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Response of foliar spray of nano dap and nutrients on growth, yield and quality of chickpea (*Cicer arietinum* L.)

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Abstract
A field investigation entitled "Response of foliar spray of Nano DAP and nutrients on growth, yield and quality of Chickpea (*Cicer arietinum* L.)" was conducted at AICRP on Integrated Farming System, MPKV, Rahuri, Maharashtra, India during the *Rabi* season of 2023-24, Mahatma Phule Krishi Vidyapeeth, Rahuri to study the growth, yield and quality attributing characters of chickpea in relation to foliar application of Nano DAP, 12:61:00 and Phosphoric acid in combination with soil application of other sources of phosphorus. The experiment consists of eight treatments *viz.* T_1: Absolute control, T_2 : GRDF (FYM @ 5 t ha^{-1}, N:P_2O_5:K_2O @ 25:50:30 kg ha^{-1}), T_3 : 100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS, T_4: 75% P_2O_5 through DAP + Two spray of Nano DAP @ 0.25% at 30 and 45 DAS, T_5 : 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS, T_6 : 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS, T_7: 100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS, T_8: 75% P_2O_5 through DAP + Two spray of Phosphoric acid @ 0.25% at 30 and 45 DAS. As regards yield attributing characters, significantly higher grain yield (34.56 q ha^{-1}), straw yield (41.59 q ha^{-1}) and biological yield (76.11 q ha^{-1}) were recorded under treatment T_5: 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS. Significantly the highest gross monetary return (₹ 177791 ha^{-1}) was obtained in 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS which also recorded a significantly maximum net monetary returns (₹ 113807 ha^{-1}) and B:C ratio (2.78) than other treatments. While, T_1: Absolute control obtained minimum gross monetary returns, net monetary returns and B:C ratio among all the treatments.

Keywords: Nano DAP, chickpea, yield, foliar

Introduction
Chickpea (*Cicer arietinum* L.) is a member of family Leguminocaea that is widely cultivated for its typically yellow-brown, pea like seeds. The high nutritional value makes chickpea an important food particularly in famine prone areas of the world. The leaves are eaten as vegetables, drinks are prepared from the plant exudates and the green seeds are consumed raw, roasted or boiled whereas the dry seeds can be used to prepare amazing array of different dishes. No crop other than chickpea is covered on all its surfaces with acid exudates and as a consequence, it has very few insect problems. Chickpea is also credited with the ability of atmospheric nitrogen fixation through symbiotic process and it has been estimated that chickpea has the capacity to fix 140 kg N ha^{-1} in a growing season (Rupela and Saxena, 1987) [12]. The fixed N not only can meet the requirements of the legume for maximum grain formation, but can also be available for use by subsequent crops, after mineralization of chickpea crop residues.

Foliar application during the growth and development of chickpea is beneficial. When fertilizers are applied as foliar, it utilized more than 90 percent by plant. When similar amount is applied to the soil, only 10 percent is utilized. Foliar nutrition is designed to eliminate the problems like fixation and immobilization of nutrients. Recently, new generation specialized fertilizers have been introduced exclusively for foliar feeding and fertilization. Specialized fertilizers are a better source for foliar application (Vibhute. C. P. 1998) [15]. These fertilizers have different ratios of N, P and K which are highly water soluble and so amenable for foliar nutrition (Jayabal *et al*., 1999) [5].

Materials and Methods

The field experiment entitled "Response of foliar spray of Nano DAP and nutrients on growth, yield and quality of chickpea (*Cicer arietinum* L.)" was conducted at All India Coordinated Research Project on Integrated Farming System, Mahatma Phule Krishi Vidyapeeth, Rahuri during *Rabi* season of 2023-24. The soil in the experimental field belongs to inceptisols order and clay loam having depth more than 60 cm and the topography was uniform and levelled. For assessment of initial soil fertility status, representative initial soil sample was created and evaluated for physical and chemical soil parameters. The soil texture of the experimental site was found to be clay loam. Soil was low in available nitrogen (236.68 kg ha^{-1}), medium in available phosphorus (18.90 kg ha^{-1}) and moderate in potassium (247.30 kg ha^{-1}). The soil was slightly alkaline in reaction (pH 7.80) with normal in electrical conductivity of 0.26 dSm^{-1}. In terms of climate, the experimental unit is located in a semi-arid region and subtropical zone with annual rainfall ranges between 307 to 619 mm. Agro-climatically this area falls under scarcity zone (drought prone area) of Maharashtra state with an annual rainfall range from 307 to 619 with average of 520 mm. Over the most of the accommodated area, rainfall and its distribution are unpredictable and variable. The average annual maximum temperature varies from 27.1°C to 34.7°C, on other side annual mean minimum temperature ranges from 11.1°C to 19.9°C. The experiment consists of eight treatments *viz.*, T_1: Absolute control, T_2 : GRDF (FYM @ 5 t ha^{-1}, N:P_2O_5:K_2O @ 25:50:30 kg ha^{-1}), T_3 : 100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS, T_4: 75% P_2O_5 through DAP + Two spray of Nano DAP @ 0.25% at 30 and 45 DAS, T_5 : 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS, T_6 : 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS, T_7: 100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS, T_8: 75% P_2O_5 through DAP + Two spray of Phosphoric acid @ 0.25% at 30 and 45 DAS. Desi variety of Chickpea 'Vishal' was obtained from AICRP on IFS, Mahatma Phule Krishi Vidyapeeth, Rahuri. The recommended seed rate of 100 kg ha^{-1} was used. Sowing was done on 12th November 2023 by drilling method with spacing 30 cm x 10 cm. Harvesting was done manually 115 DAS of maturity. The harvested crop was dried for 4 days and threshed by manual beating with sticks.

Results and Discussion

Yield characters

Grain yield (q ha^{-1})

The data pertaining to grain yield (q ha^{-1}) of chickpea as affected by different treatments are presented in table 1. The mean grain yield was 30.87 q ha^{-1}.

The data revealed that the grain yield (q ha^{-1}) was influenced by different treatments. The significantly highest grain yield (q ha^{-1}) was observed in treatment T_5 *i.e.*, 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS (34.56 q ha^{-1}) which was statistically at par with T_7 *i.e.*, 100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS (34.10 q ha^{-1}), T_3 *i.e.*, 100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS (33.44 q ha^{-1}) and T_6 *i.e.*, 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS (32.70 q ha^{-1}). Among all the treatments, the lowest grain yield (q ha^{-1}) was observed in T_1 *i.e.*, Absolute control (20.40 q ha^{-1}) over rest of the treatments at all growth stages.

There was significant increase in grain yield in chickpea due to foliar spray of 12:61:00 as high phosphorous directly supports reproductive growth enhancing the flowering, pod setting and formation, filling and overall weight of grains. It leads to an increase in both the number of pods per plant and the number of seeds per pod, which directly contributes to higher overall yield. Nitrogen contributes to better vegetative growth that supports more pods and seeds indirectly boosting grain yield. Similar observations were recorded by Adhikari *et al*. (2014) [1] and Singh *et al*. (2023) [14].

Straw yield (q ha^{-1})

The data pertaining to straw yield (q ha^{-1}) of chickpea as affected by different treatments are presented in table 1. The mean straw yield was 37.34 q ha^{-1}.

The data revealed that the straw yield (q ha^{-1}) was influenced by different treatments. The significantly highest straw yield (q ha^{-1}) was observed in treatment T_5 *i.e.*, 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS (41.59 q ha^{-1}) which was statistically at par with T_7 *i.e.*, 100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS (40.89 q ha^{-1}), T_3 *i.e.*, 100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS (40.32 q ha^{-1}) and T_6 *i.e.*, 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS (38.56 q ha^{-1}). Among all the treatments, the lowest straw yield (q ha^{-1}) was observed in T_1 *i.e.*, Absolute control (27.56 q ha^{-1}) over rest of the treatments at all growth stages.

There was significant increase in grain yield in chickpea due to foliar spray of 12:61:00 as the balanced supply of nitrogen and phosphorous enhances overall plant growth leading to more biomass production including stems and leaves which constitute the straw. Although phosphorous primarily supports reproductive growth, it also enhances root development and overall plant vigour indirectly contributing to increased biomass and straw yield. Nitrogen is crucial for vegetative growth and chlorophyll production which drives photosynthesis. The increased vegetative growth directly translates into higher straw yield as the plant develops more extensive foliage and stems. Similar observations were recorded by Gomma *et al.* (2017) [2] and Meena *et al*. (2020) [8].

Biological yield (q ha^{-1})

The data pertaining to biological yield (q ha^{-1}) of chickpea as affected by different treatments are presented in table 1. The mean biological yield was 68.19 q ha^{-1}.

In chickpea, application of treatment T_5 *i.e.*, 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS (76.11 q ha^{-1}) was significantly superior and statistically at par with T_7 *i.e.*, 100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS (74.94 q ha^{-1}), T_3 *i.e.*, 100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS (73.71 q ha^{-1}) and T_6 *i.e.*, 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS (71.23 q ha^{-1}). Among all the treatments, the lowest biological yield (q ha^{-1}) was observed in T_1 *i.e.*, Absolute control (47.93 q ha^{-1}) over rest of the treatments at all growth stages. Thus, the application of T_5 *i.e.*, 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS resulted in enhancing various growth and yield contributing characters of chickpea and finally gave significantly higher grain yield and straw yield over all other treatments.

There is significant increase in biological yield in chickpea due to foliar spray of 12:61:00 as it enhances nutrient uptake, supporting overall plant growth. It also regulates phytohormones, promoting cell elongation and expansion. It also helps to increase cytokinin levels stimulating cell division and differentiation resulting in increased biological yield. Biological yield is a critical factor in chickpea production directly affecting

biomass production, seed yield and quality, overall plant growth and development. Similar observations were recorded by Heba *et al.* (2016) [3] and Gomma *et al*. (2017) [2].

1.4 Harvest index (q ha^{-1})

The data regarding to harvest index as influenced by different treatments are given in table 1. The data pertaining to harvest index was not significantly affected by different treatments. The treatment T_6 *i.e.,* 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS (45.90%) recorded maximum harvest index (%) followed by the treatments T_8 *i.e.,* 75% P_2O_5 through DAP + Two spray of Phosphoric acid @ 0.25% at 30 DAS and 45 DAS (45.68%) followed by T_4 *i.e.,* 75% P_2O_5 through DAP + Two spray of Nano DAP @ 0.25% at 30 and 45 DAS. (45.66%).

The lowest harvest index was recorded by T_1 *i.e.,* Absolute control (42.56%). This might be due to T_1 *i.e.,* Absolute control plot has minimum grain yield, straw yield and biological yield due to lower availability of nitrogen and phosphorous. This reduces grain yield and biological yield leading to minimum harvest index.

There is significant increase in biological yield in chickpea due to foliar spray of 12:61:00 as it increases both grain and straw yields in which the proportional increase in grain yield is often greater resulting in an improved harvest index. Phosphorous is vital for reproductive growth, improving pod setting, seed filling and overall grain development. This nutrient helps shift the plant's focus towards producing more grains relative to straw, thereby increasing the harvest index. Nitrogen supports healthy vegetative growth, but when balanced with phosphorous, it also indirectly boosts grain production by improving overall plant health, enhancing photosynthesis and supporting seed filling. Similar observations were recorded by Heba *et al*. (2016) [3] and Nget *et al.* (2022) [9].

Table 1: Grain yield, straw yield, biological yield and harvest index of chickpea as influenced by different treatments

Tr. No	Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
T_1	Absolute control	20.40	27.56	47.93	42.56
T_2	GRDF (FYM @ 5 t ha^{-1}, N: P_2O_5: K_2O @ 25:50:30 kg ha^{-1})	29.65	35.94	65.58	45.20
T_3	100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS.	33.44	40.32	73.71	45.34
T_4	75% P_2O_5 through DAP + Two spray of Nano DAP @ 0.25% at 30 and 45 DAS.	31.02	36.91	67.92	45.66
T_5	100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS.	34.56	41.59	76.11	45.40
T_6	75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS.	32.70	38.56	71.23	45.90
T_7	100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS.	34.10	40.89	74.94	45.50
T_8	75% P_2O_5 through DAP + Two spray of Phosphoric acid @ 0.25% at 30 and 45 DAS.	31.11	37.00	68.10	45.68
	S. E(m) ±	1.02	1.42	2.03	1.06
	C.D. at 5%	3.09	4.33	6.16	NS
	General Mean	30.87	37.34	68.19	45.15

2. Economics

The data pertaining to the effect of different treatments on economics of chickpea is presented in table 2.

Table 2: Gross monetary returns, cost of cultivation, net monetary returns and B:C ratio as influenced by different treatments

Tr. No	Treatments	Gross monetary returns (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net monetary returns (₹ ha^{-1})	B:C ratio
T_1	Absolute control	105307	52432	52875	2.01
T_2	GRDF (FYM @ 5 t ha^{-1}, N: P_2O_5: K_2O @ 25:50:30 kg ha^{-1})	152731	64133	88598	2.38
T_3	100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS.	172038	64777	107261	2.65
T_4	75% P_2O_5 through DAP + Two spray of Nano DAP @ 0.25% at 30 and 45 DAS.	159705	66035	93670	2.41
T_5	100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS.	177791	63984	113807	2.78
T_6	75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS.	168247	64448	103799	2.61
T_7	100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS.	175406	63233	112173	2.77
T_8	75% P_2O_5 through DAP + Two spray of Phosphoric acid @ 0.25% at 30 and 45 DAS.	160030	62947	97083	2.54
	S. E(m) ±	3329	-	3329	-
	C.D. at 5%	10016	-	10016	-
	General Mean	159407	-	96158	-

2.1 Gross monetary returns

Gross monetary return was significantly influenced by different treatments. Maximum gross monetary return was observed in T_5 *i.e.,* 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS treatment (₹ 177791 ha^{-1}) which was followed by T_7 *i.e.,* 100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS (₹ 175406 ha^{-1}), T_3 *i.e.,* 100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS (₹ 172038 ha^{-1}) and T_6 *i.e.,* 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS (₹ 168247 ha^{-1}). The lowest gross monetary return was observed in T_1 *i.e.,* Absolute control (₹ 105307 ha^{-1}). Effective foliar application of 12:61:00 resulted in vigorous crop growth which resulted into higher yield as well as gross monetary returns. The highest gross monetary returns documented because of higher grain yield and straw yield due to foliar application of 12:61:00 on chickpea crop.

Foliar application of 12:61:00 is likely to improve yield components such as pods per plant, seeds per pod and seed weight. Higher yields directly translate to increased total production which is a key driver of Gross monetary returns. The foliar application can enhance nutrient uptake efficiency allowing for lower overall fertilizer inputs without sacrificing yield. This efficiency helps to reduce the cost per unit of yield positively affecting gross monetary returns. Similar observations

were recorded by Kirnapure *et al*. (2020) [6] and Jadhav *et al*. (2021) [4].

2.2 Cost of cultivation

Cost of cultivation was significantly influenced by different treatments. Maximum cost of cultivation was observed in T_4 *i.e.*, 75% P_2O_5 through DAP + Two spray of Nano DAP @ 0.25% at 30 and 45 DAS (₹ 66035 ha^{-1}) due to high cost of Nano DAP and its two sprayings at 30 and 45 DAS, followed by T_3 *i.e.*, 100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS (₹ 64777 ha^{-1}) due to foliar spray of Nano DAP which increased the cost, followed by T_6 *i.e.*, 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS (₹ 64448 ha^{-1}) due to two foliar spray of 12:61:00 at 30 and 45 DAS which increased its cost, followed by T_2 *i.e.*, GRDF (FYM @ 5 t ha^{-1}, N:P_2O_5:K_2O @ 25:50:30 kg ha^{-1} (₹ 64133 ha^{-1}) whose cost increased due to more expenditure on weeding and gap filling. The lowest cost of cultivation was observed in treatment T_1 *i.e.*, Absolute control (₹ 52432 ha^{-1}) due to complete reduction in use of fertilizers and foliar sprays.

Cost of cultivation for foliar spray of 12:61:00 was lower than foliar sprays of Nano DAP and Phosphoric acid which helped to reduce cost of cultivation. Similar observations were recorded by Kumar *et al*. (2013) [7] and Yadav *et al*. (2022) [16].

2.3 Net monetary returns

The net monetary returns were significantly influenced by different treatments. Significantly highest net monetary returns was observed in the treatment T_5 *i.e.*, 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS treatment (₹ 113807 ha^{-1}) which was at par with treatment T_7 *i.e.*, 100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS (₹ 112173 ha^{-1}), T_3 *i.e.*, 100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS (₹ 107261 ha^{-1}) and T_6 *i.e.*, 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS (₹ 103799 ha^{-1}). The lowest net monetary returns were observed in T_1 *i.e.*, Absolute control (₹ 52875 ha^{-1}). Higher grain and straw yields as well as lower cost of cultivation, were responsible for the higher net monetary returns in treatment T_5 *i.e.*, 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS.

Higher grain yield and straw yield as well as lower cost of cultivation were responsible for the higher net monetary returns due to foliar sprays of 12:61:00. While there is initial cost associated with the foliar spray, improved efficiency in nutrient uptake can lead to reduced overall fertilizer use in subsequent seasons. This reduction can lower input costs per unit of yield which ultimately results in increased net monetary returns. Similar observations were recorded by Raushan *et al*. (2020) [11] and Jadhav *et al*. (2021) [4].

2.4 B:C ratio

The data pertaining to the effect of different treatments on B:C ratio presented in table 4.15 and graphically depicted in fig. 17. The B:C ratio is related with gross monetary returns and cost of cultivation. The highest benefit cost ratio was recorded by the treatments T_5 *i.e.*, 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS (2.78) which is followed by T_7 *i.e.*, 100% P_2O_5 through DAP + One spray of Phosphoric acid @ 0.25% at 30 DAS (2.77), T_3 *i.e.*, 100% P_2O_5 through DAP + One spray of Nano DAP @ 0.25% at 30 DAS (2.65) and T_6 *i.e.*, 75% P_2O_5 through DAP + Two spray of 12:61:00 @ 1.0% at 30 and 45 DAS (2.61). The lowest benefit cost ratio was observed in T_1 *i.e.*, Absolute control (2.01).

Highest gross monetary returns was obtained in chickpea crop due to foliar spray of 12:61:00 and the cost of cultivation of foliar sprays of 12:61:00 was less than foliar sprays of Nano DAP and Phosphoric acid. Hence high yields and low cost contributed to increased B:C ratio for chickpea crop. Similar observations were recorded by Rajput *et al*. (2022) [10] and Sathyan *et al*. (2022) [13].

Conclusion

Amongst the application of different treatments to Chickpea crop, the treatment of application of 100% P_2O_5 through DAP + One spray of 12:61:00 @ 1.0% at 30 DAS recorded significantly higher grain yield (34.56 q ha^{-1}), straw yield (41.59 q ha^{-1}), biological yield (76.11 q ha^{-1}) and harvest index (45.40%) than rest of the treatments. The same treatment also obtained maximum net monetary return (₹113807 ha^{-1}) and B:C ratio (2.78) than rest of all treatments.

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