E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(11): 33-38
Received: 03-09-2024
Accepted: 14-10-2024

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Studies on foliar application of nano urea and nano dap on growth and yield of sorghum (*Sorghum bicolor* (L.) Moench)

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i11Sa.1927

Abstract
A field experiment was conducted during the *kharif*-2023 at Experimental Farm, Agronomy section, College of Agriculture, Latur, to find out Studies on foliar application of nano urea and nano DAP on growth and yield of Sorghum (*Sorghum bicolor* (L.) Moench).
The soil of experimental plot was clayey in texture, moderately alkaline in reaction having pH (7.7) with chemical composition such as low in available nitrogen (230 kg ha^{-1}), very low in available phosphorous (19.5 kg ha^{-1}) and very high in available potassium (445 kg ha^{-1}). Soil was well drained which was favourable for optimum growth.
The experiment was laid out in Randomized Block Design with nine treatments replicate thrice. The treatments were T_1 - Control (without fertilizer), T_2 – 75% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS, T_3 - Foliar spray of 75% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS, T_4 - Foliar spray of 75% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS, T_5 – 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS, T_6 - Foliar spray of 100% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS, T_7 - Foliar spray of 100% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS, T_8 - Foliar spray of 125% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS and T_9 - Foliar spray of 125% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS. Sowing was done by dibbling method by using seed rate 12-15 kg ha^{-1}. The recommended dose of fertilizer was 80: 40: 40 NPK kg ha^{-1}.
The results showed that growth and yield components of sorghum were influenced significantly due to various treatments. The application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) was recorded significantly higher growth attributes *i.e.*, plant height, number of functional leaves, leaf area, stem girth, number of internodes and dry matter accumulation which was at par with treatment foliar spray of 125% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS (T_9), foliar spray of 125% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS (T_8) and 75% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS and significantly superior over the other treatments. Application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) recorded significantly highest grain yield (3083 kg ha^{-1}) over all the treatments except foliar spray of 125% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS (T_9),foliar spray of 125% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS (T_8) and 75% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_2). The highest GMR (114848 ₹ ha^{-1}), NMR (72183 ₹ ha^{-1}), and B:C ratio (2.70) was observed with the soil application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5).

Keywords: Sorghum, RDF, commercial urea, nano urea, nano DAP, foliar application

Introduction
Sorghum is an important staple food crop in the world, it is the fifth most important cereal crop after wheat, rice, maize and barley. Sorghum is an unique crop among the major cereals and the staple food and fodder crop of the world's poor and most food-insecure populations, located primarily in the semi-arid tropics. It is one of the major cereal crops consumed in India after rice

and wheat. It is considered as king of millets and extensively grown in semi-arid tracks of Africa, China and India. Sorghum is grown on 42 million ha area in the world, producing about 57.46 million tonnes of grain with an average yield of 1368 kg ha^{-1}.

Sorghum grain contains 11.3% protein, 3.3% fat and 56.73% starch. It is relatively rich in iron, zinc, phosphorus and vitamin B complex. Tannins are found particularly in red-grain types, contain antioxidants that protect against cell damage, a major cause of diseases and aging. The protein and starch in sorghum grain are more slowly digested than those from other cereals and slower rates of digestibility are particularly beneficial for people with diabetes. Sorghum starch is gluten free, making sorghum a good alternative to wheat flour for individuals suffering from celiac disease. Sorghum fodder is considered as an essential feed for the livestock, which can help in maintaining good health of cattle and contains more than 50% digestible nutrients with 8% protein, 2.5% fat and 45% nitrogen-free extract. Its dietary value is equivalent to corn that way animals enjoy well due to its deliciousness and juicy character. Sorghum is a smart crop capable of providing raw material for the making of starch, fibre, dextrose syrup, biofuels, alcohol and other goods especially under moderate inputs and water deficit environments. Sorghum is important feed and food in the world and used as fodder to feed millions of animals providing milk and meat for man. It is also used industrial raw material in various industries. In India flour is used after grinding the grains for preparing 'Bhakri'.

Among the essential nutrients, nitrogen is deficient in Indian soils. Nitrogen is essential constitute of chlorophyll and implies dark green colour to the plant and an integral part of amino acids. It contributes to the building units of protein and growth of plants. It promotes shoot elongation, tillering and regeneration after defoliation and governs to considerable degree, the utilization of phosphorous, potassium and other elements in the plant. The sorghum crop exhausts more nutrients than other forage crops and being cereal crop, requires higher amount of nutrients for higher productivity.

One of these is the environmentally friendly and very effective fertilizer called nano-fertilizer. Nano-fertilizers have distinct properties due to their small size and large surface area, which leads to an increase in the surface of absorption, which is reflected in the increase of photosynthesis, thus increased plant productivity. As a result, nanotechnology is used to produce these agriculturally useful nanoparticles and it can be used in increasing the value of agricultural production (Noaema *et al*. (2020) [9].

Nano fertilizers enhance growth parameters (plant height, leaf area, number of leaves per plant), dry matter production, chlorophyll production, rate of the photosynthesis which result more production and translocation of photosynthesis to different parts of the plant compare with traditional fertilizers (Ali and Al-Juthery 2017) [2]. Foliar application is the technique of feeding plants by spraying liquid fertilizers or other chemical or natural product directly to the leaves of macro and micronutrients are more effective in term of getting maximum yield and reduce losses (Rahman *et al*. 2014) [10].

Nano urea is a novel and innovative form of urea fertilizer that has gained attention for its potential to improve nutrient use efficiency than conventional urea. Nano urea (liquid) contain 4% N as encapsulated nitrogen analogues or forms embedded on an organic matrix. Nano urea has been priced at ₹240 per 500 ml bottle, which contains 40,000 ppm of nitrogen with a particle size of about 20-50 nm, more surface area (10,000 times over 1 mm urea prill) (Kumar *et al*., 2021) [6].

The development of nano DAP (liquid) for agricultural use has a pretty good prospect and it is said to be an answer for precisely providing nutrients for plants through a more efficient nutrient delivery system. 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 efficiency.

Materials and Methods

The present field experiment was conducted during *kharif* season of 2023 at farm of Agronomy section, College of Agriculture, Latur (Maharashtra).

The soil of experimental plot was medium and black in colour with good drainage. The topography of experimental field was uniform and fairly leveled. The representative soil samples from 0 to 30 cm depth were taken from randomly selected plots all over the experimental field before laying out the experiment. A composite soil sample of about half kg was taken and analyzed for the determination of various physical and chemical properties of soil. The soil of experimental plot was clayey in texture with chemical composition such as low in available nitrogen (230.00 kg ha^{-1}), very low in available phosphorous (19.5 kg ha^{-1}) and very high in available potassium (445 kg ha^{-1}). The soil was moderately alkaline in reaction having pH (7.8).

The field experiment was laid out in Randomized Block Design with three replications. There were nine treatments. The treatments details are T_1 - Control (without fertilizer), T_2 – 75% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS, T_3 - Foliar spray of 75% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS, T_4 - Foliar spray of 75% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS, T_5 – 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS, T_6 - Foliar spray of 100% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS, T_7 - Foliar spray of 100% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS, T_8 - Foliar spray of 125% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS, T_9 - Foliar spray of 125% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS.

The gross and net plot size of each experimental unit was 5.4 m x 4.5 m and 4.2 m x 3.9 m, respectively. Sowing was done by dibbling method on 06th July, 2023 at spacing of 45 x 15 cm. The recommended cultural practices and plant protection measures were undertaken. The recommended dose of fertilizer 80:40:40 NPK kg ha^{-1} was applied as per treatments, half dose of nitrogen along with full dose of phosphorus and potassium applied as basal dose through urea, Diammonium phosphate and muriate of potash. The remaining half dose of nitrogen was applied one month after sowing through urea as top dressing. The application of nano urea and nano DAP were taken as per the treatments and applied after sowing the seed. The crop was harvested on 03rd November 2023.

Results and Discussion

Effect of treatments

The soil application of 100% RD of N and P with commercial urea and DAP in two equal splits sowing and 30 DAS (T_5) to different treatments was observed on important yield parameters *viz.*, seed yield (kg ha^{-1}), stalk yield (kg ha^{-1}), biological yield (kg ha^{-1}), harvest index (%), GMR, CC, NMR, B:C ratio etc,

under study.

Yield and yield attributes

Seed yield (kg ha^{-1})

The information regarding the impact of various treatments on grain yield (kg ha^{-1}), which indicates that the average grain yield achieved was 3828.25 kg ha^{-1}.

The treatment with soil application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) which was recorded significantly higher grain yield of sorghum crop as compared to remaining other treatments.

The results of this investigation are consonance with the findings of Chavan *et al*. (2023) [4].

Stalk yield (kg ha^{-1})

The information regarding the impact of various treatments on straw yield (kg ha^{-1}), which indicates that the average grain yield achieved was 6018.77 kg ha^{-1}.

The treatment with soil application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) which was recorded significantly higher straw yield of sorghum crop as compared to remaining other treatments.

The results of this investigation are consonance with the findings of Chavan *et al*. (2023) [4] Meena *et al*. (2012) [7].

Biological yield (kg ha^{-1})

The information regarding the impact of various treatments on biological yield (kg ha^{-1}) which indicates that the average grain yield achieved was 10620.72 kg ha^{-1}.

The treatment with soil application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) which was recorded significantly higher biological yield of sorghum crop as compared to remaining other treatments.

Gross monetary return (₹ ha^{-1})

It was noted that the average gross financial returns for 2023–2024 were ₹ 92486 ha^{-1}. The treatment with soil application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) which was recorded highest gross monetary returns.

Net monetary return (₹ ha^{-1})

Data on net monetary returns (GMR) impacted by various treatments which showed that average gross financial returns for 2023–2024 were ₹ 49808 ha^{-1}. The treatment with soil application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) which was recorded highest net monetary returns.

Benefit: cost ratio

Data regarding the B:C ratio as influenced by different treatments. It was found that the average benefit to cost ratio was 2.20.

The highest B: C ratio (3.6) was observed with the soil application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) followed by treatments foliar spray of 125% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS (T_9), foliar spray of 125% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS (T_8) and 75% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_2) which were found to be at par with treatment T_5, whereas treatment (T1) control gave minimum benefit cost ratio i.e., (1.8)

Table 1: Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}), biological yield (kg ha-^{1}), Gross monetary returns (₹ ha^{-1}) and Net monetary returns (₹ ha^{-1}) of sorghum as influenced by different treatments.

Treatments	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	GMR (₹ ha^{-1})	CC (₹ ha-^{1})	NMR (₹ ha^{-1})	B:C Ratio
T_1 - Control (without fertilizer)	2344	4560	70330	40050	30280	1.8
T_2 – 75% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS	3351	6049	100559	42275	58284	2.4
T_3 - Foliar spray of 75% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS	2787	5650	83621	42665	40956	2.0
T_4 - Foliar spray of 75% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS	2858	5708	85764	42665	43099	2.0
T_5 – 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS	3828	6792	114848	42665	72183	2.7
T_6 - Foliar spray of 100% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS	2891	5874	86753	43185	43568	2.0
T_7 - Foliar spray of 100% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS	2911	6214	87339	43185	44154	2.0
T_8 - Foliar spray of 125% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS	3354	6547	100621	43705	56916	2.3
T_9 - Foliar spray of 125% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS	3417	6771	102536	43705	58831	2.3
SE(m)	168	355	5026	-	5026	-
C.D.at 5%	502	1065	20088	-	15066	-
General Mean	3083	6018	92486	42677	49808	2.20

Plate 1: General View Experimental plot

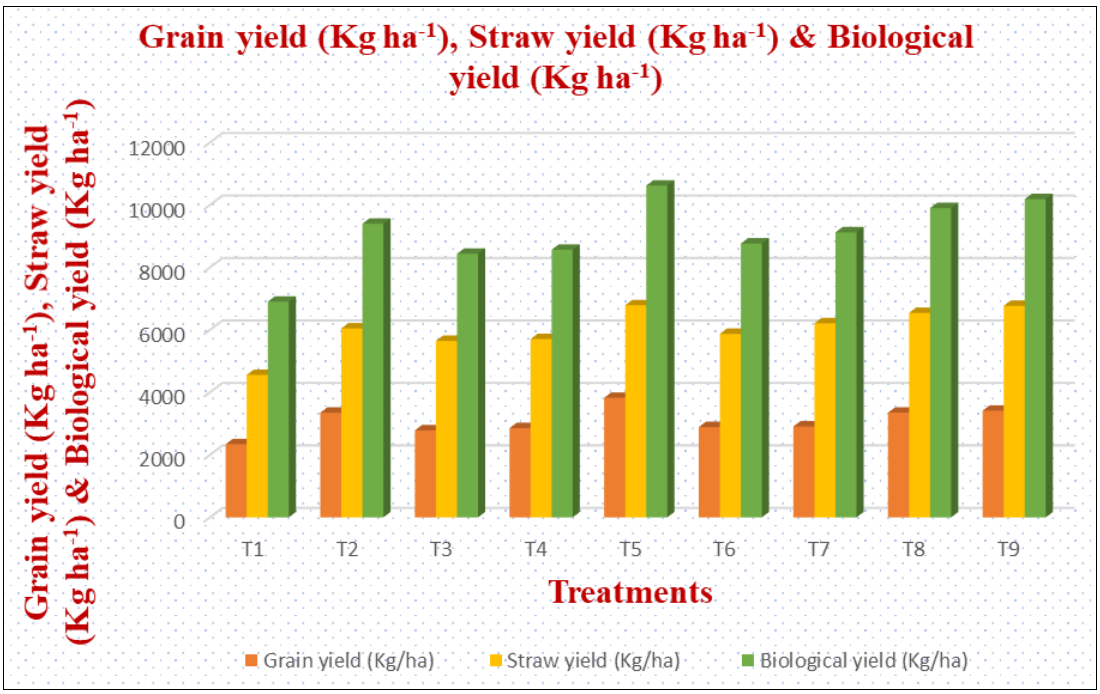

Fig 1: Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) & biological yield (kg ha-^{1}) of sorghum as influenced by different treatments

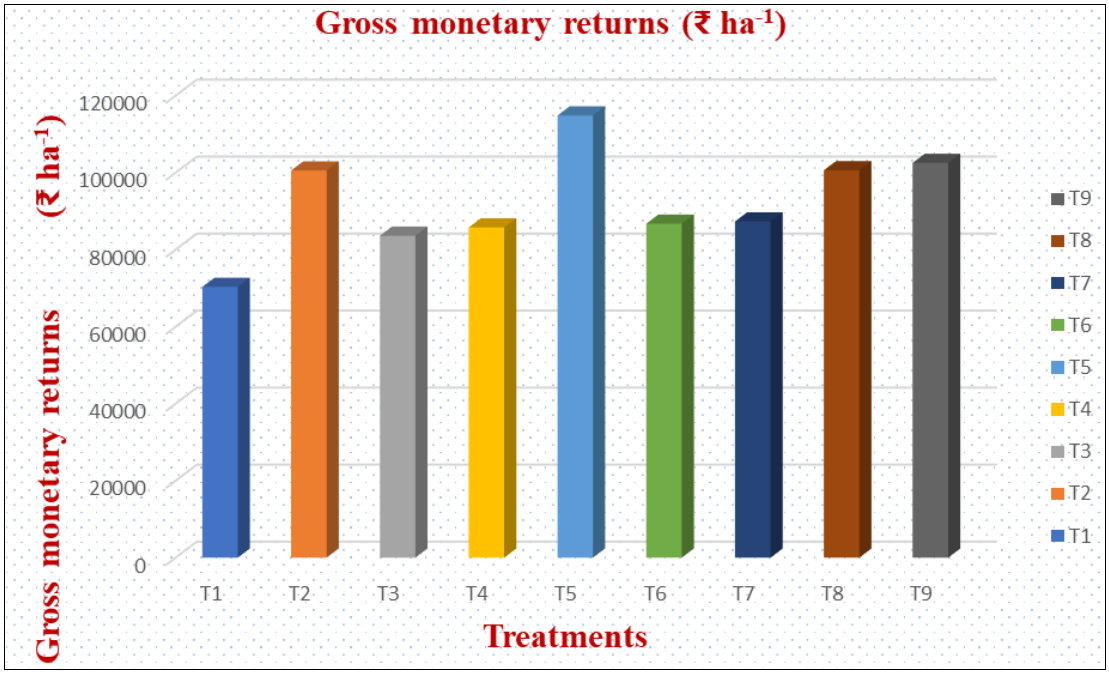

Fig 2: Gross monetary returns (₹ ha^{-1}) of sorghum as influenced by different treatments

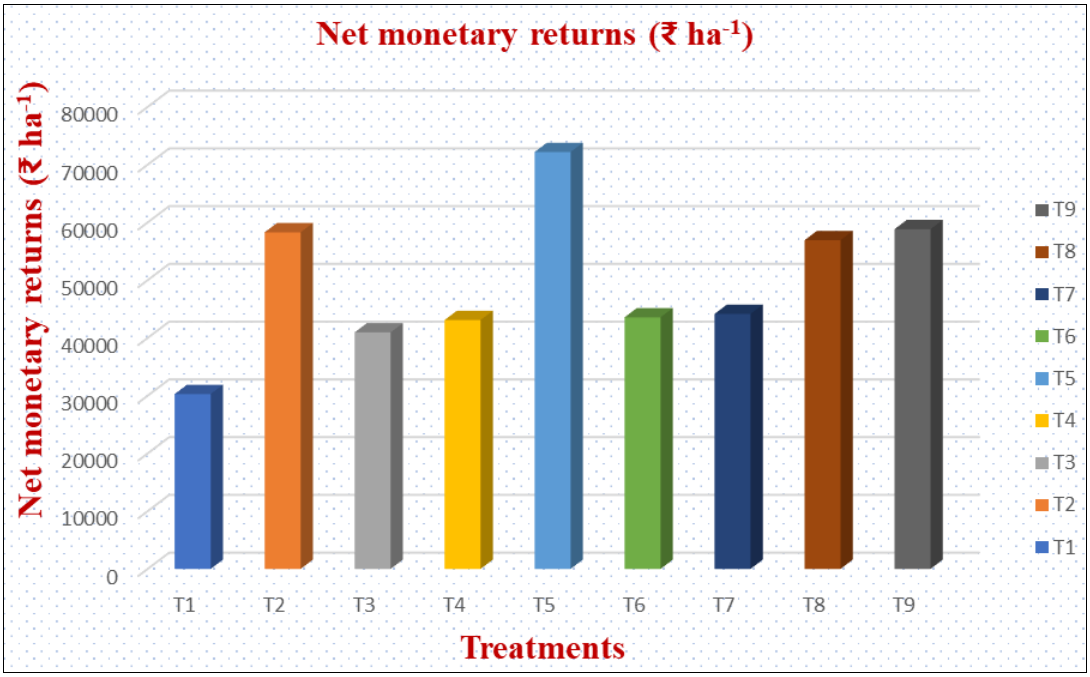

Fig 3: Net monetary returns (₹ ha^{-1}) of sorghum as influenced by different treatments

Conclusion

1. Grain yield and straw yield of sorghum was higher with application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) followed by foliar spray of 125% RD of N and P with nano urea and nano DAP in 3 equal splits 15, 30 and 45 DAS (T_9), foliar spray of 125% RD of N and P with nano urea and nano DAP in 2 equal splits 20 and 40 DAS (T_8) and 75% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_2)
2. The application of 100% RD of N and P with commercial urea and DAP in 2 equal splits at sowing and 30 DAS (T_5) was recorded in higher gross monetary, net monetary returns and B:C ratio. T9, T8 and T7 were the next best treatments.

Acknowledgement

We are grateful to College of Agriculture, Latur, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani for the financial assistance and infrastructure facilities provided for the conduct of this work.

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