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Veeramallu Jagadeesh
Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

MS Deshmukh
Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

SR Pilewad
Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Corresponding Author:
Veeramallu Jagadeesh
Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra, India

Studies on effect of NANO DAP on yield and nutrient uptake of soybean grown on Vertisol

Veeramallu Jagadeesh, MS Deshmukh and SR Pilewad

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Abstract
The present field experiment was conducted during *Kharif* season of 2023-24 at Research Farm, Department of Soil Science and Agricultural Chemistry, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. The experiment was laid out in RBD (Randomized Block Design) with 3 replications and 10 treatments *viz*. T_1 – (Absolute Control), T_2 - [RDF (N 30:P 60: K 60: S 20:Zn 25) kg ha^{-1}], T_3 –[50% RDF + 1 Foliar Spray of Nano-DAP (30 DAS)], T_4 –[50% RDF + 2 Foliar Spray of Nano-DAP (30 & 60 DAS)], T_5 – [75% RDF + 1 Foliar Spray of Nano-DAP (30 DAS)], T_6 – [75% RDF + 2 Foliar Spray of Nano-DAP (30& 60 DAS)], T_7 – [100% RDF + 1 Foliar Spray of Nano-DAP (30 DAS)], T_8 – [100% RDF + 1 foliar spray Grade II (30DAS)], T_9 – [100% RDF + 1 foliar sprays of 19:19:19 (30DAS)] and T_{10}– [100% RDF + 1 foliar sprays of 00:52:34 (30DAS)].
By the application of treatment T_7–100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS), there was significantly higher grain and straw yield in soybean. The treatment T_7 with 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS) showed significantly higher values for available N, P_2O_5, K_2O and sulphur at the harvest stage of soybean. The treatment T_7 with 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS) showed positive response over other treatments significantly increased in content and uptake of nitrogen, phosphorus, potassium and sulphur. Results concluded that, one spray of NANO DAP @ 30DAS along with recommended dose of fertilizer seems to be beneficial for enhancing the soil fertility and soybean yield.

Keywords: Nano DAP, Foliar spray, soybean, growth, quality, yield

Introduction
The term "nanotechnology" is derived from the Greek word "Nano," which means “dwarf." Therefore, "nanotechnology" refers to the creation of materials by controlling their structure and properties at the Nano scale level typically within a length scale ranging from one to one hundred Nano meters (Raliya *et al*. 2013) [15]. Nano fertilizers and coated Nano-nutrients have been developed to enhance crop growth, provide nutrients as needed, regulate nutrient release to support plant development, and improve targeted functions (Al-juthery *et al*. 2018) [2].
Nanotechnology, which plays a significant role in agricultural revolution, improves the bioavailability, bioactivity, adhesion properties, and surface interactions of nanoparticles (Al-Juthery *et al*. 2018) [3] (Abdelkader *et al*. 2022) [1]. It involves the manipulation of materials at the Nano-scale, offering numerous sustainable benefits in agriculture. (Khairy *et al*. 2022) [8] (El-Saadony *et al*. 2021) [7]. These distinct properties resulted from small molecular size and altered intermolecular interactions. Its application encompasses fertilizers, pesticides, herbicides, and plant growth regulators which presents solutions to various challenges in farming (Easwaran *et al*. 2024) [6].
Nano fertilizer technology is an innovative approach to maximize crop yields through the use of nanoparticles. The efficiency of conventional fertilizers is only 30-35% for nitrogen (N), 18-20% for phosphorus (P), and 35-40% for potassium (K). To enhance this efficiency and minimize the waste of chemical fertilizers, the application of Nano fertilizers is essential. Nano fertilizers have a larger surface area and can retain nutrients more effectively than traditional fertilizers (Chuprova *et al*. 2004) [5].
Nano-fertilizers serve as a powerful tool in agriculture for more efficient nutrient management due to their enhanced penetration capacity, larger surface area, and greater efficiency, which

boost both fertilizer performance and absorption. Nano-fertilizers can be utilized for future nutrient applications, offering a more environmentally friendly option and reducing environmental pollution (Shang *et al.* 2019) [16].

Materials and Methods

The current experiment was carried out in the *Kharif* season of 2023-2024 at research farm Department of Soil Science and Agricultural Chemistry, College of Agriculture, Parbhani on soybean variety MAUS-158. The experiment was laid out in RBD (Randomized Block Design) with 3 replications and 10 treatments *viz*. T_1 - (Absolute Control), T_2 - [RDF (N 30:P 60: K 60: S 20:Zn 25) kg ha^{-1}], T_3 -[50% RDF + 1 Foliar Spray of Nano-DAP (30 DAS)], T_4 -[50% RDF + 2 Foliar Spray of Nano-DAP (30 & 60 DAS)], T_5 - [75% RDF + 1 Foliar Spray of Nano-DAP (30 DAS)], T_6 - [75% RDF + 2 Foliar Spray of Nano-DAP (30& 60 DAS)], T_7 - [100% RDF + 1 Foliar Spray of Nano-DAP (30 DAS)], T_8 - [100% RDF + 1 foliar spray Grade II (30 DAS)], T_9 - [100% RDF + 1 foliar sprays of 19:19:19 (30 DAS)] and T_{10}- [100% RDF + 1 foliar sprays of 00:52:34 (30 DAS)]. Nano DAP was applied @ 4ml/lit. Seeds were sown by dibbling method.

Results and Discussion

Grain and Straw Yield

The highest grain yield and straw yield was recorded in treatment T_7, which involved 100% RDF and a single foliar spray of Nano-DAP at 30 DAS, resulting in 1851.90 kg ha^{-1} and 4467.26 kg ha^{-1} respectively. Followed by treatment T_9, featuring 100% RDF and a single foliar spray of 19:19:19 at 30 DAS, yielding 1812.12 kg ha^{-1} and 4017.64 kg ha^{-1} respectively. The lowest grain and straw yield was recorded in the absolute control treatment T_1, with 753.10 kg ha-1 and 1608.99 kg ha^{-1} respectively. (Table 1.) The results give a clear view that by the utilisation of Nano DAP on plants there will be better grain yield due to increase in all other growth factors similar findings were obtained to Maloth *et al.* (2024) [10] who's study in Paddy that, the highest grain yield was achieved by applying 100% NK, 75% P, along with two foliar applications of Nano-DAP during the tillering and PI stages (T_6) compared to the standard 100% RDF treatment (T_1). The lowest yield was noted in the treatment with 100% NK and no P (T_7).

Table 1: Effect of Nano-DAP on grain yield and straw yield of soybean

Treatment details	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})
T_1: Control (No Fertilizer)	753.10	1608.99
T_2: RDF (N 30 :P 60 : K 30: S 20: Zn 25)	1679.04	3722.42
T_3: 50% RDF + 1 Foliar Spray of NANO -DAP (30 DAS)	977.39	2166.87
T_4: 50% RDF + 2 Foliar Spray of NANO-DAP (30 & 60DAS)	1089.33	2415.05
T_5: 75% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	1300.44	2883.08
T_6: 75% RDF + 2 Foliar Spray of NANO-DAP (30& 60 DAS)	1389.53	3081.32
T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	1851.90	4105.66
T_8:100% RDF + 1 foliar spray Grade II (30DAS)	1780.36	3947.05
T_9:100% RDF + 1 foliar sprays of 19 : 19 :19 (30DAS)	1812.20	4017.64
T_{10}:100% RDF + 1 foliar sprays of 00: 52: 34 (30DAS)	1801.12	3993.07
S.Em. ±	97.19	217.30
C.D. at 5%	288.78	645.62

Major Nutrient (NPKS) uptake in Grain and Straw (kg ha^{-1}) of Soybean

The highest nitrogen uptake (grain: 130.43 kg ha^{-1}, straw: 43.89 kg ha^{-1}, and total: 174.32 kg ha^{-1}) in soybean was recorded in treatment T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS), which was on par with treatment T_9 (grain: 125.05 kg ha^{-1}, straw: 41.39 kg ha^{-1}, and total: 166.44 kg ha^{-1}) and T_{10} (grain: 123.13 kg ha^{-1}, straw: 38.99 kg ha^{-1}, and total: 168.12 kg ha^{-1}). In contrast, the lowest nitrogen uptake was observed in treatment T_1 (absolute control), with values of grain: 43.14 kg ha^{-1}, straw: 11.64 kg ha^{-1}, and total: 54.78 kg ha^{-1}. (Table 2)The results clearly show that due to use of foliar Nano fertilizers there is enhancement of uptake and content of macro nutrients so that there is good yield. The results are similar to Chinnappa *et al.* (2023) [4] who reported that the uptake of major nutrients, particularly nitrogen (133.9 kg ha^{-1}), was significantly higher in treatments where a foliar application of 75% RNP as basal, along with Nano urea and DAP spray at 1.5 ml l^{-1} each at 30 and 45 DAS, was applied. Conversely, the lowest levels were recorded in the absolute control, where no fertilizers were applied.

The highest phosphorus uptake (grain: 28.56 kg ha^{-1}, straw: 42.56 kg ha^{-1} and total: 71.12 kg ha^{-1}) in soybean was recorded in treatment T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS), which was on par with treatment T_9 (grain: 25.18 kg ha^{-1}, straw: 38.32 kg ha^{-1}, and total: 63.50 kg ha^{-1}) and T_{10} (grain: 26.13 kg ha^{-1}, straw: 37.12 kg ha^{-1}, and total: 63.25 kg ha^{-1}). In contrast, the lowest phosphorus uptake was observed in treatment T_1 (absolute control), with values of grain: 5.43 kg ha^{-1}, straw: 8.53 kg ha^{-1} and total: 13.96 kg ha^{-1}.(Table 2) Similar results were also reported by Thakur *et al.* (2022) [19] that the impact of Nano-DAP fertilizers on the available phosphorus in soil after harvest. The control plot, which received 0% P, recorded the lowest phosphorus level. However, the plot that received 50% P through DAP, the remaining N, and 100% K, along with seed treatment with Nano-DAP at 5 ml/kg seed, and two foliar sprays one at 4 ml/litre of water at 30 DAG and another at 45 DAG (T_{10}) recorded higher phosphorus level.

The highest potassium uptake (grain: 32.39kg ha^{-1}, straw: 39.35 kg ha^{-1}, and total: 71.64 kg ha^{-1}) in soybean was recorded in treatment T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS), which was on par with treatment T_9 (grain: 30.63 kg ha^{-1}, straw: 36.83 kg ha^{-1}, and total: 67.46 kg ha^{-1}) and T_{10} (grain: 29.37 kg ha^{-1}, straw: 34.75 kg ha^{-1}, and total: 64.12 kg ha^{-1}). In contrast, the lowest potassium uptake was observed in treatment T_1 (Absolute control), with values of grain: 8.90 kg ha^{-1}, straw: 9.33 kg ha^{-1}, and total: 18.23 kg ha^{-1}. (Table 2) The results are consistent with the findings of Neeruggi *et al.* (2024) [12] who reported that the highest available potassium in the soil (224.13 kg ha^{-1}) was observed in the treatment receiving T_9: Nano DAP and Urea at 6 ml each + 100% RNP, which was comparable to T_6: Nano DAP and Urea at 6 ml each + 75% RNP, with a recorded value of 234.72 kg ha^{-1}. In contrast, the lowest available potassium in the soil (292.23 kg ha^{-1}) was recorded in

the T_{10} (control) treatment. The highest sulphur uptake (grain: 8.10kg ha^{-1}, straw: 16.49 kg ha^{-1}, and total: 24.59 kg ha^{-1}) in soybean was recorded in treatment T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS), which was on par with treatment T_9 (grain: 7.07 kg ha^{-1}, straw: 14.86 kg ha^{-1}, and total: 21.93 kg ha^{-1}) and T_{10} (grain: 6.65 kg ha^{-1}, straw: 13.99 kg ha^{-1}, and total: 20.64 kg ha^{-1}). In contrast, the lowest sulphur uptake was observed in treatment T_1 (absolute control), with values of grain: 1.7 kg ha^{-1}, straw: 3.05 kg ha^{-1}, and total: 4.62 kg ha^{-1}. (Table 2) The results were in agreement with findings of Suresh *et al.* (2015) [18] who mentioned that the nitrogen content in S-MAP is approximately 6.5%, while the concentration of P_2O_5 is about 39.5%. Sulphur content in its elemental form is around 9%, and as thiosulfate, it ranged between 3.3% and 5.5%.With the analytical results showing a recovery of about 68% of elemental sulphur as particles during the process.

Iron and Manganese Content (g ha^{-1})

The highest Fe uptake (grain: 6.27kg ha^{-1}, straw: 12.73 kg ha^{-1}, and total: 19.00 kg ha^{-1}) in soybean was recorded in treatment T_8:100% RDF + 1 foliar spray Grade II (30DAS), which was on par with treatment T_9 (grain: 6.02 kg ha^{-1}, straw: 11.72 kg ha^{-1}, and total: 17.74 kg ha^{-1}) and T_7 (grain: 6.47 kg ha^{-1}, straw: 13.13 kg ha^{-1}, and total: 19.60 kg ha^{-1}). In contrast, the lowest Fe uptake was observed in treatment T_1 (absolute control), with values of grain: 2.18 kg ha^{-1}, straw: 3.94 kg ha^{-1}, and total: 6.12 kg ha^{-1}. (Table 3) Similarly, this was observed in findings of Poudel *et al.* (2023) [13] that the use of Nano-P in combination with varying levels of P fertilizer influenced the micronutrient levels in both the grain and straw of wheat. The T_3 treatment exhibited the highest concentrations of Cu, Mn, Zn and Fe in the grain, measuring 21.2, 22.9, 36.4 and 61.1 mg kg^{-1}, respectively.

Table 2: Effect of Nano-DAP on uptake of nitrogen in soybean

Treatment detail	N uptake (kg ha^{-1})		
	Grain	Straw	Total
T_1: Control (No Fertilizer)	43.14	11.64	54.78
T_2: RDF (N 30 :P 60 : K 30: S 20: Zn 25)	110.39	35.14	145.53
T_3: 50% RDF + 1 Foliar Spray of NANO -DAP (30 DAS)	59.27	17.70	76.97
T_4: 50% RDF + 2 Foliar Spray of NANO-DAP (30 & 60 DAS)	66.86	19.80	86.66
T_5: 75% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	84.03	25.16	109.19
T_6: 75% RDF + 2 Foliar Spray of NANO-DAP (30& 60 DAS)	90.40	27.15	117.55
T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	130.43	43.89	174.32
T_8:100% RDF + 1 foliar spray Grade II (30DAS)	120.41	37.50	157.91
T_9:100% RDF + 1 foliar sprays of 19 : 19 :19(30DAS)	125.05	41.39	166.44
T_{10}:100% RDF + 1 foliar sprays of 00: 52: 34 (30DAS)	123.13	38.99	162.12
S.Em. ±	6.42	1.71	8.13
C.D. at 5%	19.08	5.09	24.17

Table 3: Effect of Nano-DAP on uptake of phosphorus in soybean

Treatment detail	P uptake (kg ha^{-1})		
	Grain	Straw	Total
T_1: Control (No Fertilizer)	5.43	8.53	13.96
T_2: RDF (N 30 :P 60 : K 30: S 20: Zn 25)	20.62	30.07	50.69
T_3: 50% RDF + 1 Foliar Spray of NANO -DAP (30 DAS)	9.00	13.20	22.20
T_4: 50% RDF + 2 Foliar Spray of NANO-DAP (30 & 60 DAS)	10.59	16.42	27.01
T_5: 75% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	13.16	20.75	33.91
T_6: 75% RDF + 2 Foliar Spray of NANO-DAP (30& 60 DAS)	14.81	23.78	38.59
T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	28.56	42.56	71.12
T_8:100% RDF + 1 foliar spray Grade II (30DAS)	23.32	34.35	57.67
T_9:100% RDF + 1 foliar sprays of 19 : 19 :19(30DAS)	25.18	38.32	63.50
T_{10}:100% RDF + 1 foliar sprays of 00: 52: 34 (30DAS)	26.13	37.12	63.25
S.Em. ±	1.36	1.48	2.84
C.D. at 5%	4.03	4.39	8.42

Table 4: Effect of Nano-DAP on uptake of potassium in soybean

Treatment detail	K uptake (kg ha^{-1})		
	Grain	Straw	Total
T_1: Control (No Fertilizer)	8.90	9.33	18.23
T_2: RDF (N 30 :P 60 : K 30: S 20: Zn 25)	24.06	28.24	52.30
T_3: 50% RDF + 1 Foliar Spray of NANO -DAP (30 DAS)	12.01	13.89	25.90
T_4: 50% RDF + 2 Foliar Spray of NANO-DAP (30 & 60 DAS)	13.94	16.20	30.14
T_5: 75% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	17.05	20.71	37.76
T_6: 75% RDF + 2 Foliar Spray of NANO-DAP (30& 60 DAS)	18.92	23.17	42.09
T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	32.29	39.35	71.64
T_8:100% RDF + 1 foliar spray Grade II (30DAS)	27.06	32.10	59.16
T_9:100% RDF + 1 foliar sprays of 19 : 19 :19(30DAS)	30.63	36.83	67.46
T_{10}:100% RDF + 1 foliar sprays of 00: 52: 34 (30DAS)	29.37	34.75	64.12
S.Em. ±	1.66	1.83	3.49
C.D. at 5%	4.94	5.43	10.37

Table 5: Effect of Nano-DAP on uptake of sulphur in soybean

Treatment detail	S uptake (kg ha^{-1})		
	Grain	Straw	Total
T_1: Control (No Fertilizer)	1.7	3.05	4.62
T_2: RDF (N 30 :P 60 : K 30: S 20: Zn 25)	5.01	10.74	15.75
T_3: 50% RDF + 1 Foliar Spray of NANO -DAP (30 DAS)	2.44	4.99	7.43
T_4: 50% RDF + 2 Foliar Spray of NANO-DAP (30 & 60 DAS)	2.83	5.80	8.63
T_5: 75% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	3.51	7.75	11.26
T_6: 75% RDF + 2 Foliar Spray of NANO-DAP (30& 60 DAS)	4.05	8.69	12.74
T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	8.10	16.49	24.59
T_8:100% RDF + 1 foliar spray Grade II (30DAS)	5.87	12.23	18.10
T_9:100% RDF + 1 foliar sprays of 19 : 19 :19(30DAS)	7.07	14.86	21.93
T_{10}:100% RDF + 1 foliar sprays of 00: 52: 34 (30DAS)	6.65	13.99	20.64
S.Em. ±	0.33	0.89	1.22
C.D. at 5%	0.96	2.65	3.61

Similarly, in the straw, the same treatment recorded the highest levels of Cu, Mn, Zn and Fe at 15.0, 13.4, 25.3 and 25.1 mg kg−1, respectively.

The highest Mn uptake (grain: 82.61kg ha^{-1}, straw: 164.00 kg ha^{-1}, and total: 246.61 kg ha^{-1}) in soybean was recorded in treatment T_8:100% RDF + 1 foliar spray Grade II (30DAS), which was on par with treatment T_9 (grain: 78.20 kg ha^{-1}, straw: 153.15 kg ha^{-1}, and total: 231.35 kg ha^{-1}) and T_7 (grain: 74.72 kg ha^{-1}, straw: 142.84 kg ha^{-1}, and total: 217.56 kg ha^{-1}). In contrast, the lowest Mn uptake was observed in treatment T_1 (absolute control), with values of grain: 21.71 kg ha^{-1}, straw: 40.10 kg ha^{-1}, and total: 61.81 kg ha^{-1}. The results clearly show that Cu, Mn, Fe and Zn content and uptake increase due to application of Nano mineral fertilizers. (Table 3) Similarly Singh *et al.* (2023) [17] reported that the total uptake of Cu, Mn, Zn and Fe ranged from 78.7 to 132, 101 to 135, 109 to 179, and 240 to 341 g ha^{-1}, respectively. The treatments T_4 and T_6 showed significantly higher grain and straw uptake of Cu (73.5 and 65.8 g ha^{-1}), Mn (82.1 and 55.7 g ha^{-1}) and Zn (98.5 and 85.6 g ha^{-1}). In contrast, T_4 had the highest grain and straw uptake of Fe, at 227 and 114 g ha^{-1}, respectively.

Table 6: Effect of Nano-DAP on uptake of iron by soybean

Treatment detail	Fe uptake (g ha^{-1})		
	Grain	Straw	Total
T_1: Control (No Fertilizer)	2.18	3.94	6.12
T_2: RDF (N 30 :P 60 : K 30: S 20: Zn 25)	5.46	10.54	16.00
T_3: 50% RDF + 1 Foliar Spray of NANO -DAP (30 DAS)	2.90	5.65	8.55
T_4: 50% RDF + 2 Foliar Spray of NANO-DAP (30 & 60 DAS)	3.30	6.47	9.77
T_5: 75% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	4.02	7.87	11.89
T_6: 75% RDF + 2 Foliar Spray of NANO-DAP (30& 60 DAS)	4.38	8.54	12.92
T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	6.02	11.72	17.74
T_8:100% RDF + 1 foliar spray Grade II (30DAS)	6.47	13.13	19.60
T_9:100% RDF + 1 foliar sprays of 19 : 19 :19(30DAS)	6.27	12.73	19.00
T_{10}:100% RDF + 1 foliar sprays of 00: 52: 34 (30DAS)	6.12	12.42	18.54
S.Em. ±	0.31	0.63	0.94
C.D. at 5%	0.93	1.87	2.80

Table 7: Effect of Nano-DAP on uptake of manganese by soybean.

Treatment detail	Mn uptake (g ha^{-1})		
	Grain	Straw	Total
T_1: Control (No Fertilizer)	21.71	40.10	61.81
T_2: RDF (N 30 :P 60 : K 30: S 20: Zn 25)	66.41	131.21	197.62
T_3: 50% RDF + 1 Foliar Spray of NANO -DAP (30 DAS)	31.19	62.17	93.36
T_4: 50% RDF + 2 Foliar Spray of NANO-DAP (30 & 60 DAS)	35.32	70.37	105.69
T_5: 75% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	49.09	91.71	140.80
T_6: 75% RDF + 2 Foliar Spray of NANO-DAP (30& 60 DAS)	53.54	103.37	156.91
T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	74.72	142.84	217.56
T_8:100% RDF + 1 foliar spray Grade II (30 DAS)	82.61	164.00	246.61
T_9:100% RDF + 1 foliar sprays of 19 : 19 :19(30 DAS)	78.20	153.15	231.35
T_{10}:100% RDF + 1 foliar sprays of 00: 52: 34 (30 DAS)	75.77	149.02	224.79
S.Em. ±	3.98	7.88	11.86
C.D. at 5%	11.82	23.40	35.22

Zinc and Copper Content (g ha^{-1})

The highest Zn uptake (grain: 3.27 kg ha^{-1}, straw: 4.03 kg ha^{-1}, and total: 7.30 kg ha^{-1}) in soybean was recorded in treatment T_8:100% RDF + 1 foliar spray Grade II (30DAS), which was on par with treatment T_9 (grain: 3.10 kg ha^{-1}, straw: 3.66 kg ha^{-1}, and total: 6.76 kg ha^{-1}) and T_7 (grain: 2.83 kg ha^{-1}, straw: 3.24 kg ha^{-1}, and total: 6.07kg ha^{-1}). In contrast, the lowest Zn uptake was observed in treatment T_1 (absolute control), with values of grain: 0.66 kg ha^{-1}, straw: 1.01 kg ha^{-1}, and total: 1.67 kg ha^{-1}. (Table 4) The results were in similarity with Raju *et al.* (2023)

[14] with noted that seed treatment using a bio-inoculant consortia of NPK combined with 0.004% Nano Zno and 0.001% Nano Cuo, which were as effective as Nano forms in addressing deficiencies of N, P, K, S, Mg, Zn and B.

The highest Cu uptake (grain: 33.55kg ha^{-1}, straw: 39.96 kg ha^{-1}, and total: 73.51 kg ha^{-1}) in soybean was recorded in treatment T_8:100% RDF + 1 foliar spray Grade II (30 DAS), which was on par with treatment T_9 (grain: 32.38 kg ha^{-1}, straw: 37.00 kg ha^{-1}, and total: 69.38 kg ha^{-1}) and T_7 (grain: 29.75 kg ha^{-1}, straw: 35.41 kg ha^{-1}, and total: 65.16 kg ha^{-1}). In contrast, the lowest Cu uptake was observed in treatment T_1 (absolute control), with values of grain: 6.92 kg ha^{-1}, straw: 11.60 kg ha^{-1}, and total: 18.52 kg ha^{-1}. (Table 4) The results clearly show that the application of Nano mineral fertilizers leads to an increase in the content and uptake of Cu, Mn, Fe and Zn. Similarly Manikanta *et al.* (2023) [11] observed that the highest copper content in both the haulm and tuber of Potato, was recorded in the T_9 treatment, which received RDF along with two sprays of Nano Copper. This was significantly higher than all other treatments, including the control, with respect to copper content in the haulm. In tubers, the copper content in T_9 was significantly higher than in the control. Among all treated plots, the lowest copper content in both haulm and tuber was found in the T_1 control treatment.

Table 8: Effect of Nano-DAP on uptake of zinc by soybean.

Treatment detail	Zn uptake (g ha^{-1})		
	Grain	Straw	Total
T_1: Control (No Fertilizer)	0.66	1.01	1.67
T_2: RDF (N 30 :P 60 : K 30: S 20: Zn 25)	2.49	2.95	5.44
T_3: 50% RDF + 1 Foliar Spray of NANO -DAP (30 DAS)	1.06	1.54	2.60
T_4: 50% RDF + 2 Foliar Spray of NANO-DAP (30 & 60 DAS)	1.30	1.74	3.04
T_5: 75% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	1.60	2.13	3.73
T_6: 75% RDF + 2 Foliar Spray of NANO-DAP (30& 60 DAS)	1.93	2.31	4.24
T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	2.83	3.24	6.07
T_8:100% RDF + 1 foliar spray Grade II (30DAS)	3.27	4.03	7.30
T_9:100% RDF + 1 foliar sprays of 19 : 19 :19(30DAS)	3.10	3.66	6.76
T_{10}:100% RDF + 1 foliar sprays of 00: 52: 34 (30DAS)	2.97	3.43	6.40
S.Em. ±	0.15	0.20	0.35
C.D. at 5%	0.44	0.58	1.02

Table 9: Effect of Nano-DAP on uptake of copper by soybean

Treatment detail	Cu uptake (g ha^{-1})		
	Grain	Straw	Total
T_1: Control (No Fertilizer)	6.92	11.60	18.52
T_2: RDF (N 30 :P 60 : K 30: S 20: Zn 25)	26.21	32.13	58.34
T_3: 50% RDF + 1 Foliar Spray of NANO -DAP (30 DAS)	11.31	17.48	28.79
T_4: 50% RDF + 2 Foliar Spray of NANO-DAP (30 & 60 DAS)	13.85	19.88	33.73
T_5: 75% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	17.80	24.36	42.16
T_6: 75% RDF + 2 Foliar Spray of NANO-DAP (30& 60 DAS)	19.88	26.22	46.12
T_7: 100% RDF + 1 Foliar Spray of NANO-DAP (30 DAS)	29.75	35.41	65.16
T_8:100% RDF + 1 foliar spray Grade II (30DAS)	33.55	39.96	73.51
T_9:100% RDF + 1 foliar sprays of 19 : 19 :19(30DAS)	32.38	37.00	69.38
T_{10}:100% RDF + 1 foliar sprays of 00: 52: 34 (30DAS)	30.96	36.06	67.02
S.Em. ±	1.57	1.94	2.51
C.D. at 5%	4.65	5.76	10.41

Conclusion

In summary, it can be concluded that a single foliar spray of Nano-DAP combined with RDF had a positive impact on all growth attributes and yield of the soybean crop, as well as improved nutrient availability in the soil and plant after harvest.

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