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Influence of nano DAP on plant growth and seed yield in heat resilient maize hybrid/RCRMH-2 seed production

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Abstract
A field experiment was conducted to study the effect of seed treatment and foliar spray of nano DAP on plant growth and seed yield in heat-resilient maize hybrid RCRMH-2 seed production at the College of Agriculture, Bheemarayanagudi, during *rabi* 2023-24. The experiment was laid out in RCBD consisting of nine treatments replicated three times. The treatment consists of different levels of RDP along with seed treatment and foliar sprays of nano DAP. Among different treatments, 75% RDP + Seed treatment with nano DAP @ 5 ml kg^{-1} + two foliar sprays of nano DAP at 30 and 60 DAS recorded significantly higher plant height for female (124.73 cm, 146.5 cm at 60 DAS and harvest, respectively), plant height for male (102.98 cm, 136.20 cm at 60 DAS and harvest, respectively), cob length (14.50 cm), cob weight (112.66 cm), cob diameter (3.85 cm), hundred seed weight (37.39 g), seed yield per ha (30.80 q), and shelling percentage (87.36) over other treatments, which was followed by 100% RDP + Seed treatment with nano DAP @ 5 ml kg^{-1}. The lower yield parameters were recorded in seed treatment with nano DAP at 5 ml kg^{-1} + two foliar sprays of nano DAP. Based on the results of this experiment, it can be concluded that application of 75% RDP + seed treatment with nano DAP @ 5 ml kg^{-1}+ two foliar sprays of nano DAP can be used for obtaining maximum seed yield, which is most beneficial to seed producers.

Keywords: Heat resilient maize hybrid**,** nano DAP, seed treatment, foliar spray

Introduction
Maize (*Zea mays* L.) is the world's leading cereal crop which is widely cultivated for grain. It is one of the most versatile emerging crops having wider adaptability that was domesticated in Central America. Globally, it is known as the queen of cereals because of its highest genetic yield potential. It has a high nutritional profile and is composed of starch (72%), protein (10%), fiber (8.5%), oil (4.8%), sugar (3.0%), and ash (1.7%), underscoring its nutritional significance in agricultural and dietary terms (Hokmalipour *et al*., 2010) [7]. Beyond its role as a staple crop for human consumption and a high-quality feed for livestock, maize plays a multidimensional role in India's agricultural landscape. It serves as a fundamental raw material for diverse industrial applications, including the production of starch, oil, protein, alcoholic beverages, and food sweeteners. Additionally, maize has emerged as a promising candidate in the realm of biofuels, reflecting its potential to contribute to India's renewable energy initiatives.
Currently, nearly 1216.87 million tonnes of maize is being produced together by over 170 countries from an area of 205 million ha with an average productivity of 5.94 t ha^{-1} (FAO Stat., 2022) [4]. Among the maize-growing countries, India ranks 4th in area and 7th in production, representing around 4 per cent of the world's maize area and 2 per cent of total production. In India, it occupies an area of 10.74 million ha with a production of 38.08 million t and an average productivity of 3545 kg ha^{-1} (India stat., 2023) [8]. Maize has attained a commercial crop status due to its ease of cultivation, tolerance for pests and diseases, high yield, and better market price. It comes up well under a wide range of soil and climatic conditions. There is a lot of scope to increase the present maize yields.
Nano fertilizer is an important input in agriculture to improve crop growth, yield, and quality parameters with increased nutrient use efficiency, a reduction in fertilizer waste, and the cost of cultivation. Applying macronutrients at the nanoscale to seeds via seed treatment presents

several benefits, including enhanced nutrient absorption during seedling development, minimized nutrient runoff, increased seedling vitality, and optimized resource utilization. Foliar application is a method of providing plants with nutrients by directly spraying liquid fertilizers or other chemicals or natural products onto their leaves. This method is more effective for macro and micro-nutrients (Chavan *et al*., 2023) [3]. Nano DAP with its nano-sized particles, improves phosphorus availability, leading to enhanced root development, increased flowering and improved seed formation. Preliminary studies conducted on nano DAP under controlled conditions highlighted improved input use efficiency and enhanced crop productivity with reduced environmental concerns. The performance of nano DAP on the growth and yield of crops under field conditions needs to be studied for its efficacy.

Materials and Methods

A field experiment was conducted during *rabi* 2023-24 at College of Agriculture Bheemarayangudi. It is situated in the North-Eastern dry zone (Zone 2) of Karnataka state at latitude of 16.73^0 N, a longitude of 76.79^0 E, and an altitude of 379.40 m above mean sea level. The experiment was laid out in Randomized Complete Design (RCBD) with three replications. The nine treatments were T_1 [RDF (150:80:80 N:P_2O_5:K_2O kg ha^{-1})], T_2 (100% RDP and seed treatment with nano DAP @ 5 ml kg^{-1}), T_3 (75% RDP and seed treatment with nano DAP @ 5 ml kg^{-1}), T_4 (75% RDP and seed treatment with nano DAP @ 5 ml kg^{-1} and foliar spray of nano DAP @ 4 ml L^{-1}), T_5 (75% RDP and foliar spray of nano DAP @ 4 ml L^{-1}), T_6 (50% RDP and seed treatment with nano DAP @ 5 ml kg^{-1}), T_7 (50% RDP and seed treatment with nano DAP @ 5 ml kg^{-1} and foliar spray of nano DAP @ 4 ml L^{-1}), T_8 (50% RDP and foliar spray of nano DAP @ 4 ml L^{-1}), and T_9 (seed treatment with nano DAP @ 5 ml kg^{-1} and foliar spray of nano DAP @ 4 ml L^{-1}). Whereas recommended dose of nitrogen and potassium were common for all treatments and two foliar spray of nano DAP was sprayed at 30 and 60 DAS. The recommended dose of fertilizer in form of urea, DAP and MOP were applied as per treatments with recommended dose of 150:80:80 N:P_2O_5:K_2O kg ha^{-1}. IFFCO liquid nano DAP (8:16:0) was used for seed treatment and foliar spray. The freshly harvested seeds of the female parent (CAL 1514) and male parent (CML 451) of the maize hybrid RCRMH-2 was used for the study and planted in a 4:1 of female to male planting ratio followed by spacing of 60 cm x 20 cm.

The soil of the experimental site was black loamy in texture, moderately alkaline in reaction, low in available nitrogen and medium in available phosphorus and high in available potassium. For synchronization of flowering of the parental lines foliar spray of amino acid @ 2 ml L^{-1} + GA_3 @ 250 ppm + potash @ 5 per cent + urea @ 2 per cent to male parent was given at 30 and 45 days as the male parent was late flowering by 4-5 days. Detasseling was done as and when tassels emerged from the female parental line (CAL 1514).

Growth parameters such as plant height at 60 DAS and harvest were recorded from five randomly selected plants from net plot area. Days to 50% tasseling and days to 50% silking were recorded based on the emergence of tassels and silk in 50 per cent of the plants of the male parent (CML 451) and female parent (CAL 1514) in each plot respectively and the mean was expressed in number. The cobs were harvested after attaining physiological maturity based on the visual observations of the plant drying and the husk turning white. Cobs from male parent were harvested first, then from females (F_1) and kept separately. The cobs were sun dried in the threshing yard and yield parameters were recorded. The data collected from the experiment were analyzed statistically by the procedure prescribed by Sundararajan *et al*. (1972) [15]. Critical difference was calculated at 5 per cent level wherever 'F' test was significant.

Results and Discussion

Growth parameters

The influence of seed treatment and foliar spray of nano DAP showed a significant effect on plant height of female at 60 DAS and harvest are presented in table 1. Among the different treatments imposed on female parent, application of 75 per cent RDP combined with nano DAP as seed treatment @ 5 ml kg^{-1} and two foliar sprays @ 4 ml L^{-1} at 30 and 45 DAS recorded significantly highest plant height at 60 DAS (124.73 cm) and at harvest (146.55 cm) over other treatments. At harvest the same treatment T_4 was statistically on par with 100 per cent RDP with nano DAP as seed treatment @ 5 ml kg^{-1} (T_2) (138.00 cm). Whereas, sole application of nano DAP as seed treatment @ 5 ml kg^{-1} and two foliar sprays @ 4 ml L^{-1} (T_9) recorded the lowest plant height at 60 DAS (72.37 cm) and at harvest (118.62 cm). Nano fertilizers enhance nutrient availability to the growing plant by facilitating quick nutrient absorption through the stomata of leaves. This might have increased chlorophyll formation, photosynthetic rate, dry matter accumulation, better enzyme activity, and auxin metabolism in the plant, resulting in taller plants (Samui *et al*., 2022) [14]. Findings from Alzreejawi and Al-Juthery (2020) [2], Gomaa *et al*. (2020) [5], Yasser *et al*. (2020) [16] and Poudel *et al*. (2023) [12] supported the results.

A significant difference was observed for days to 50 per cent tasseling and 50 per cent silking in female parent due to the influence of seed treatment and foliar spray of nano-DAP along with different dose of conventional DAP and is presented in table 1. Significantly less number of days (61.12) for 50 per cent tasseling and (59.62) for 50 per cent silking were recorded by the treatment T_4 (75 per cent RDP combined with nano DAP as seed treatment @ 5 ml kg^{-1} and foliar spray @ 4 ml L^{-1}). The more number of days (64.12) for 50 per cent tasseling and (61.45) for 50 per cent silking were taken by the treatment T_9 (sole application of nano DAP as seed treatment @ 5 ml kg^{-1} and two foliar sprays @ 4 ml L^{-1}). compared to all other treatments. Improved phosphorus availability through nano DAP enhances the synthesis and activity of plant hormones like auxins and gibberellins, leading to early flowering (Liu and Lal 2014) [10].

Seed yield and yield parameters

The results pertaining to cob length, diameter and weight of the maize hybrid (RCRMH-2) were found to be significant due to the effect of seed treatment and foliar spray of nano DAP and are presented in table 2. Among the different treatments imposed application of 75 per cent RDP combined with nano DAP as seed treatment @ 5 ml kg^{-1} and two foliar sprays @ 4 ml L^{-1} at 30 DAS and 45 DAS (T_4) recorded significantly highest cob length (14.50 cm), cob diameter (3.85 cm) and cob weight (112.66 g) which was on par with treatment T_2 (100% RDP + Seed treatment with nano DAP at 5 ml kg^{-1}). In contrast, sole application of nano DAP as seed treatment @ 5 ml kg^{-1} and two foliar sprays @ 4 ml L^{-1} at 30 DAS and 45 DAS (T_9) recorded lowest cob length (12.33 cm), cob diameter (3.56 cm) and cob weight (87.77 g). Combined application of conventional DAP and nano DAP ensured the timely supply of nitrogen and phosphorus, leading to increased photosynthate production and translocation for seed development. This intensified the plant's photosynthetic activity, generating higher sugars and starch,

which were efficiently transported to developing grains, resulting in increased seed formation (Alzreejawi and Al-Juthery 2020) [2]. This aligns with the findings of Ajithkumar *et al.* (2021) [1] and Hena *et al*. (2022) [6].

The seed treatment and foliar spray of nano DAP applied to seed parent has significantly affected the hundred seed weight and seed yield presented in table 2. Among the different treatments imposed application of 75 per cent RDP combined with nano DAP as seed treatment @ 5 ml kg^{-1} and two foliar sprays @ 4 ml L^{-1} 30 DAS and 45 DAS (T_4) recorded significantly highest hundred seed weight (37.39g), and seed yield (30.80 q) which was on par with T_2 and T_3. In contrast, sole application of nano DAP as seed treatment @ 5 ml kg^{-1} and two foliar sprays @ 4 ml L^{-1} 30 DAS and 45 DAS (T_9) recorded the lowest hundred seed weight (32.51g), and seed yield (17.76 q). Increased seed yield is due to synergistic effect achieved by soil-applied conventional DAP and seed treatment and foliar spray of nano DAP, enhancing root establishment and foliar growth. Nano fertilizer particles, with their increased surface area, enhance spreading, penetration, and translocation through the phloem, binding with carrier proteins via aquaporins and undergoing rapid metabolism within plant cells (Kumar *et al*., 2021) [9]. Results are in line with the findings of Naveen *et al*. (2022) [11], and Poudel *et al*. (2023) [12].

Table 1: Effect of seed treatment and foliar spray of nano DAP on plant height of female parental line (CAL 1514), Days to 50% tasseling in pollen parent and days to 50% silking in seed parent of maize hybrid RCRMH-2

Treatments	Plant height (cm)		Days to 50% tasselling	Days to 50% silking
	60 DAS	At harvest		
T_1: RDF	100.04	132.18	61.56	59.89
T_2: 100% RDP + seed treatment with nano DAP @ 5 ml kg^{-1}	115.44	138.00	61.16	59.73
T_3: 75% RDP + seed treatment with nano DAP @ 5 ml kg^{-1}	112.98	135.45	61.35	59.82
T_4: 75% RDP + seed treatment with nano DAP @ 5 ml kg^{-1}+ two foliar sprays of nano DAP @ 4 ml kg^{-1} at 30DAS and 45 DAS	124.73	146.55	61.12	59.62
T_5: 75% RDP + two foliar sprays of nano DAP at 4 ml L^{-1} at 30DAS and 45 DAS	109.51	134.28	61.41	59.87
T_6: 50% RDP + seed treatment with nano DAP at 5 ml kg^{-1}	89.24	130.46	61.77	59.95
T_7: 50% RDP + seed treatment with nano DAP @ 5 ml kg^{-1}+ two foliar sprays of nano DAP at 4 ml L^{-1} at 30DAS and 45 DAS	97.91	131.02	61.66	59.92
T_8: 50% RDP + two foliar sprays of nano DAP @ 4 ml kg^{-1}	75.31	125.73	62.12	60.12
T_9: Seed treatment with nano DAP @ 5 ml kg^{-1}+ two foliar sprays of nano DAP @ 4 ml kg^{-1} at 30DAS and 45 DAS	72.37	118.62	64.12	61.45
Mean	99.73	132.47	61.81	60.04
S.Em.±	1.94	4.69	0.08	0.16
CD @ 5%	5.81	14.05	0.24	0.47

Table 2: Effect of seed treatment and foliar spray of nano DAP on cob length, diameter, weight, hundred seed weight and seed yield of RCRMH-2 F_1 hybrid maize

Treatments	Cob length (cm)	Cob diameter (cm)	Cob weight (g)	Hundred seed weight (g)	Seed yield per ha (q)
T_1: RDF	12.67	3.69	100.37	34.06	25.77
T_2: 100% RDP + seed treatment with nano DAP @ 5 ml kg^{-1}	14.37	3.79	101.92	35.18	27.98
T_3: 75% RDP + seed treatment with nano DAP @ 5 ml kg^{-1}	13.37	3.76	101.89	34.81	26.58
T_4: 75% RDP + seed treatment with nano DAP @ 5 ml kg^{-1}+ two foliar sprays of nano DAP @ 4 ml kg^{-1} at 30DAS and 45 DAS	14.50	3.85	112.66	37.39	30.80
T_5: 75% RDP + two foliar sprays of nano DAP at 4 ml L^{-1} at 30DAS and 45 DAS	12.85	3.72	101.00	34.09	26.22
T_6: 50% RDP + seed treatment with nano DAP at 5 ml kg^{-1}	12.53	3.67	93.18	33.82	22.04
T_7: 50% RDP + seed treatment with nano DAP @ 5 ml kg^{-1}+ two foliar sprays of nano DAP at 4 ml L^{-1} at 30DAS and 45 DAS	12.62	3.67	95.08	33.86	22.76
T_8: 50% RDP + two foliar sprays of nano DAP @ 4 ml kg^{-1}	12.45	3.63	88.07	32.78	20.72
T_9: Seed treatment with nano DAP @ 5 ml kg^{-1}+ two foliar sprays of nano DAP @ 4 ml kg^{-1} at 30DAS and 45 DAS	12.33	3.56	87.77	32.51	17.76
Mean	13.08	3.71	97.99	34.28	24.51
S.Em.±	0.15	0.02	1.39	0.81	1.42
CD @ 5%	0.46	0.06	4.16	2.44	4.24

Conclusion

Based on experimental results, it was concluded that application of 75% RDP + seed treatment with nano DAP at 5 ml kg^{-1} + two foliar spray of 4 ml L^{-1} nano DAP at 30 and 60 DAS recorded higher growth parameters, seed yield and yield attributing parameters of hybrid maize. By application of 75 per cent RDP combined with nano DAP as seed treatment @ 5 ml kg^{-1} and two foliar sprays @ 4 ml L^{-1} at 30 DAS and 45 DAS seed producers may get around 16.33 per cent more seed yield compare to application of only RDF.

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