

Optimization of nano-DAP fertilization for improvement in growth and yield of finger millet (*Eleusine coracana* (L.) Gaertn.)

Aim: Optimization of nano-DAP fertilization for improvement in growth, yield and to maximize the production of finger millet.

Study Design: Randomized Block Design (RBD)

Place and Duration of Study: This investigation was conducted in *Kharif* 2021-22, with variety VL-352 at the Research and Extension Centre, Gaja, College of Forestry, Ranichauri (TehriGarhwal), Uttarakhand, [India](#).

Methodology: Volatilization, denitrification, and leaching losses brought on by excessive fertilizer use have reduced fertilizer efficiency. Phosphorus fixing at soil collisions results in decreased phosphorus accessibility. One of the quickest ways to improve crop growth is to treat seeds with foliar spray of nano-DAP to prevent or minimize such losses and fixation. This experiment comprised of ten treatments viz., T1- NK 100% (Control), T2- NPK 100%, T3- 75%P + 100%N + 100%K, T4- 50%P + 100%N + 100%K, T5- 75%P + 100%N + 100%K + ST + FS(2ml), T6- 75%P + 100%N + 100%K + ST + FS(4ml), T7- 50%P + 100%N + 100%K + ST + FS(2ml), T8- 50%P + 100%N + 100%K + ST + FS (4ml), T9- 50%P + 100%N + 100%K + ST + FS(2ml) + FS(2ml), T10- 50%P + 100%N + 100%K + ST + FS (4ml) + FS(4ml) and was laid out in Randomized Block Design (RBD) with three replications. The plant growth parameters and yield attributing parameters were recorded significantly higher in the treatment T10- 50%P + 100%N + 100%K + ST + FS (4ml) + FS(4ml) while significantly lower yield was recorded in T1- NK 100% (Control).

Result: The findings of this study showed that finger millet yield and plant growth were significantly increased by applying 50% P through DAP and 100% NK, treating the seed with nano-DAP at a rate of 5 ml/kg seed, and performing two foliar sprays of nano-DAP at a rate of 4 ml/l of water, one at 30-35 days after seed germination and the other at 45 days.

Conclusion: The use of 50% P through DAP and 100% NK along with seed treatment by nano DAP @5ml/kg seed as well as two foliar sprays of nano-DAP @4 ml/l of water, first at 30-35 days after germination and second at 45 days after seed germination gave significantly higher plant growth, seed yield and seed quality of finger millet.

ABSTRACT

Keywords: Volatilization, Denitrification, Leaching losses, Soil collisions, Randomized Block Design, Foliar sprays, Finger millet, nano-DAP

1. INTRODUCTION

India ranks second in consumption and third in the production of fertilizers worldwide [1]. The usage of urea, diammonium phosphate (DAP), and muriate of potash (MOP) results in lower fertilizer efficiency due to volatilization, leaching and denitrification losses [2], ranging from 20-50% for nitrogen, 10-25% for phosphorous and 70-80% for potassium [3] [4]. Overuse of fertilizer increases the cost of products economically that have a negative impact on farmers' income [5], and due to its losses from the root zone, it also contributes to soil, water, and air pollution [6] [7]. Continuous nutrient extraction from the soil along with improper and uneven fertilizer application has led to increased secondary and micronutrient deficiency due to which the ability of the crop to respond to the application of primary nutrients (N, P & K) is inhibited [8] [9]. Nitrogen and phosphorous have prominent roles in plant metabolic system, in various physiological processes and are essential nutrients for the life of

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Comment [u2]: ...nutrients: nitrogen (N), phosphorus (P) and potassium (K) is inhibited

plants[10]. The low availability of N and P limits grain yield. The management of nutrients becomes crucial for increasing the yield of the crops. Finger millet (*Eleusine coracana* (L.) Gaertn.), locally known as mandua or ragi[11] [12] is the most dominant *khari* season crop in rainfed hills of Uttarakhand [12]. It is an important small millet crop grown in India that is valued for food, fodder, and high nutritional security. Even though finger millet is important, less study has been done on it and very little information is available about how to manage the crop's P levels in dry/rainfed environments. So, it is necessary to know the optimum dose of the P fertilizer to be applied for maximum yields without compromising the environment [13].

To avoid or minimize losses from the use of chemical fertilizers, several measures have been adopted all over the world in the R&D of fertilizers. The use of nano-fertilizers acts as an alternative substitute for conventional phosphate fertilizers which are made from non-renewable phosphoric rocks whose supplies are already depleting [14]. Nano-fertilizers through precision agriculture improves agricultural production and enhances P use efficiency [14] [15]. Nanoscale materials enhance the fertilizer use efficiency while foliar application meets the crop nutrient requirement effectively as per its need. Under rainfed conditions when the availability of moisture becomes scarce, the application of nutrients as foliar spray results in efficient absorption and usage which is economical in respect to the other methods of fertilization [5]. Nano-P applied via foliar application increases P usage efficiency, promoting sustainable productivity, quality and reduces nutrient losses, P leaching/fixation into underground water through direct internalization of crops and slow release over a longer period of time while synthetic P fertilizers supplied directly to the soil have high fixation rates in the soil and low uptake efficiency [16].

Nano-DAP formulation is an efficient source of available nitrogen (8.0% N w/v) and phosphorus (16.0 % P_2O_5 w/v) for all the crops and helps in correcting the nitrogen & phosphorus deficiencies in standing crops. Liquid nano-DAP has an advantage in terms of surface area to volume as its particle size is less than 100 nanometres (nm). The incorporation of nano-DAP into the plant system results in higher seed vigour and quality, more chlorophyll, greater photosynthetic efficiency, optimum growth and higher crop yields because the nano clusters of nitrogen.

Phosphorus in nano-DAP are functionalized with bio-polymers and other substances for enhanced spreading capacity. Additionally, nano-DAP meets the nutritional needs of crops through precise, targeted application without damaging the environment [17]. As very limited information is available about the effect of nano-DAP on the finger millet growth, development, seed quality and yield, therefore, keeping this in view the present investigation has been undertaken with the objective to assess the effect of nano-DAP fertilizer on growth parameters and seed yield of finger millet.

2. Materials and methods

The field experiment to assess the performance of variety VL-352 of finger millet, its growth and yield due to nano-DAP was carried out at Research and Extension Centre, Gaja, Tehri, Garhwal, Uttarakhand, India during 2 *khari* seasons of the year 2021 and 2022. The experiment comprised of 10 treatments (Tabel 1) that were laid out in Randomized Block Design (RBD) with three replications in 30 plots each of size 2.75m x 2.5m. Plant population per meter row length was measured by counting the number of plants present in one meter row length at initial (30DAS) and at harvest stage. Other plant growth parameters such as plant height (cm), root length (cm), shoot length (cm), number of green leaves per plant and number of tillers per plant of five randomly selected plants from each treatment of each replication were recorded.

Yield attributes and economic parameters: Panicle length (cm), finger length (cm), and number of fingers per ear of five randomly selected plants were recorded at maturity. Test weight (g), seed yield (kg/ha), straw yield (kg/ha), biological yield (kg/ha) and harvest index % were recorded after harvesting. Economic parameters such as cost of cultivation (₹/ha), gross return (₹/ha), net return (₹/ha) and B:C ratio were also calculated.

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Yield attributes.....
Economic parameters.....

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Statistical analysis: The experimental data obtained during the investigation was statistically analysed by applying analysis of variance (ANOVA) through Randomized Block Design with OPSTAT Programme, designed and developed by O.P. Sheoran, Computer Programmer, Computer Section, CCS HAU, Hisar, India

[Table 1. Treatments details](#)

	Treatment details	Time of nano-DAP application
T ₁	0% P; Remaining N & 100% K (Control)	No Basal DAP
T ₂	100% P through DAP (100% N&K University Recommended)	No foliar spray of nano-DAP
T ₃	75% P through DAP (100% N&K University Recommended)	No foliar spray of nano-DAP
T ₄	50% P through DAP (100% N&K University Recommended)	No foliar spray of nano-DAP
T ₅	T ₃ + Seed treatment with nano-DAP @5ml/kg seed + Foliar spray with nano-DAP @2 ml/l of water	At 30-35 days after germination
T ₆	T ₃ + Seed treatment with nano-DAP @5ml/kg seed + Foliar spray with nano-DAP @4 ml/l of water	At 30-35 days after germination
T ₇	T ₄ + Seed treatment with nano-DAP @5ml/kg seed + Foliar spray with nano-DAP @2 ml/l of water	At 30-35 days after germination
T ₈	T ₄ + Seed treatment with nano-DAP @5ml/kg seed + Foliar spray with nano-DAP @4 ml/l of water	At 30-35 days after germination
T ₉	T ₄ + Seed treatment with nano-DAP @5ml/kg seed + 2 Foliar sprays with nano-DAP @2 ml/l of water	At 30-35 & 45 days after germination
T ₁₀	T ₄ + Seed treatment with nano-DAP @5ml/kg seed + 2 Foliar sprays with nano-DAP @4 ml/l of water	At 30-35 & 45 days after germination

[Below the table, please write a legend with explanations for the abbreviations in the table](#)

List 1 : **Treatment details**

3. RESULTS AND DISCUSSION

Plant growth parameters: As shown by the data in [Table 24](#), the influence of treatments on the plant population per meter row length at initial and at harvesting stage, plant height, root length, shoot length, number of green leaves per plant and number of tillers per plant were found significant. The plant population of finger millet were recorded higher at the initial stage than at the harvest stage maybe due to mortality (intraspecific competition) of the plants [18]. It was observed that the plant height, root length and shoot length of finger millet increased with the crop age and this rise was rapid at the early growth stages while very slow increase from 90 DAS to harvest stage while number of tillers per plant increased till 90 DAS and then had become stagnant [19]. There was a linear increase in number of green leaves from 30 DAS to 90 DAS maybe due to more availability of nitrogen which produces cytokinin and stimulates the growth of underground and aboveground parts of plants, giving them intense green colour [20] [21].

The higher plant growth parameters were recorded in treatments where foliar spray of nano-DAP was applied as compared to the treatments without phosphorous application. This might be due to less fixation of the phosphorus in the soil, better absorption and utilization of macro & micro nutrients [22], more availability of nitrogen and phosphorous during the early and vegetative growth stages either through basal, seed treatment or foliar application of nano-DAP that might have helped the plants to absorb water and light more effectively through stomata, increased chlorophyll formation, higher

Comment [u6]: The management of nutrients is crucial for increasing finger millet's yield. The overuse of fertilizers have resulted in lower fertilizer efficiency due to leaching losses, volatilization and denitrification losses. The availability of phosphorus is lesser due to fixation of phosphorus at soil collides. In order to avoid or minimize such losses and fixation, seed treatment with foliar application of nano-DAP is one of the fastest ways to enhance crop growth. The current investigation was conducted in kharif 2022, with variety VL-352 at Research and Extension Centre, Gaja, College of Forestry, Ranichauri (TehriGarhwal), Uttarakhand.

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metabolic activity and increased photosynthesis rate resulting in taller plants, increased number of functioning leaves, higher leaf area index and possibly more number of tillers [23] [24] [25].

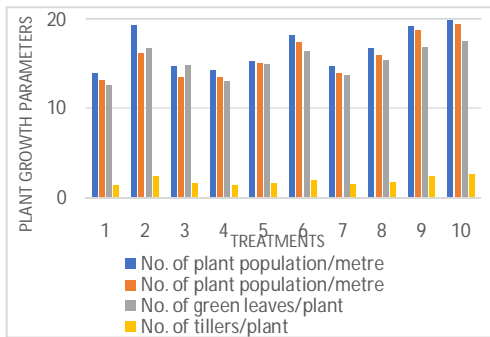
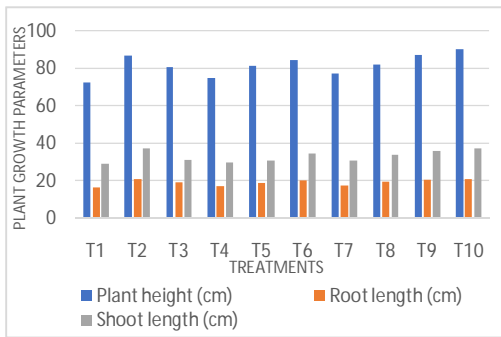
Table 42.:-Effect of nano-DAP on different plant growth parameters of finger millet.

S. No.	Parameters Treatments	Plant growth parameters						
		No. of plant population/metre		Plant height (cm)	Root length (cm)	Shoot length (cm)	No. of green leaves /plant	No. of tillers/plant
		At 30DAS	At harvest					
T1	NK 100%	14.0	13.1	72.02	16.26	28.80	12.65	1.37
T2	NPK 100%	19.3	16.2	86.69	20.55	36.77	16.69	2.48
T3	75% P+ 100%N+ 100%K	14.8	13.5	80.56	18.90	31.08	14.83	1.61
T4	50% P+ 100%N+ 100%K	14.3	13.5	74.72	16.70	29.46	13.03	1.46
T5	75%P+ 100%N+ 100%K+ ST+FS(2ml)	15.3	15.0	81.09	18.57	30.56	14.91	1.62
T6	75%P+ 100%N+ 100%K+ ST+FS(4ml)	18.2	17.4	84.29	19.97	34.32	16.42	1.95
T7	50%P+ 100%N+ 100%K+ ST+FS(2ml)	14.7	14.0	77.02	16.95	30.47	13.66	1.51
T8	50%P+ 100%N+ 100%K+ ST+FS(4ml)	16.7	15.9	81.80	19.35	33.57	15.43	1.75
T9	50%P+100%N+100%K+ST+FS(2ml)+FS(2ml)	19.2	18.7	86.99	20.20	35.57	16.85	2.36
T10	50%P+100%N+100%K+ST+FS(4ml)+FS(4ml)	19.8	19.4	89.88	20.69	37.14	17.53	2.70
	C.D. @ 5%	1.8	2.8	10.05	3.03	NS	2.03	0.36
	SE(m)±	0.6	0.9	3.36	1.01	2.19	0.68	0.12

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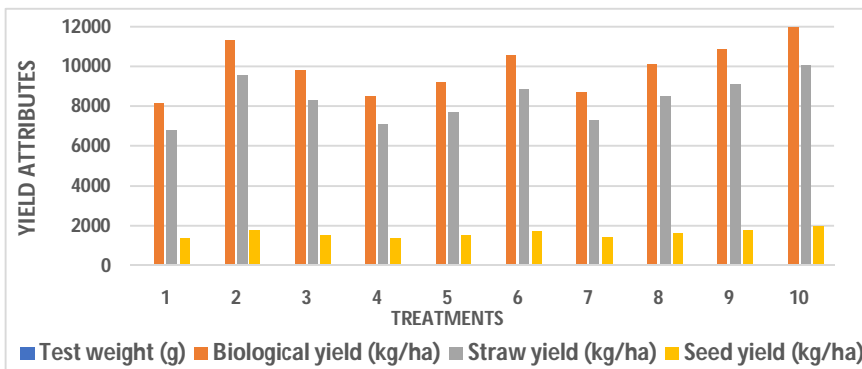
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N functions as a signalling molecule to promote seed germination by lowering the abscisic acid/gibberellins ratio [26] that regulates seed dormancy and seed germination [27] and helps in cell division and elongation which promotes healthy vegetative growth and vigorous plant growth [28] [29] [30]. The P present in seeds are the only P available to plants at the time of seed germination [10]. Phosphorus is a vital component of the energy unit of plants ATP structure, which is utilized in cellular processes, including synthesis of macromolecules, membrane phospholipids and nutrient transport and processes from the beginning of seedling growth. This higher availability of phosphorus could have accelerated various physiological processes such as seed germination, seedling establishment, increased root and shoot development and higher plant growth in finger millet [13] [31]. Similar findings were also reported by [32] that the foliar application of DAP in pigeon pea resulted in higher growth as DAP contains nutrients (nitrates and exchangeable P) which are easily available to plant shoots that are involved in cell division, cell elongation, increase in photosynthetic activity and better accumulation of photosynthates.



Yield attributes and economic parameters: As depicted in [Table 32](#), the yield attributes viz. panicle length (cm), finger length (cm), number of fingers per ear, test weight (g), seed yield (kg/ha), straw yield (kg/ha) and biological yield (kg/ha) were significantly influenced by the seed treatment and foliar application of nano-DAP. The yield attributes were recorded significantly higher in treatment T10 [50%P+ 100%N+ 100%K+ ST+FS(4ml) +FS(4ml)] which were statistically at par with T2 [100%NPK], T9 [50%P+ 100%N+ 100%K+ ST+FS(2ml) +FS(2ml)], T6 [75%P+ 100%N+ 100%K+ ST+FS(4ml)] and T8 [50%P+ 100%N+ 100%K+ ST+FS(4ml)]. The increase in the panicle length and finger length might be due to the direct availability of optimum phosphorus and nitrogen through foliar spray of nano-DAP which might have improved nutrient absorption, resulting in activated metabolic processes such as photosynthesis that helped in higher accumulation of photosynthates and translocation to the plant's economic parts, improving crop growth, development and yield [13][16]. The increase in the number of fingers per ear could be due to the synthesis of amino acid, chlorophyll and better transformation of carbohydrates [33]. The higher test weight in T10 might be due to the positive effect of phosphorus and nitrogen to increase the leaf area index which might have increased the surface exposed to light and its absorption that may have increased the products of the carbon assimilation process in the leaf as well as stored in other plant tissues that move later when forming seeds to increase their fullness and weight gain [34].

Phosphorus is a major compound in seeds and an effective source of energy as it moves into newly formed grains to gain weight. The amount of nitrogen and phosphorus applied by the foliar spray of nano-DAP enhanced all the growth parameters, dry matter production and yield attributes as a result of greater photosynthesis that greatly influenced straw yield which affects biological yield which in turn effects grain yield production [35][36][37] reported that the application of nano-fertilizer resulted in increased growth rate by 32.6% and seed production by 20.4% in comparison to non-nano-fertilizer. [38] also observed that foliar spray of nano-fertilizer boosted wheat crop yield and its yield attributes. The economics parameters for finger millet were calculated and presented in [Table 32](#). The highest gross return (₹/ha), net return (₹/ha) and benefit-cost (B:C) ratio were found with the treatment T10 [50%P+ 100%N+ 100%K+ ST+FS(4ml) +FS(4ml)] while lowest were recorded in T1[0%P+NK 100%]. This might be due to the higher grain yield production. It was reported by [39] that the application of basal dose of fertilizer along with 2% DAP spray twice gave higher net return in rice fallow green gram. [40] also reported that the foliar spray of 2% DAP at two different growth stages registered higher gross monetary return, net monetary return and benefit-cost ratio in chickpea. Similarly, [41] also observed that the foliar application of 2% DAP increased the gross return, net return and B:C ratio of soybean.



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Fig 3: Graph depicting Yield attributes against different treatments.

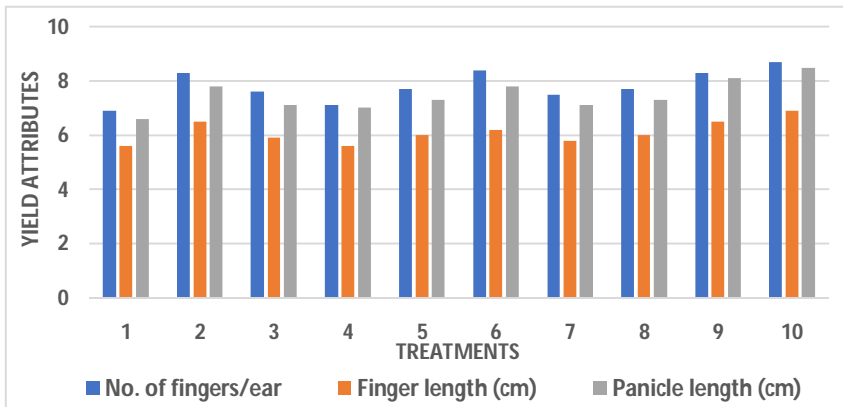


Fig 4: Graph showing Yield attributes against different treatments.

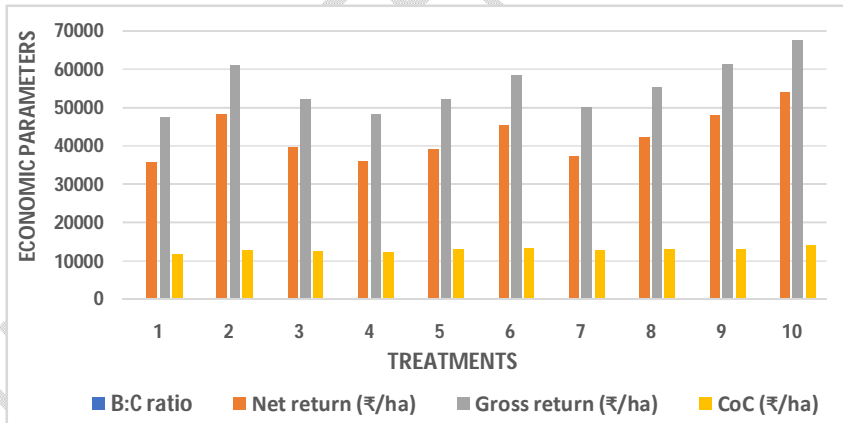


Fig 5: Graph depicting economic parameters against different treatments.

Table 2: Effect of nano-DAP on yield, yield attributes and economic parameters of ONC LUSION

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Yield Attributes and Economic Parameters														
S.No.	Treatments	Panicle length (cm)	Finger length (cm)	No. of fingers/ear	Panicle weight (g)	Test weight (g)	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index %	CoC (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B:C ratio
T1	NK 100%	6.6	5.6	6.9	5.93	2.57	1360	6751	8111	16.10	11661	47381	35720	3.06
T2	NPK 100%	7.8	6.5	8.3	8.79	2.96	1758	9546	11305	15.21	12705	60974	48269	3.80
T3	75%P+100%N+100%K	7.1	5.9	7.6	7.16	2.77	1494	8314	9808	14.63	12443	52120	39677	3.19
T4	50%P+100%N+100%K	7.0	5.6	7.1	6.10	2.63	1377	7106	8483	15.47	12182	48130	35948	2.95
T5	75%P+100%N+100%K + ST+FS(2ml)	7.3	6.0	7.7	6.86	2.77	1501	7689	9190	15.84	12943	52114	39171	3.03
T6	75%P+100%N+100%K + ST+FS(4ml)	7.8	6.2	8.4	7.81	2.87	1690	8836	10526	15.77	13243	58584	45341	3.42
T7	50%P+100%N+100%K + ST+FS(2ml)	7.1	5.8	7.5	6.29	2.72	1433	7278	8711	15.72	12682	49980	37298	2.94
T8	50%P+100%N+100%K + ST+FS(4ml)	7.3	6.0	7.7	7.29	2.82	1600	8482	10082	15.32	12982	55324	42342	3.26
T9	50%P+100%N+100%K + ST+FS(2ml)	8.1	6.5	8.3	8.65	2.92	1770	9085	10855	15.91	13182	61168	47986	3.64
T10	50%P+100%N+100%K + ST+FS(4ml)	8.5	6.9	8.7	9.24	3.15	1947	10035	11983	15.78	13782	67616	53834	3.91
	C.D. @ 5%	0.7	0.6	0.7	1.36	0.20	228.2	1491.1	1484	N/A				
	SE(m)±	0.2	0.2	0.2	0.46	0.07	76.2	498.0	495	0.991				

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the use of 50% P through DAP and 100% NK along with seed treatment by nano DAP @5mL/kg seed as well as two foliar sprays of nano-DAP @4 mL of water, first at 30-35 days after germination and second at 45 days after seed germination gave significantly higher plant growth, seed yield and seed quality of finger millet.

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