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Response of nano DAP on growth, yield and quality of soybean

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Abstract
A field experiment was conducted during *kharif* 2022 at ICAR-KVK, Kalaburagi to study the response of nano DAP on growth, yield and quality of soybean. There were nine treatments consisting of different doses of RDF (two treatments with 50% RDF, two with 75% RDF, three with 100% RDF and one absolute control) with different doses of nano DAP spray (2 and 4 ml L^{-1}) at 30 & 45 DAS. Results revealed that application of 100% RDF as basal and nano DAP foliar spray @ 4 ml L^{-1} at 30 and 45 DAS has produced significantly higher number of leaves (4.5) per plant at harvest and higher number of branches per plant (8.7) at harvest. It has resulted in enhanced number of pods per plant (65.2), test weight (14.21 g) and seed yield per plant (25.45 g). Quality (38.53%, 18.98% and 376.7 kg ha^{-1}, protein content, oil content and oil yield, respectively) of soybean also enhanced by application of nano DAP.

Keywords: Nano DAP, foliar spray, soybean, RDF

1. Introduction

Soybean (*Glycine max* L.) is the world's most important seed legume, which contributes to 25 percent of the global edible oil, about two-thirds of the world's protein concentrate for livestock feeding. Soybean meal is a valuable ingredient in formulated feeds for poultry and fish. It contains about 40 percent protein and 20 percent oil content hence it is known as a "wonder crop".

Globally, soybean is grown over an area of 136.03 m ha and annual production of 369.72 m t with a productivity of 2720 kg ha^{-1} (Anon., 2023) [1]. In India, it occupies an area of 13.00 m ha with a production of 12.04 m t and productivity of 930 kg ha^{-1} (Anon., 2023a) [2], In Karnataka, soybean is cultivated in an area of 0.381 m ha with a production of 0.437 m t and productivity of 1147 kg ha^{-1} (Anon., 2022) [3].

Nanotechnology is the science of manipulating materials at the nano scale. Application of nanotechnology in agriculture has vast and sustainable benefits over many problems. In agriculture this technology can be used in fertilizers, pesticides, herbicides, and growth regulators.

This unique property enables it to enter easily inside the seed surface or through stomata and other plant openings. Nano clusters of nitrogen and phosphorus in nano DAP are functionalized with bio-polymers and other excipients. Better spread ability and assimilation of nano DAP inside the plant system leads to higher seed vigour, more chlorophyll, photosynthetic efficiency, better quality and increase in crop yields. Apart from this, nano DAP through precision and targeted application fulfils the nutritional requirement of crops without harming the environment. In view of the above facts, the present investigation was carried out to study the "Response of nano DAP on growth, yield and quality of soybean".

2. Materials and Methods

A field experiment was conducted during *kharif* 2022 at ICAR-Krishi Vigyan Kendra, Kalaburagi. It is situated in the North Eastern Dry Zone of Karnataka (Zone-2) between 17° 34' N latitude and 76° 79' E longitude with an altitude of 478 meters above the mean sea level.

The soil of the experimental site belongs to Vertisols (medium black soil). Regarding chemical properties, the soil was moderately alkaline in pH (8.21), low in EC (0.20 dS m^{-1}) and low in organic carbon content (4.65 g kg^{-1}), the soil was low in available nitrogen (216 kg ha^{-1}), medium in available phosphorus (28.60 kg ha^{-1}), high in available potassium (340 kg ha^{-1}) and medium in sulphur (14.20 kg ha^{-1}). The concentrations of DTPA extractable (mg kg^{-1}) micronutrients *viz.*, zinc, iron, copper and manganese, were 0.45, 2.16, 1.21 and 3.57, respectively and hot water soluble boron was recorded to be 0.27 mg kg^{-1}.

The experiment was laid out in randomized complete block design (RCBD) with three replications. There were nine treatments *viz.*, RDF (40:80:25 N: P_2O_5: K_2O kg ha^{-1}), 50% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS, 50% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS, 75% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS, 75% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS, 100% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS, 100% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS, Absolute control and were replicated thrice in the experiment.. Whereas, recommended dose of fertilizers in the form of urea, DAP, MOP, bentonite sulphur, zinc sulphate and borax were applied as per treatments with recommended dose of 40:80:25 kg N: P_2O_5:K_2O ha^{-1}. FYM @ 10 tonnes ha^{-1} was applied to all the treatments except absolute control. The soybean variety KDS-726 was selected for the study with spacing of 30 cm × 10 cm in furrows on July 16, 2022.
Intercultivation was done to remove all weeds from the field in order to check crop weed competition. Growth parameters such as number of leaves and branches per plant were recorded at 30, 45, 60 DAS and harvest. Harvesting was done at physiological maturity of the crop. The experimental area was harvested by cutting near to ground. After harvesting, the crop plants were tied together and dried under sun. The crop seed was threshed with wooden sticks after it had dried completely under the sun and then yield parameters were recorded**.** The protein content in grain was calculated by multiplying the nitrogen percentage with factor 6.25. Dried seeds of soybean drawn from the net plot of each treatment were used for estimation of oil content by Nuclear Magnetic Resonance (NMR) method and expressed in percentage. The instrument used is Nuclear Magnetic Resonance Spectrometry. The NMR technique measures the resonance of energy absorbed by the hydrogen atoms in the sample. Usually, oil content is expressed based on specific moisture content basis (%). Using the NMR in measuring oil content is referenced by ISO 10565:1998 Oilseeds. Oil yield was calculated by multiplying the oil percent with seed yield and whole divided by hundred. Data analysis and interpretation was done using Gomez and Gomez (1984) [4] technique.

3. Results and Discussion
3.1 Effect of nano DAP on growth parameters
3.1.1 Number of leaves per plant
Number of leaves per plant was significantly influenced by different levels of conventional fertilizers and nano DAP (Table 1). Application of 100% RDF and nano DAP foliar spray @ 4 ml L^{-1} at 30 and 45 DAS recorded significantly higher number of leaves per plant. However, it was on par with application of 100% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS. Whereas, significantly lower number of leaves per plant was recorded in absolute control. This might be due to the fact that basal application of conventional fertilizers along with foliar spray of nano DAP can enhance the photosynthetic efficiency of soybean plants. Increased activity of enzymes and auxin metabolism in the plant, which helps the plant grow taller and emerge with more nodes, resulting in a higher number of leaves per plant. Similar results were revealed by Yuvakumar *et al.* (2011) [5] and Akshay (2021) [6].

3.1.2 Number of branches per plant
Number of branches per plant at different growth stages was significantly affected by the application of different levels of chemical fertilizers and nano DAP (Table 2). Significantly more number of branches per plant was recorded in treatment T_7, *i.e.*, 100% RDF + nano DAP foliar spray @ 4 ml L^{-1} at 30 and 45 DAS and it was found on par with treatment T_6, *i.e.*, 100% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS. Whereas, less number of branches per plant was recorded in T_8 treatment, *i.e.*, the absolute control. Tiny size of nano DAP helps absorb nutrients directly into the leaves, where nutrients can be absorbed more quickly and efficiently, adequate nutrients can lead to increased cell division and elongation. Nutrient uptake in plants increases with more branches per plant. Similar observations were recorded by Vaghar *et al*. (2020) [7] and Manjunath Gondi (2018) [8].

3.2 Effect of nano DAP on yield parameters
At harvest, all the recorded data related to yield parameters of soybean were effectively influenced by nano DAP application and data related to yield parameters, *viz.*, number of pods per plant, test weight (g), seed yield per plant (g) are furnished in Table 3.

3.2.1 Number of pods per plant
Significantly maximum number of pods per plant (65.2) was recorded in 100% RDF through conventional fertilizer and two foliar sprays of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS and it was on par (61.7) with soil application of 100% RDF and nano DAP foliar spray @ 2 ml L^{-1} at 30 and 45 DAS. However, the absolute control recorded a significantly lower number of pods per plant (22.5). It might be due nano DAP supported all growth and yield parameters by means of cell enlargement, nutrient content enzymatic activities *etc.* In addition to combined application of conventional and nano 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. Similar results were reported by Manjili *et al.* (2014) [9] and Abdelghany *et al.* (2022) [10].

3.2.2 Test weight (g)
No significant difference was observed among the various treatments for test weight at harvest. However, a numerically higher test weight (14.21 g) was recorded in treatment with an application of 100% RDF and two foliar sprays of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS compared to other treatments. In comparison, a numerically lower test weight (11.35 g) was recorded in the absolute control.

3.2.3 Seed yield per plant (g)
Significantly higher seed yield per plant *i.e.*, 25.45 g was recorded with 100% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS. It was on par with 100% RDF and 2 ml L^{-1} nano DAP foliar spray at 30 and 45 DAS *i.e.*, 23.68 g. However, significantly lower seed yield per plant *i.e.*, 9.37 g was observed in absolute control. Foliar application of nano DAP helps to increase nutrient efficiency on a nanometer

scale in the form of nanoparticles. The particle size of liquid nano fertilizer is smaller than 30 nanometers. Due to its super tiny size and surface qualities allowing for easier penetration into leaves and increasing the yield contributing characteristics and yield. The present study results are in consensus with the findings of Manjunath Gondi (2018) [11] and Valadkhan *et al*. (2015) [12].

3.3 Effect of nano DAP on quality parameters

3.3.1 Protein content (%): The results found that foliar spray of nano DAP increased the protein content of soybean and depicted in Fig. 1. The maximum protein content, *i.e.*, 38.53% was significantly recorded with two foliar sprays of 4 ml L^{-1} nano DAP at 30 and 45 DAS with 100% RDF and it was on par with 100% RDF along with 2 m L^{-1} nano DAP foliar spray at 30 and 45 DAS, *i.e.*, 37.18%. Whereas, a significantly lower protein content, *i.e.*, 28.84% was recorded in the absolute control. Protein is composed of amino acids and nitrogen is a critical component of amino acids. When nitrogen is available in sufficient quantities during the reproductive phase of soybean growth (flowering and seed development) through RDF and two foliar sprays of nano DAP, it enhances the synthesis of amino acids, leading to increased protein content in the seeds. Similar results were found by Duraisamy and Mani (2001) [13] and Nget *et al.* (2022) [14].

3.3.2 Oil content (%)

Oil content was not significantly different due to the foliar application of nano DAP and it is depicted in Fig. 1. But the maximum oil content (18.98%) was recorded with application of 100% RDF + nano DAP @ 4 ml L^{-1} at 30 and 45 DAS. Whereas, lower oil content (17.53%) was recorded in absolute control (T_8).

3.3.3 Oil yield (kg ha^{-1})

A significant difference was observed in oil yield among various treatments. The higher oil yield (397.6 kg ha^{-1}) was recorded in treatment with 100% RDF + 4 ml L^{-1} nano DAP at 30 and 45 DAS. Which was on par (376.7 kg ha^{-1}) with treatment 100% RDF + 2 ml L^{-1} nano DAP at 30 and 45 DAS. However, a lower oil yield (203.7 kg ha^{-1}) was recorded in absolute control (Fig. 1). It might be due to supplying essential nutrients according to plant needs can lead to an increase in seed oil percentage due to enhanced enzymatic activity and effectively increased photosynthesis and translocation of assimilates to the seed. This might have resulted in a higher oil content compared to the control. However, no significant difference was observed in the oil content statistically, but the highest oil yield was recorded due to the higher seed yield and oil content produced. Similar results were reported by Yacoub *et al.* (2020) [15].

Table 1: Number of leaves per plant at different growth stages of soybean as influenced by foliar spray of nano DAP

Treatments	Number of leaves per plant			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
T_1 – RDF (40:80:25 N:P_2O_5:K_2O kg ha^{-1})	5.8	16.0	29.4	3.7
T_2 – 50% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	5.6	13.1	22.6	2.5
T_3 – 50% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	5.7	14.2	25.2	2.7
T_4 – 75% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	5.8	16.3	30.1	3.8
T_5 – 75% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	5.9	18.5	32.4	4.0
T_6 – 100% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	6.1	20.6	34.2	4.3
T_7 – 100% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	6.2	22.9	36.9	4.5
T_8 – Absolute Control	5.2	9.0	17.0	2.0
S.Em. ±	0.19	0.79	1.40	0.12
C.D. @ 5%	NS	2.41	4.24	0.37

Note: FYM @ 10 tonnes + 30:12.5:10 (S: Zn: B) kg ha^{-1} for all the treatment except T_8

DAS: Days after sowing

Table 2: Number of branches per plant at different growth stages of soybean as influenced by foliar spray of nano DAP

Treatments	Number of branches per plant			
	30 DAS	**45 DAS**	**60 DAS**	**At harvest**
T_1 – RDF (40:80:25 N:P_2O_5:K_2O kg ha_{-1})	2.2	4.1	6.7	7.4
T_2 – 50% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	1.8	3.2	5.6	6.1
T_3 – 50% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	2.0	3.4	5.9	6.4
T_4 – 75% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	2.2	4.1	6.9	7.4
T_5 – 75% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	2.3	4.3	7.2	7.6
T_6 – 100% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	2.3	4.7	7.6	8.2
T_7 – 100% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	2.3	5.1	8.1	8.7
T_8 – Absolute Control	1.8	2.6	4.0	4.2
S.Em. ±	0.13	0.14	0.27	0.29
C.D. @ 5%	NS	0.43	0.82	0.88

Note: FYM @ 10 tonnes + 30:12.5:10 (S: Zn: B) kg ha^{-1} for all the treatment except T_8

DAS: Days after sowing

Table 3: Yield attributes of soybean as influenced by foliar spray of nano DAP

Treatments	No. of pods plant^{-1}	100 seeds weight (g)	Seed yield plant^{-1} (g)
T_1 – RDF (40:80:25 N:P_2O_5:K_2O kg ha^{-1})	44.0	13.42	17.72
T_2 – 50% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	30.1	13.18	12.61
T_3 – 50% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	35.5	13.35	14.37
T_4 – 75% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	45.7	13.59	18.58
T_5 – 75% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	50.1	13.84	19.80
T_6 – 100% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	61.7	14.06	23.68
T_7 – 100% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	65.2	14.21	25.45
T_8 – Absolute Control	22.5	11.35	09.37
S.Em. ±	2.04	0.57	0.76
CD @ 5%	6.19	NS	2.31

Note – FYM @ 10 tonnes + 30:12.5:10 (S: Zn: B) kg ha^{-1} for all the treatment except T_8
DAS: Days after sowing

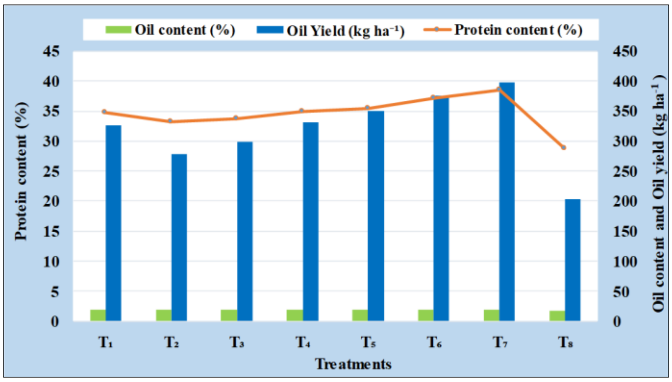

Fig 1: Quality parameters of soybean as influenced by foliar application of nano DAP

4. Conclusion

Application of 100% RDF (40:80:25 N: P_2O_5: K_2O) and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS of soybean was found to be on par with 100% RDF along with foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS in terms of crop growth, yield and quality Hence, for effective management of nano DAP in soybean, the application of 100% RDF and two foliar sprays of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS was recommended.

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