were treated with nano DAP @ 5 ml/litre seed but this treatment was not at par with any other treatment.

DISCUSSION

The increase in germination percentage and improvement in seedling indices might be associated with easy entry of nano DAP particles into the seed, which supplied both nitrogen and phosphorus to the seed. Phosphorus application switched on many biochemical and physiological processes necessary for seed germination. Phosphorus absorption might have triggered these processes. Phosphorus availability during initial stages affected the seed germination by early replication and maintenance of DNA, increased RNA and protein synthesis and greater ATP availability (Varier *et al*., 2010).

Nanofertilizers, due to their nanoscale dimensions, readily penetrate seed coats, enhancing water uptake by activating aquaporin genes. Pre-sowing treatment of seeds with nanoparticles modifies seed physiology to expedite germination by regulating various metabolic and biochemical pathways (Nile *et al*., 2022). Numerous studies indicate that the application of nanofertilizers prior to planting enables direct interaction between seeds and nanoparticles in an aqueous medium, thereby promoting germination(Al Zoubi *et al*., 2024).In this context, nanofertilizers serve as nanocatalysts, increasing the activity of starch-degrading enzymes, functioning as mild stress inducers or reactive oxygen species (ROS) generators, and facilitating nanopore formation in the seed coat. However, excessive or suboptimal application of nanofertilizers during seed priming may adversely affect plant growth due to nanoparticle-induced toxicity, oxidative stress, and alterations in soil microbiota, underscoring the necessity for precise optimization of both concentration and exposure duration.

Abdel-Aziz *et al*. (2019) documented a reduction in all growth parameters of French bean plants subjected to seed priming, in contrast to control and foliar application treatments. In a subsequent study, Abdel-Aziz *et al*. (2019) demonstrated that nanochitosan, applied as a seed priming agent at concentrations of 0.05% and 0.1%, exerted a negative effect on both germination and seedling growth in broad beans. This observed suppression of growth associated with seed priming treatment is likely attributable to the cytotoxic characteristics of the nanomaterial used. Consistent with this, Khalifa and Hasaneen (2018) observed that nanochitosan nanoparticles in pea seedlings were able to penetrate the seed coat, subsequently accumulating within embryonic tissues and exerting inhibitory effects on cell division and tissue development.

Kundu and Bordolui (2023) observed that soaking of carrot seeds in Ag-Nanoparticles @ 20 ppm for 6 hours resulted in significantly highest performance for seed quality parameter like germination percentage, germination energy, seedling vigour Index-I, and germination index than other priming concentrations and durations.

These findings highlighted the necessity for precise optimization of nanoparticle concentration and application protocols to minimize cytotoxic impacts on germination, cellular division, and tissue development, thereby enabling the safe and efficacious integration of nanotechnology in agricultural practices.

Table 1: Effect of seed treatment with nano DAP on germination indices of wheat.

Treatments	Germination percentage	Shoot length (cm/seedling)	Root length (cm/seedling)	Seedling length (cm/seedling)	Shoot dry weight (mg/seedling)	Root dry weight (mg/seedling)	Seedling dry weight (mg/seedling)	SVI	SVII
Control	94.0	5.0	8.0	13.0	4.0	4.3	8.3	1226.2	782.8
2.5 ml/litre	97.7	7.0	12.0	19.0	5.3	6.9	12.2	1855.2	1182.3
5 ml/litre	98.9	7.2	12.4	19.6	5.4	7.1	12.5	1938.4	1236.4
7.5 ml/litre	93.0	4.5	7.7	12.2	3.9	4.1	8.0	1134.3	744.2
10 ml/litre	92.6	4.5	7.5	12.0	3.8	4.0	7.8	1111.0	722.4
12.5 ml/litre	91.3	4.2	7.1	11.3	3.3	3.7	7.0	1031.7	639.1
15 ml/litre	90.0	4.1	6.9	11.0	3.2	3.4	6.6	990.0	594.0
SEm±	1.5	0.1	0.1	0.2	0.1	0.1	0.1	27.7	18.5
CD (P = 0.05)	4.5	0.3	0.4	0.6	0.2	0.2	0.3	84.2	56.1

Table 2: Effect of seed treatment with nano DAP on germination indices of rice.

Treatments	Germination Percentage	Shoot length (cm/seedling)	Root length (cm/seedling)	Seedling length (cm/seedling)	Shoot dry weight (mg/seedling)	Root dry weight (mg/seedling)	Seedling dry weight (mg/seedling)	SVI	SVII
Control	91.3	2.7	4.5	7.2	1.8	2.5	4.3	657.7	392.8
2.5 ml/litre	98.0	4.6	6.4	11.0	3.0	3.6	6.6	1078.5	656.6
5 ml/litre	99.3	4.8	7.0	11.8	3.2	4.0	7.2	1171.7	715.0
7.5 ml/litre	90.6	2.6	4.3	6.9	1.8	2.4	4.2	625.2	380.7
10 ml/litre	90.2	2.5	4.0	6.5	1.7	2.2	3.9	586.3	351.7
12.5 ml/litre	90.0	2.4	3.8	6.2	1.7	2.0	3.7	558.0	333.0
15 ml/litre	90.0	2.3	3.7	6.0	1.7	1.9	3.6	539.9	323.9
SEm±	1.3	0.04	0.1	0.1	0.0	0.0	0.0	18.3	8.2
CD (P = 0.05)	4.0	0.1	0.3	0.4	0.1	0.1	0.2	55.5	24.8

Table 3: Effect of seed treatment with nano DAP on germination indices of maize.

Treatments	Germination Percentage	Shoot length (cm/seedling)	Root length (cm/seedling)	Seedling length (cm/seedling)	Shoot dry weight (mg/seedling)	Root dry weight (mg/seedling)	Seedling dry weight (mg/seedling)	SVI	SVII
Control	94.3	22.2	14.2	36.4	8.3	10.9	19.2	3436.0	1810.5
2.5 ml/litre	98.0	24.2	16.0	40.2	10.6	14.0	24.6	3941.2	2401.7
5 ml/litre	99.2	24.3	16.2	40.5	10.8	14.2	25.0	4017.6	2480.0
7.5 ml/litre	93.2	21.7	13.3	35.0	8.2	10.7	18.9	3260.7	1761.3
10 ml/litre	92.6	21.2	13.0	34.2	8.0	10.5	18.5	3167.1	1712.7
12.5 ml/litre	91.3	20.8	12.7	33.5	7.4	9.8	17.2	3059.2	1570.5
15 ml/litre	91.0	20.5	12.5	33.0	7.3	9.7	17.0	3003.6	1546.9
SEm±	1.5	0.4	0.3	0.5	0.1	0.2	0.2	88.9	37.0
CD (P = 0.05)	4.6	1.1	0.8	1.5	0.2	0.5	0.5	269.6	112.3

Table 4: Effect of seed treatment with nano DAP on germination indices of oats.

Treatments	Germination Percentage	Shoot length (cm/seedling)	Root length (cm/seedling)	Seedling length (cm/seedling)	Shoot dry weight (mg/seedling)	Root dry weight (mg/seedling)	Seedling dry weight (mg/seedling)	SVI	SVII
Control	94.2	6.0	6.2	12.2	5.0	4.3	9.3	1149.0	876.3
2.5 ml/litre	99.2	8.0	12.0	20.0	6.3	7.2	13.5	1984.8	1339.4
5 ml/litre	99.8	8.2	12.2	20.4	6.4	7.4	13.8	2035.7	1377.0
7.5 ml/litre	93.3	5.5	6.4	11.9	4.9	4.1	9.0	1110.3	839.5
10 ml/litre	92.6	5.4	5.9	11.3	4.8	4.0	8.8	1046.1	814.4
12.5 ml/litre	92.3	5.2	5.8	11.0	4.3	3.7	8.0	1015.2	738.2
15 ml/litre	91.4	5.1	5.8	10.9	4.2	3.4	7.6	996.4	694.8
SEm±	1.8	0.1	0.1	0.1	0.1	0.1	0.1	31.2	19.4
CD (P = 0.05)	5.4	0.2	0.3	0.4	0.2	0.2	0.3	94.7	58.9

Table 5: Effect of seed treatment with nano DAP on germination indices of soybean.

Treatments	Germination Percentage	Shoot length (cm/seedling)	Root length (cm/seedling)	Seedling length (cm/seedling)	Shoot dry weight (mg/seedling)	Root dry weight (mg/seedling)	Seedling dry weight (mg/seedling)	SVI	SVII
Control	92.6	10.2	6.2	16.40	4.7	6.0	10.70	1518.5	991.7
2.5 ml/litre	97.6	14.0	8.8	22.80	6.1	8.5	14.60	2225.3	1425.0
5 ml/litre	98.9	14.2	9.0	23.20	6.2	8.8	15.00	2295.1	1483.3
7.5 ml/litre	91.3	10.0	6.0	16.00	4.5	5.7	10.20	1460.8	931.4
10 ml/litre	91.0	9.8	6.0	15.80	4.5	5.5	10.00	1438.1	910.1
12.5 ml/litre	90.9	9.5	5.7	15.20	4.4	5.2	9.60	1381.5	872.5
15 ml/litre	90.3	9.3	5.5	14.80	4.3	5.1	9.40	1336.4	848.8
SEm±	1.5	0.1	0.1	0.2	0.1	0.1	0.1	35.4	21.8
CD (P = 0.05)	4.5	0.4	0.4	0.6	0.3	0.3	0.4	107.5	66.1

Table 6: Effect of seed treatment with nano DAP on germination indices of mustard.

Treatments	Germination Percentage	Shoot length (cm/seedling)	Root length (cm/seedling)	Seedling length (cm/seedling)	Shoot dry weight (mg/seedling)	Root dry weight (mg/seedling)	Seedling dry weight (mg/seedling)	SVI	SVII
Control	92.6	3.8	6.5	10.3	2.6	3.4	6.0	953.8	555.4
2.5 ml/litre	99.3	5.3	10.0	15.3	4.0	5.1	9.1	1519.3	923.6
5 ml/litre	99.8	5.6	10.3	15.9	4.2	5.4	9.6	1587.0	958.5
7.5 ml/litre	91.8	3.6	6.2	9.8	2.5	3.3	5.8	899.7	532.4
10 ml/litre	91.2	3.5	6.1	9.6	2.4	3.2	5.6	875.6	510.7
12.5 ml/litre	90.3	3.4	5.8	9.2	2.2	3.0	5.2	830.8	469.6
15 ml/litre	90.0	3.3	5.7	9.0	2.0	3.0	5.0	810.7	450.0
SEm±	1.4	0.05	0.1	0.1	0.03	0.1	0.1	18.1	11.0
CD (P = 0.05)	4.2	0.1	0.2	0.3	0.1	0.2	0.2	55.1	33.5

Table 7: Effect of seed treatment with nano DAP on germination indices of gram.

Treatments	Germination Percentage	Shoot length (cm/seedling)	Root length (cm/seedling)	Seedling length (cm/seedling)	Shoot dry weight (mg/seedling)	Root dry weight (mg/seedling)	Seedling dry weight (mg/seedling)	SVI	SVII
Control	92.3	11.2	6.2	17.40	5.7	7.0	12.70	1606.4	1171.8
2.5 ml/litre	97.4	15.0	9.5	24.50	7.1	9.5	16.60	2385.9	1616.4
5 ml/litre	98.3	15.2	9.8	25.00	7.2	9.8	17.00	2457.9	1670.8
7.5 ml/litre	91.9	11.0	6.0	17.00	5.5	6.7	12.20	1562.3	1121.2
10 ml/litre	91.3	10.8	5.9	16.70	5.5	6.5	12.00	1525.8	1096.2
12.5 ml/litre	90.3	10.5	5.8	16.30	5.4	6.2	11.60	1472.3	1047.7
15 ml/litre	90.0	10.3	5.4	15.70	5.3	6.1	11.40	1413.0	1026.0
SEm±	1.6	0.1	0.1	0.2	0.1	0.1	0.1	38.1	22
CD (P = 0.05)	4.8	0.4	0.4	0.5	0.3	0.3	0.4	115.6	66.7

CONCLUSION

Significantly higher germination percentage, seedling length as well as seedling dry weight was recorded with treatment in which seeds were treated with nano DAP @ 5 ml/litre though this treatment was at par with nano DAP @ 2.5 ml/litre seed in all the crops. Further increasing the concentration of nano DAP in the solution made for treating the seeds above 5ml/litre (7.5,10.0, 12.5 and 15 ml/litre) significantly lowered the germination percentage. On the basis of this study it can be concluded that nano DAP has a great potential in increasing the germination of different crops as well as ensuring early seedling vigour which might result in better crop productivity. Also the seed treatment with nano DAP should be done at dose of 2.5-5 ml/litre.

FUTURE SCOPE

The study of the effect of nano DAP (Diammonium Phosphate) on germination, seedling indices, and seedling vigor of various crops presents significant future potential in sustainable agriculture. Research can focus on optimizing nano DAP formulations for better nutrient uptake, understanding long-term soil health impacts, and assessing crop-specific responses. Field trials can validate its effectiveness in diverse environments, while exploring its synergistic use with other nano-fertilizers could boost nutrient efficiency. Additionally, studying its impact on plant resilience under stress conditions like drought and salinity can support climate-resilient agriculture. Overall, this research can drive advancements in precision farming, enhance crop yields, and contribute to sustainable food production.

Conflict of Interest. None.

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