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Response of nano DAP on growth, yield and economics of Soybean (*Glycine max* L.)

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Abstract
The application of fertilizers in the right quantity and balanced manner at the right time is an important factor in enhancing the productivity of crops. Among different major nutrients, nitrogen and phosphorus are applied in high dose and the nutrient use efficiency of nitrogen is only 30 to 50 per cent. The remaining 50 to 70 per cent is lost due to volatilization, deep percolation and weed clearance. In case of phosphorus usage efficiency is just 15 to 20 per cent and remaining is lost due to soil fixation. Hence, nanotechnology assumes a greater role in reaching this task. Along with advancements in science, nano fertilizers or nano encapsulated nutrients are shown to have properties that are effective to crop. The nutrients on demand, controlled release of chemical fertilizers that regulate the plant growth and enhance yield. These fertilizers are appropriate alternatives to conventional fertilizers for a gradual and controlled supply of nutrients in the crops. The experiment was laid out in Randomized Complete Block Design with three replications. A field experiment was carried out in medium black soil at ICAR-KVK, Kalaburagi, during *Kharif* 2022 for one year. There were nine treatment combinations, consisting of different doses of RDF i.e., 50%, 75%, 100% RDF and absolute control along with different doses of nano DAP foliar spray @ 2 and 4 ml L^{-1}. Application of 100% RDF as basal and nano DAP foliar spray @ 4 ml L^{-1} at 30 and 45 DAS recorded significantly higher plant height at harvest (37.4 cm), total dry matter production at harvest (37.20 g $plant^{-1}$), higher seed yield (2095 kg ha^{-1}) and stover yield (3735 kg ha^{-1}). It also produced higher net returns (61,305 Rs. ha^{-1}) and BC ratio (2.86). However, lower growth, yield and economics was noticed in absolute control. Combined application of RDF @ 100% and two foliar sprays of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS increased the growth, yield and economics of soybean.

Keywords: Response, nano, DAP, economics, Soybean, *Glycine max* L.

1. Introduction

Soybean seed includes approximately 38 to 43 per cent protein, 18 to 20 percent oil, 26 per cent carbohydrate, 4 per cent minerals and 2 per cent phospholipids. The protein is rich in lysine and the oil extracted is edible with fairly high unsaturated fatty acids Endres, 2001 [1]. It is also known as “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 2,720 kg ha^{-1} Anon, 2023 [2]. In India, it occupies an area of 13.00 m ha with the production of 12.04 m t and productivity of 930 kg ha^{-1} Anon, 2023a [3], which is much lower than the global average. 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 [4].

Nano fertilizers produced through nanotechnology enhance soil fertility, agricultural productivity and crop quality by modifying traditional fertilizers or extracting plant components using various physical, chemical or biological techniques. Singh *et al.*, 2017 [5]. Nano fertilizers have garnered significant attention due to their distinctive attributes, such as exceptional penetration capacity, small size and remarkably extensive surface area, setting them apart from their bulk counter parts. These characteristics not only make them environment friendly but also contribute to reduction in environmental pollution.

To address the imbalanced and excessive use of conventional urea and DAP fertilizers, IFFCO has developed nanotechnology based liquid nano urea and nano DAP fertilizers. This nano fertilizer was produced for the first time in the world at IFFCO Nano Biotechnology Research Centre (NBRC), Kalol, Gujarat, using a proprietary patented method.

Nano DAP (liquid) is the source of nitrogen and phosphorus. Nitrogen is the first and foremost nutrient required for crops as it is the constituent of chlorophyll, proteins and enzymes, thus playing a significant role during the vegetative growth of crops. Along with nitrogen, phosphorus is also an important plant nutrient.

Phosphorus is vital for plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis and transformation of sugars, starches and nutrient movement within the plant. This nano DAP contains about 8 per cent (80,000 ppm) of nitrogen and 16 per cent (1,60,000 ppm) of phosphorus. IFFCO nano DAP is prepared by nanotechnology and effectively fulfills crop nitrogen and phosphorus requirement when used as a foliar spray.

Farmers are using urea and DAP fertilizers for soil as well as foliar application to crops. However, the efficacy is lower. Soybean being nitrogen and phosphorus responsive crop need maximum quantity of phosphorus compared to other oilseed crops. Thus, the goal of the current study is to determine the response of nano DAP on growth, yield and quality of soybean.

2. Materials and Methods

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

During the cropping period, the mean annual rainfall received was 815.2 mm with 49 rainy days. July month received a maximum rainfall of 304.2 mm, followed by August with 182.8 mm and the maximum temperature was 39.90 ℃ in April and the minimum was 15.69 ℃ in January. The mean relative humidity fluctuated between 37.23 per cent in March and 88.94 per cent in July. However, the distribution of rainfall was erratic. There was no much variation in the mean minimum temperature. The mean minimum and maximum relative humidity during the crop growth period were normal as given in Figure 1.

The experiment was laid in a randomized complete block design (RCBD) with eight treatments *viz.*, RDF (40:80:25 N: P_2O_5: K2O 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. The variety, KDS-726 was used. The basal application of fertilizers in the form of urea, DAP, MOP, Zinc Sulphate, Bentonite sulphur, Borax and FYM @ 10 tonnes ha^{-1} were applied as per treatments with recommended dose of 40:80:25 kg $N:P_2O_5:K_2O$ ha^{-1}. The crop was sown on 16th July 2022 with a spacing of 30 × 10 cm. Intercultivation was done to remove all weeds from the field in order to check crop weed competition. Growth parameters such as plant height and total dry matter production were recorded at 30, 45, 60 DAS and at 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 grain was threshed with wooden sticks after it had dried completely under the sun and then yield parameters were recorded. The economics was worked out based on the prevailing market price for the existing year.

The data collected from the experiment at different growth stages and at harvest were subjected to statistical analysis as described by Gomez and Gomez, 1984 [6]. The level of significance used in "F" test was given at 5 per cent. Critical difference (CD) values are given in the table at 5 per cent level of significance, wherever the "F- test was significant at 5 per cent level.

3. Results and Discussion

3.1 Growth parameters

Plant height at 30 DAS, no significant difference was observed among treatment combinations. From 45 DAS onwards, significantly higher plant height was recorded with application of 100% RDF + nano DAP foliar spray @ 4 ml L^{-1} at 30 and 45 DAS (23.7, 31.5 and 37.4 cm at 45, 60 DAS and at harvest, respectively). It was on par with 100% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS (22.6, 30.3 and 35.8 cm at 45, 60 DAS and at harvest, respectively). In contrast, the lowest plant height (13.5, 17.3 and 19.4 cm at 45, 60 DAS and at harvest, respectively) was recorded in T_8 treatment, *i.e.*, absolute control (Table 1). The significant increase in plant height with higher dose RDF level and nano DAP foliar sprays at different times and concentrations might be due to an adequate quantity of fertilizer in a balanced proportion that supplied the optimum amount of nitrogen and phosphorus to the crop. Increases amino acid synthesis and supports cell division, leading to the development of more robust, healthy and taller soybean plants. Similar results were reported by Mishra *et al.*, 2020 [7].

At 30 DAS, no significant difference was observed among various treatments with respect to total dry weight. From 45 DAS onwards, significantly higher total dry matter production was recorded (9.23, 21.91 and 37.20 g $plant^{-1}$ at 45, 60 DAS and harvest, respectively) in 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 nano DAP @ 2 ml L^{-1} at 30 and 45 DAS (8.63, 19.41 and 34.17 g $plant^{-1}$ at 45, 60 DAS and harvest, respectively). Significantly lower total dry matter production was recorded in the absolute control (4.58, 9.67 and 14.61 g $plant^{-1}$ at 45, 60 DAS and harvest, respectively) (Table 2). Higher doses of RDF and folir spray of nano DAP might have favourably influenced carbohydrate metabolism and also enhanced the synthesis of amino acids, RNA and DNA, as well as leaf area, which has increased photosynthesis and thus increased the plant's ability to promote vegetative growth and dry matter. Nano DAP fertilizer have higher nutrient use efficiency which lead to higher growth and dry matter production. These findings were in accordance with Aziz and Zrar, 2021 [8].

3.2 Yield parameters

Significantly higher seed yield was recorded by application of 100% RDF as basal and nano DAP foliar spray @ 4 ml L^{-1} at 30 and 45 DAS (2095 kg ha^{-1}) and was found on par with 100% RDF and foliar spray of nano DAP @ 2.0 ml L^{-1} at 30 and 45 DAS (1987 kg ha^{-1}). Whereas, significantly lower grain yield (1162 kg ha^{-1}) was recorded in absolute control as compared to all other treatments. Higher grain yield might be due to combined application of conventional fertilizer and nano DAP ensured optimum and balanced nutrient availability throughout the crop period. 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 phosphorus. 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 Choudhary *et al*., 2018 [9] and Kailas *et al*., 2017 [10].

Application of 100% RDF and nano DAP spray @ 2 ml L^{-1} at 30 and 45 DAS recorded significantly higher stover yield (3735 kg ha^{-1}) as compared to other treatments and found on par with 100% RDF as + nano DAP foliar spray @ 2 ml L^{-1} at 30 and 45 DAS (3602 kg ha^{-1}). Whereas, significantly lower stover yield (2138 kg ha^{-1}) was produced in absolute control. An application of 100% RDF along with two foliar sprays of nano DAP at 4 ml L^{-1} helped in the better growth and development of soybean plant and enhanced the target activity, which leads to the biological production of crop. Which aided in better rates of photosynthesis and more dry matter accumulation resulting in higher stover yield. Similar results were found by Mehta and Bharat, 2019 [11].

3.3 Economics

Among different treatments, application of 100% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS has incurred greater cost of cultivation of soybean (Rs. 32,970 ha^{-1}) and gross returns (Rs. 94,275 ha^{-1}) as compared to all other treatments (Figure 2). It was lowest in absolute control (Rs.21, 768 ha^{-1} and 52,290 ha^{-1}, cost of cultivation and gross returns, respectively). Significantly higher net returns and B: C was recorded in 100% RDF as basal and nano DAP foliar spray @ 4 ml L^{-1} at 30 and 45 DAS (Rs. 61,305 ha^{-1} and 2.86, respectively). However, it was found on par with 100% RDF application and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS (Rs. 57,645 ha^{-1} and 2.81, respectively). Whereas, lower net returns and B: C was noticed in the absolute control (Rs. 30,522 ha^{-1} and 2.40). Higher net returns and B: C was due to higher yield of the crop in that particular treatment. These results are in accordance with the findings of Chavan *et al*., 2023 [12] and Ravishankar *et al*., 2008 [13].

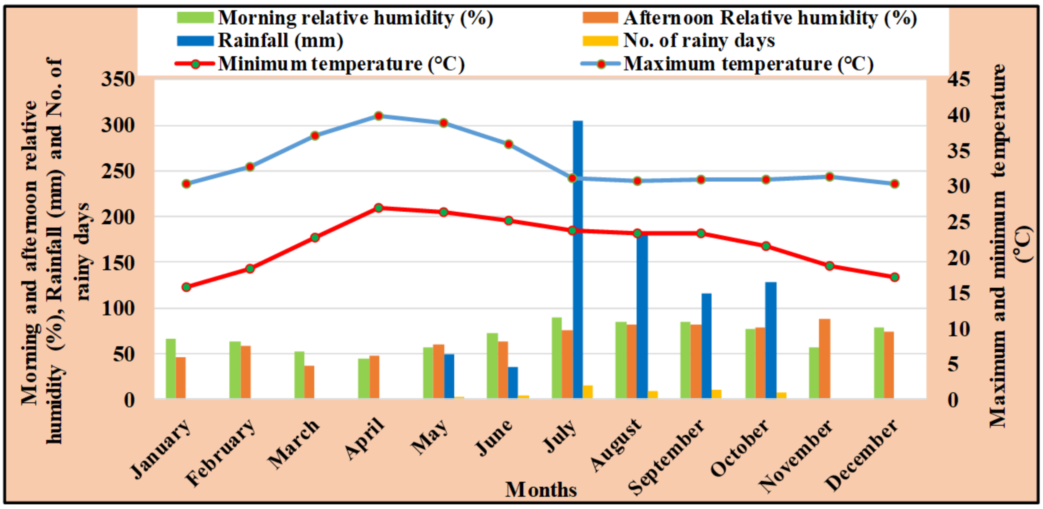

Fig 1: Monthly meteorological data during 2022 at KVK, Kalaburagi

Table 1: Plant height at different growth stages of soybean as influenced by foliar spray of nano DAP

Treatments	Plant height (cm)			
	30 DAS	45 DAS	60 DAS	At harvest
T_1 – RDF (40:80:25 N:P_2O_5:K_2O kg ha^{-1})	13.2	19.2	26.2	31.5
T_2 – 50% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	12.0	16.6	22.7	26.2
T_3 – 50% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	12.5	17.4	23.6	27.5
T_4 – 75% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	13.2	19.3	26.6	31.8
T_5 – 75% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	13.8	20.2	27.5	33.4
T_6 – 100% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	13.7	22.6	30.3	35.8
T_7 – 100% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	14.3	23.7	31.5	37.4
T_8 – Absolute Control	9.7	13.5	17.3	19.4
S.Em. ±	0.93	0.74	1.14	1.30
C.D. @ 5%	NS	2.25	3.45	3.95

Table 2: Total dry matter accumulation at different growth stages of soybean as influenced by foliar spray of nano DAP

Treatments	Total dry matter accumulation (g $plant^{-1}$)			
	30 DAS	45 DAS	60 DAS	At harvest
T_1 – RDF (40:80:25 N:P_2O_5:K_2O kg ha^{-1})	2.17	7.71	15.32	26.93
T_2 – 50% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	1.85	6.92	11.45	20.53
T_3 – 50% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	2.05	7.13	13.52	22.72
T_4 – 75% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	2.17	7.72	15.57	28.17
T_5 – 75% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	2.19	8.02	17.57	30.85
T_6 – 100% RDF and foliar spray of na no DAP @ 2 ml L^{-1} at 30 and 45 DAS	2.23	8.63	19.41	34.17
T_7 – 100% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	2.37	9.23	21.91	37.20
T_8 – Absolute Control	1.20	4.58	9.67	14.61
S.Em. ±	0.41	0.27	1.04	1.14
CD @ 5%	NS	0.81	3.16	3.46

Table 3: Seed yield, stover yield and harvest index of soybean as influenced by foliar spray of nano DAP

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
T_1 – RDF (40:80:25 N:P_2O_5:K_2O kg ha^{-1})	1743	3196	35.29
T_2 – 50% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	1498	2584	36.70
T_3 – 50% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	1604	2857	35.96
T_4 – 75% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	1769	3254	35.22
T_5 – 75% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	1863	3416	35.29
T_6 – 100% RDF and foliar spray of nano DAP @ 2 ml L^{-1} at 30 and 45 DAS	1987	3602	35.55
T_7 – 100% RDF and foliar spray of nano DAP @ 4 ml L^{-1} at 30 and 45 DAS	2095	3735	35.93
T_8 – Absolute Control	1162	2138	35.21
S.Em. ±	56.39	99.14	1.63
CD @ 5%	171.05	300.72	NS

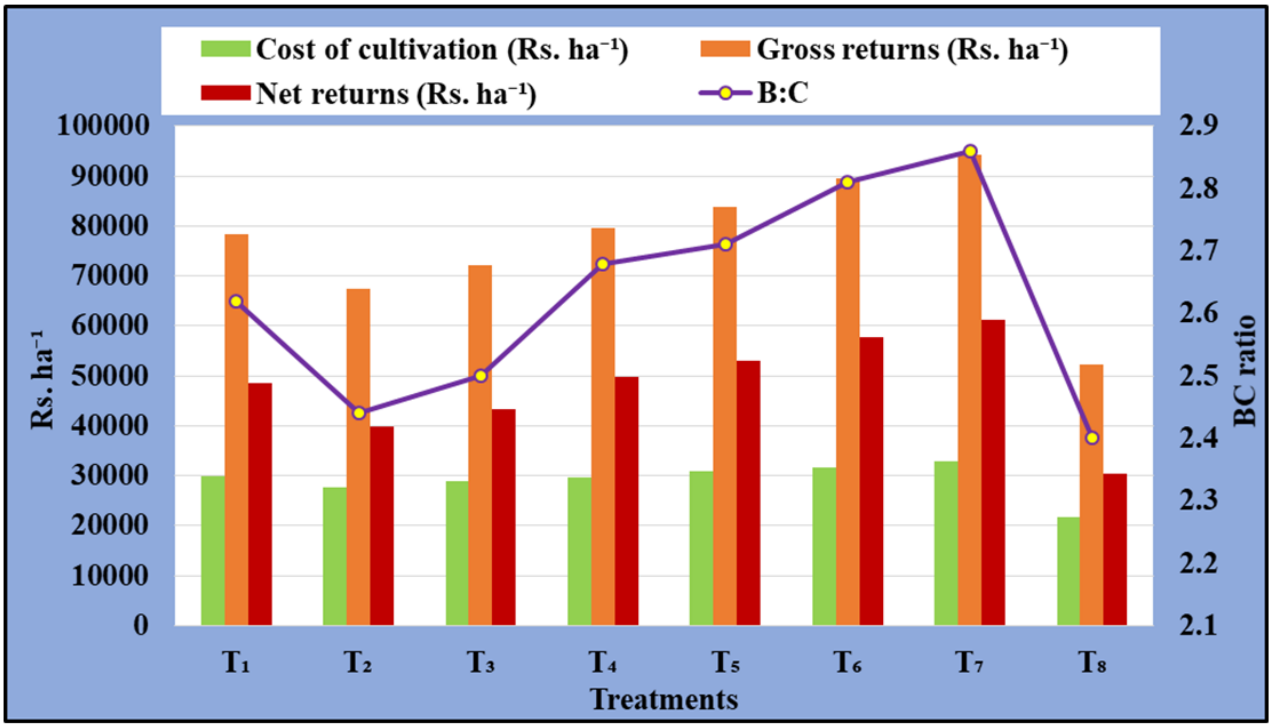

Fig 2: Influence of foliar application of nano DAP on economics of soybean

4. Conclusion

Combined application of conventional fertilizer and nano DAP *i.e.*, 100% RDF and nano DAP foliar spray @ 4 ml L^{-1} at 30 and 45 DAS and 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, quality, net returns and BC ratio. 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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