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Response of nano fertilizers on growth, yield and economics of *kharif* sorghum

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Abstract
A field experiment was conducted during *kharif* 2022 at ARS, Hagari to study the effect of nano fertilizers on growth and yield of *kharif* sorghum. There were ten treatments consisting of different doses of RDF (four treatments with 50% RNP, four with 75% RNP, one with 100% RDF and one absolute control) with different doses of nano urea and DAP sprayed at 30 & 45 DAS. Results revealed that application of 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS has produced significantly higher plant height and dry matter accumulation. It has resulted in enhanced grain yield (3281 kg ha^{-1}) by 120.6% over absolute control (1487 kg ha^{-1}). It was profitable too in terms of higher net returns (Rs. 84,319 ha^{-1}) and B C ratio (2.99) of sorghum production. Results confirmed that reduced rate of conventional fertilizer can be substituted by foliar application of nano fertilizers to enhance nutrient use efficiency and economics.

Keywords: Nano urea, nano DAP, nano fertilizers, sorghum, yield

1. Introduction
Sorghum (*Sorghum bicolor* L. Moench) is an important crop of resource poor, small and marginal farmers in semi-arid regions. Grain sorghum, like other grains, is a good source of starch and protein, and as a gluten-free grain, can be used to treat celiac disease (Ratnavathi and Komala, 2016) [1]. As principal crop of dryland, it is popular with farmers due to assured grains and fodder yields for low-input cultivation under harsh weather, especially in drought.
Since the green revolution, chemical fertilizers have been deemed indispensable in modern crop production systems. In order to increase crop output and nutritional quality, fertilizers have become increasingly important, especially with the emergence of fertilizer-responsive crop types. Conventional fertilizers offer nutrients in chemical forms that are not often fully accessible to plants (Akshay Kumar Kurdekar, 2021) [2]. Additionally, the inversion of these chemical fertilizers to sparingly soluble forms in the soil is the main reason for the low utilization of most of the added macronutrients. As Sorghum being a nutritive exhaustive crop, it demands relatively higher amount of fertilizers but unscientific fertilizer management has affected the soil health and resulted in avert yield responses to applied fertilizer.
To address these challenges, we should think of an alternate technology such as nanotechnology to precisely detect and deliver correct quantity of nutrients and other inputs required by crops in suitable proportion that promote productivity while ensuring environmental safety. Farmers are using urea and DAP fertilizers for soil as well as foliar application to crops. However, the efficacy is lower. In view of the above facts, the present investigation was carried out to study the "Effect of nano fertilizers on growth and yield of *kharif* sorghum".

2. Materials and Methods
A field experiment was conducted during *kharif* 2022-23 at Agricultural Research Station Hagari, UAS, Raichur Karnataka (15º13´N, 77º05´ E, altitude 414 m). The soil of the experimental site belongs to Vertisols (medium black soil). Regarding chemical properties, the soil was neutral in reaction (pH-7.95), low in EC (0.79 dS m^{-1}) and medium in organic carbon content (5.40 g kg^{-1}). The soil was low in available nitrogen (236.50 kg ha^{-1}), medium in available phosphorus (42.70 kg ha^{-1}) and high in available potassium (348.60 kg ha^{-1}).
The experiment was laid out in randomized complete block design (RCBD) with three replications.

There were ten treatments consisting of different doses of RDF (four treatments with 50% RNP, four with 75% RNP, one with 100% RDF and one absolute control) with different doses of nano urea and DAP (1, 1.5, 2 and 3 ml l^{-1}) sprayed at 30 and 45 days after sowing (DAS). Whereas, recommended dose of K, S and FYM (37.5, 15 and 5,500 kg ha^{-1}, respectively) was applied to all the treatments except absolute control. The sorghum hybrid CSH-16 was selected for the study. Seeds were hand dibbled at 45 cm × 15 cm spacing in furrows on July 04, 2022 and harvested on October, 29, 2022.

From randomly tagged five plants, plant height was measured on the five tagged plants individually from ground level to the base of fully opened top leaf. Biometric observations were recorded at 30 days interval. The observation on grain and stover yield was recorded at harvest. The economics was worked out based on the prevailing market price for the existing year. Data analysis and interpretation was done using Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1967) [3].

3. Results and Discussion

3.1 Effect of nano fertilizers on growth attributes

3.1.1 Plant height

Plant height of sorghum was significantly influenced by different levels of chemical and nano fertilizers (Table 1). Application of 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS recorded significantly higher plant height. However, it was comparable with application of 75% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS and recommended dose of fertilizers (RDF). Significantly dwarf plants of sorghum were recorded in absolute control. Significant increase in plant height might be due to the fact that basal application of conventional fertilizers along with foliar spray of nano fertilizers increased activity of enzymes and auxin metabolism in the plant, which in turn enlarge the cell and cell elongation might resulted in taller plants. This is in conformity with the works of Yasser *et al.* (2020) [4] and Gupta *et al.* (2022) [5].

3.1.2 Dry matter production

Dry matter production and its accumulation at various growth stages was significantly affected by the application of different levels of chemical and nano fertilizers (Fig. 1). Significantly higher dry matter accumulation at harvest was noticed in 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS (216 g $plant^{-1}$) and it was found on par with 75% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS (211.7 g $plant^{-1}$) and recommended dose of fertilizers (RDF) (208.3 g $plant^{-1}$). While, lower dry matter accumulation was observed in the absolute control. Tiny size of nano fertilizers results in better absorption of nano nutrients which affects plant growth mechanisms. Plant metabolic activities such as chlorophyll synthesis and photosynthetic activity both of which enhance vegetative growth increased due to proper supply of nutrients and accumulation of dry matter in leaves helped, the photosynthetic area to remain active for, longer period and was responsible for overall growth of plant in terms of dry matter. Production. Similar observations were recorded by Sharma *et al.* (2022) [6] and Maheta *et al.* (2023) [7].

3.2 Effect of nano fertilizers on yield

Significant differences were observed in yield and yield components viz., length of earhead (cm), number of grains per earhead, grain weight per earhead (g), test weight (g 1000 $grains^{-1}$), grain yield (kg ha^{-1}), stover yield (kg ha^{-1}), biomass yield (kg ha^{-1}) and harvest index (%) due to different levels of chemical and nano fertilizers (Table 2).

3.2.1. Grain yield

Significantly higher grain yield was recorded by application of 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS (3281 kg ha^{-1}) over rest of the treatments and was found on par with 75% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS (3189 kg ha^{-1}) and recommended dose of fertilizers (RDF) (3163 kg ha^{-1}). Significantly lower grain yield was recorded in absolute control (1487 kg ha^{-1}) as compared to all other treatments. Higher grain yield might be attributed to higher yield components viz. earhead length, maximum number of grains per earhead, grain weight and test weight. In addition to combined application of conventional and nano fertilizers (nano urea and DAP) ensured optimum and balanced nutrient availability throughout the crop period especially during the critical stages of crop. This is due to smaller size and larger effective surface area of nano particles which can easily penetrate into the plant and lead to better uptake of nitrogen and phosphorous. The higher uptake results in optimal growth of plant parts and metabolic processes like photosynthesis that increase photosynthates accumulation and translocation to the economically productive parts of the plant which results in increased biomass, yield attributing characters and finally yield by amplifying the translocation of assimilates to seeds. Similar results were reported by Bhargavi and Sundari (2023) [8] and Rajesh (2023) [9].

3.2.2 Stover yield

Application of 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS recorded significantly higher stover yield (9731 kg ha^{-1}) as compared to other treatments and found on par with 75% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS (9515 kg ha^{-1}) and recommended dose of fertilizers (RDF) (9446 kg ha^{-1}). Whereas, significantly lower stover yield was produced in absolute control (5226 kg ha^{-1}) as compared all to other treatments. Likewise, the increase in stover production with the foliar spray of nano fertilizers might be credited to nano fertilizers because of the rapid uptake of nano fertilizers by the plant and ease of translocation which assisted in a quicker rate of photosynthesis and more dry matter accumulation, resulting in a higher stover yield. This is in conformity with the results of Mallikarjuna (2021) [10] and Rajput *et al.* (2022) [11].

3.2.3 Harvest index

The harvest index (%) of sorghum was not influenced by different levels of chemical and nano fertilizers (Table 12). However, higher and lower harvest index was recorded in 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS (25.2%) and absolute control (22.1%), respectively.

3.3 Effect of nano fertilizers on economics

Among different teratments, application of 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS has incurred greater cost of cultivation of sorghum (Rs. 42,330 ha^{-1}) as compared to all other treatments (Table 3). It was lowest in absolute control (Rs. 27,380 ha^{-1}). Significantly higher gross returns, net returns and B:C were noticed in 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS (Rs. 1,26,649 ha^{-1}, Rs. 84,319 ha^{-1} and 2.99, respectively). However, it was found on par with 75% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS (Rs. 1,23,258 ha^{-1}, Rs. 81,608 ha^{-1} and 2.96) and recommended dose of fertilizers (RDF) (Rs. 1,22,289 ha^{-1}, Rs. 80,415ha^{-1} and 2.92). Whereas, lower gross returns, net returns and B:C were noticed in in absolute control (Rs. 59,843 ha^{-1}, Rs. 32,013 ha^{-1} and 2.15).

The gross returns, net returns and b:c was lowest in absolute control because the nutrient requirement of plant was not met, as a result of this the plant produced lower yields and fetched lower returns. Whereas, basal application of conventional and foliar application of nano fertilizers supplied the required amount of nutrients adequately and resulted in producing higher yields fetching higher returns. Similar results were also obtained by Rawat (2017) [12] and Sankar *et al.* (2020) [13].

Table 1: Plant height at different growth stages of *kharif* sorghum as influenced by different levels of chemical and nano fertilizers

Treatments	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1 : 50% RNP as basal + nano urea & DAP spray @ 1.0 ml l^{-1} each at 30 and 45 DAS	27.5	105.5	135.1	141.9
T_2 : 50% RNP as basal + nano urea & DAP spray @ 2.0 ml l^{-1} each at 30 DAS	27.6	104.7	134.2	139.5
T_3 : 50% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS	28.4	106.6	138.1	144.8
T_4 : 50% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS	28.3	105.8	135.4	142.2
T_5 : 75% RNP as basal + nano urea & DAP spray @ 1.0 ml l^{-1} each at 30 and 45 DAS	29.4	108.8	140.4	147.6
T_6 : 75% RNP as basal + nano urea & DAP spray @ 2.0 ml l^{-1} each at 30 DAS	29.2	107.4	138.4	145.2
T_7 : 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS	29.1	115.0	151.0	160.8
T_8 : 75% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS	29.4	112.7	146.4	157.2
T_9 : Recommended dose of fertilizers (RDF)	30.5	111.5	142.8	153.0
T_{10} : Absolute control (No NPKZn)	25.6	98.1	123.6	129.9
S.Em±	0.3	2.0	3.4	2.7
C.D. (P=0.05)	NS	5.9	10.2	8.0

Note
RNP - Recommended NP (100:75 kg N:P_2O_5 ha^{-1})
RDF -100:75:37.5:15 kg N:P_2O_5:K_2O:$ZnSO_4$ ha^{-1}; FYM @ 5.5 t ha^{-1}
DAS: Days after sowing

Table 2: Grain yield, straw yield and harvest index (%) of *kharif* sorghum as influenced by different levels of chemical and nano fertilizers

Treatments	Grain yield (Kg ha^{-1})	Stover yield (Kg ha^{-1})	Harvest index (%)
T_1 : 50% RNP as basal + nano urea & DAP spray @ 1.0 ml l^{-1} each at 30 and 45 DAS	2288	7314	23.8
T_2 : 50% RNP as basal + nano urea & DAP spray @ 2.0 ml l^{-1} each at 30 DAS	2217	6721	24.8
T_3 : 50% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS	2546	7654	25.0
T_4 : 50% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS	2502	7493	25.1
T_5 : 75% RNP as basal + nano urea & DAP spray @ 1.0 ml l^{-1} each at 30 and 45 DAS	2683	8236	24.6
T_6 : 75% RNP as basal + nano urea & DAP spray @ 2.0 ml l^{-1} each at 30 DAS	2598	8146	24.2
T_7 : 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS	3281	9731	25.2
T_8 : 75% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS	3189	9515	25.1
T_9 : Recommended dose of fertilizers (RDF)	3163	9446	25.1
T_{10} : Absolute control (No NPKZn)	1487	5226	22.1
S.Em±	41	197	0.5
C.D. (P=0.05)	122	585	1.6

Note
RNP - Recommended NP (100:75 kg N:P_2O_5 ha^{-1})
RDF -100:75:37.5:15 kg N:P_2O_5:K_2O:$ZnSO_4$ ha^{-1}; FYM @ 5.5 t ha^{-1}
DAS: Days after sowing

Table 3: Economics of *kharif* sorghum cultivation as influenced by different levels of chemical and nano fertilizers

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C
T_1 : 50% RNP as basal + nano urea & DAP spray @ 1.0 ml l^{-1} each at 30 and 45 DAS	38193	89896	51703	2.35
T_2 : 50% RNP as basal + nano urea & DAP spray @ 2.0 ml l^{-1} each at 30 DAS	37569	85999	48430	2.29
T_3 : 50% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS	39136	98579	59443	2.52
T_4 : 50% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS	38553	96787	58234	2.51
T_5 : 75% RNP as basal + nano urea & DAP spray @ 1.0 ml l^{-1} each at 30 and 45 DAS	40878	104403	63525	2.55
T_6 : 75% RNP as basal + nano urea & DAP spray @ 2.0 ml l^{-1} each at 30 DAS	40214	101598	61384	2.53
T_7 : 75% RNP as basal + nano urea & DAP spray @ 1.5 ml l^{-1} each at 30 and 45 DAS	42330	126649	84319	2.99
T_8 : 75% RNP as basal + nano urea & DAP spray @ 3.0 ml l^{-1} each at 30 DAS	41650	123258	81608	2.96
T_9 : Recommended dose of fertilizers (RDF)	41874	122289	80415	2.92
T_{10} : Absolute control (No NPKZn)	27830	59843	32013	2.15
S.Em±	-	1468	1468	0.04
C.D. (P=0.05)	-	4361	4361	0.11

Note
RNP - Recommended NP (100:75 kg N:P_2O_5 ha^{-1})
RDF -100:75:37.5:15 kg N:P_2O_5:K_2O:$ZnSO_4$ ha^{-1}; FYM @ 5.5 t ha^{-1}
DAS: Days after sowing

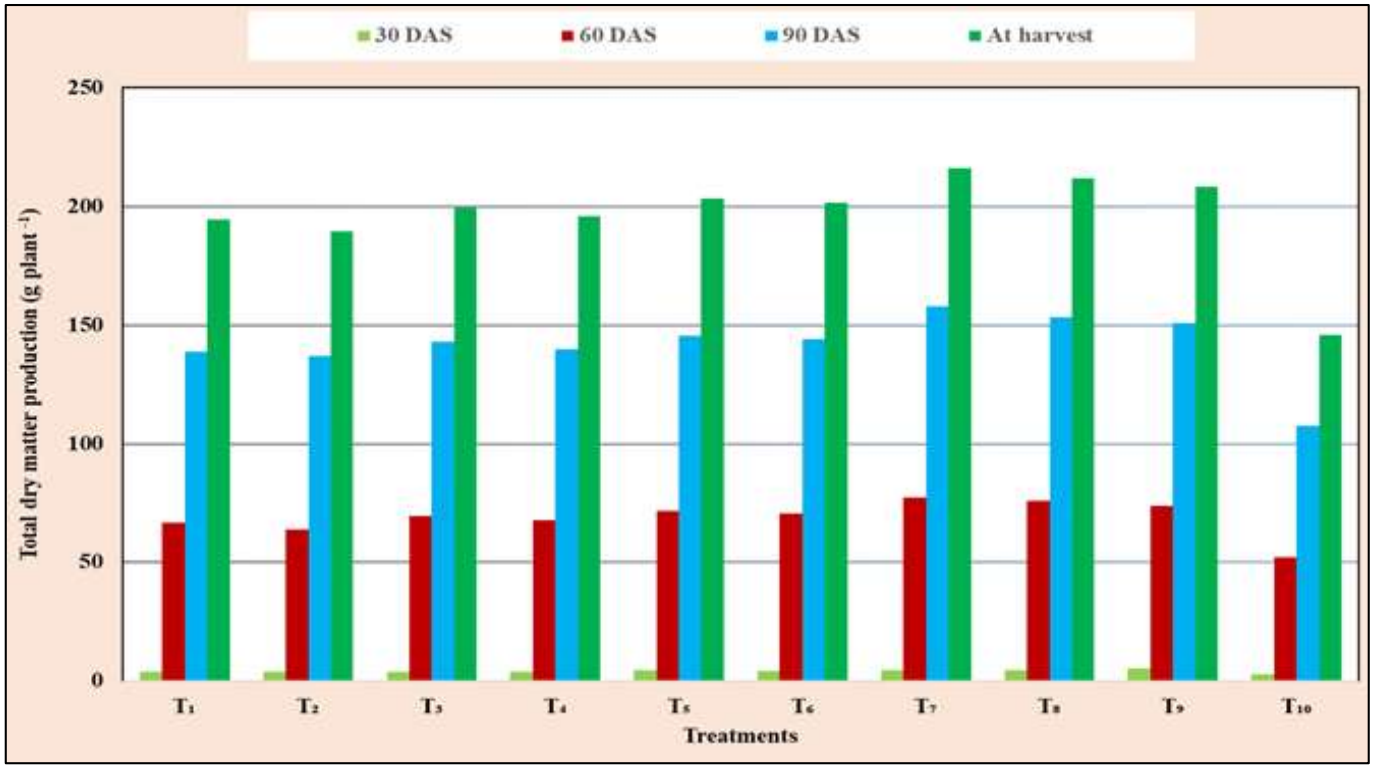

Fig 1: Total dry matter production of sorghum at harvest as influenced by different level of chemical and nano fertilizers

Conclusion

It was concluded that application of 75 percent of RNP along with nano urea and DAP spray @ 1.5 ml l^{-1} each at 30 & 45 DAS recorded higher plant height, dry matter production, grain yield, stover yield, gross returns, net returns and benefit cost ratio of sorghum as compared to other treatments. However, it was found on par 75 percent of RNP along with nano urea and DAP spray @ 3.0 ml l^{-1} each at 30 DAS and recommended dose of fertilizers. Lowest was noticed under absolute control.

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