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Agriculture Drone-A Boon Technology for Foliar Nutrition to Enhance Productivity of Blackgram (*Vigna mungo*)

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ABSTRACT

Background: The current study aimed to evaluate the effect of foliar nutrition of TNAU pulse wonder and polyfeed using an agricultural drone in comparsion with hand spray on black gram growth and yield efficiency.

Methods: The field experiment conducted during the summer of 2023 at the VOC Agricultural College and Research Institute, Tamil Nadu Agricultural University, Killikulam. A randomized block design of eight treatments and three replications was used to set up the experiment. The treatments included drone spray with two different concentration of TNAU pulse wonder and Poly feed individually at the rate of 1.0% and 2.0%). Similarly manual spraying of the same product at 1.0% and 2.0% were performed.

Result: The results revealed that drone spray of 2% TNAU pulse wonder with spray fluid of 75 L ha^{-1} using atomizer nozzle recorded higher plant dry matter production (3952 kg ha^{-1}), more LAI (3.54), higher grain (725 kg ha^{-1}) and haulm yield (2935 kg ha^{-1}), with the net return of 25335 Rs.ha^{-1} and B:C ratio of Rs.2.20 per rupee invested. it was followed by application of Poly feed 2.0% through drone. Manual spray of both TNAU pulse wonder and Poly feed were underperformed in blackgram. Hence, it is concluded that application of 2% TNAU pulse wonder at 30 and 45 DAS through drone could be a viable technology to improve the growth and yield of black gram.

Key words: Black gram, Foliar nutrition, Manual spray, Poly feed, Pulse wonder, UAV.

INTRODUCTION

Black gram cultivation in India predominantly occurs in marginal lands with limited external input supply. As a result, the crop frequently experiences nutritional deficits at different growth stages which lead to lower growth and yield than the average yield reported globally. The foliar application of nutrients helps in quick correction of nutritional deficiencies, reduce nutrient loss and increase nutrient usage efficiency (Ashraf *et al*., 2024). It enhances nutrient absorption (8 to 20 times) more effectively than traditional soil application methods which leading to stimulated root development, nodulation, energy transformation, metabolic processes, pod setting and the translocation of photosynthates in plants thereby significantly boosting overall crop yield. The manual spraying of nutrients often leads to improper application, increased labor demand, escalated labor wages and subsequently higher production costs. Unmanned aerial vehicle systems (UAVs) commonly known as drones are increasingly proposed as a potential alternative to solve these issues. UAV can cover large areas and expedite the application process, transitioning from traditional large-volume locomotive spray technology to low-volume spray technology (Vijayakumar *et al.,* 2022). However, the efficiency of drone-assisted foliar application of nutrients and crop boosters compared to manual spraying remains largely untested across various crops, pesticides and climatic conditions (Kumar *et al*., 2021). Among the numerous factors influencing the efficiency of foliar spraying, the concentration of pesticides assumes paramount importance. Therefore, a field experiment has been undertaken with the primary objective of standardizing nutrient concentrations for the foliar application of nutrients and crop boosters through drones.

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MATERIALS AND METHODS

A field experiment was carried out during the summer season (April-July 2023) at VOC Agricultural College and Research Institute, Killikulam, Tamil Nadu. The experimental site (Fig 1) is situated in the Southern agro-climatic zone of Tamil Nadu at 8°46′North latitude and 77°42′East longitude, at an altitude of 40 m above MSL. The soil of experimental plot was sandy clay loam with a pH of 7.1 which was neutral in nature. The treatment details were T_1- Drone spray of Poly feed @ 1%, T_2- Drone spray of Pulse wonder @ 1%,

T_3- Manual spray of Poly feed @ 1%, T_4 - Manual spray of Pulse wonder @ 1%, T_5- Drone spray of Poly feed @ 2%, T_6- Drone spray of Pulse wonder @ 2%, T_7 - Manual spray of Poly feed @ 2% and T_8- Manual spray of Pulse wonder @ 2%. KKM 1 was the variety used for the trial. Seeds were sown at a spacing of 30×10 cm.

Fertilizers and chemicals

The recommended dose of 25:50:25:40 kg of NPKS and 25 kg of $ZnSO_4$ applied using Urea, DAP, MOP, Gypsum and Zinc sulphate as basal soil application. The foliar spray of TNAU pulse wonder and poly feed was given on 30 and 45 DAS as per the treatment using manual knapsack sprayer and agricultural drone.

Polyfeed

Polyfeed contains NPK in the ratio of 19:19:19 per cent which is water soluble in crystalline form. It is used for the crops grown in green houses as well as other field crops which was applied through fertigation and foliar spraying. It is chloride free fertilizer. Polyfeed enables instant uptake of nutrients and it minimizes the voltalization. It is applied to the crops at all stages *viz.,* seedling stage, vegetative stage and flowering stage. The recommended dosage of spray is 1.0%.

TNAU pulse wonder

The Department of Crop Physiology of Tamil Nadu Agricultural University Coimbatore has developed a crop booster to improve the yield potential of pulses. TNAU Pulse Wonder has been specifically developed to increase the yield of blackgram and greengram apart from the preventive management of physiological and nutritional disorders that occurs in different stages of pulse crop. It contains both macro, micro nutrients and plant growth hormones that promotes better growth and development for the pulse crop and also it contains ingredients that are water soluble which facilitates complete absorption of nutrients. It reduces flower drop and improves the yield by 10-20 %. The recommended dosage is 5 kg ha^{-1} at 1.0 per cent concentration as foliar spray.

Foliar application

The Hexacopter Agriculture drone model E610P with dimensions of 1365×1365×480 mm and 10 liters pay load capacity was used for foliar spraying of nutrients with Flood Jet Nozzle. The operational parameters namely GPS, flight height (1.5 m), flight velocity (0-10 ms^{-1}), flight time (25 min with Lithium ion), spraying width (4-5 m) and maximum tilt angle (15®) were pre-determined for the experimental site and controlled by the well-trained operator and the vehicle was operated as manual flight mode. The spray volume used for drone spray is 75lit ha^{-1}. The specification of hexacopter drone is mentioned in Table 1 and Fig 2.

A Knapsack sprayer fitted with a flat fan nozzle was used for manual spraying of foliar nutrients with 500 litres / hectare of spray volume and the loading capacity of the knapsack sprayer was 10 liters.

Growth and yield parameters

The height was measured from the base to the tip of the terminal bud and the mean value is expressed in cm. Similarly, the number of branches $plant^{-1}$ was counted from the tagged plants and mean value was worked out and expressed in number $plant^{-1}$. Leaf area index (LAI) of irrigated black gram was measured at 30 and 45 days after sowing (DAS) by non-destructive method as suggested by Palaniswamy and Gomez (1977). Dry matter production (DMP) was estimated from randomly selected five plants at all growth stages outside the net plot area. Samples were collected, shade-dried and then oven-dried at 60±5°C for 72 hours until constant weights were achieved and expressed in kg ha^{-1}. Pods from each tagged plants were counted and the total value was expressed as the number of pods per plant. The number of seeds from the pods was then counted and the

Fig 1: General view of experimental field.

Table 1: Specifications of hexa-copter battery-operated drone sprayer.

Main parameter	Norms and numerical values
Type	Hexacopter
Item model	E610P
Unfold fuselage size, mm (L×W×H),	2000×1800 ×670
Folding Size, (L×W× H), mm	950×850×670
Power source	12S 16,0000 mAh (Lithium polymer battery)
Tank capacity, L	10
Self-weight, kg	6.9
Take-off weight, kg	26
Flight height, m	1-20
Forward travel speed, ms^{-1}	0-8
Type of spray nozzle	Flat fan shape (2020A-132 series)
Number of nozzle	4
Discharge rate, l m^{-1}	0-3.2
Swath width of spray, m	3-5
Liquid pressure, kg cm^{-2}	3.4
Remote controller distance, km	1.5
No-load flight time, min	25
Charging time, min	90
Maximum tilt angle (°)	30

mean value was expressed as the number of seeds per pod. Finally the grain and haulm yield were arrived after harvest of the crop from the net plot area and expressed in kg ha^{-1}.

Statistical analysis

The experiment was laid out in a randomized block design with eight treatments and three replications. Statistical analysis of data was done by the analysis of variance method as suggested by Gomez and Gomez (1984). Wherever treatment differences were significant, critical difference was worked out at five per-cent probability level. Treatment differences that were non-significant are denoted by 'NS'.

RESULTS AND DISCUSSION

Growth parameters

Irrigated blackgram markedly influenced by foliar fertilization that too with the aid of un-maned aerial vehicle like agriculture drone. Foliar application of TNAU pulse wonder @ 2.0% through drone with spray fluid of 75 L ha^{-1} using atomizer nozzle recorded significantly taller plants (38.1 cm), higher number of branches per plant (7.8) and dry matter production (3952 kg ha^{-1}) over manual spray of both TNAU pulse wonder and polyfeed either 1.0% nor 2.0% (Table 2). However, foliar spray of polyfeed @ 2.0% recorded the next best growth parameters of blackgram. Manual spray of 1% poly feed recorded shorter plants (29.4 cm), lesser number of branches per plant (6.8) and dry matter production (3248 kg ha^{-1}). The presence of micronutrients in addition to macro nutrients in pulse wonder might have responsible for boosted plant height and dry matter production. Moreover the hexacopter Agriculture drone propellers created turbulence, causing downwash air flow to flutter and turn the leaves over. This resulted in increased deposition of pulse wonder on the active sites of the leaves from top to bottom of the crop canopy. The delivery of finer spray

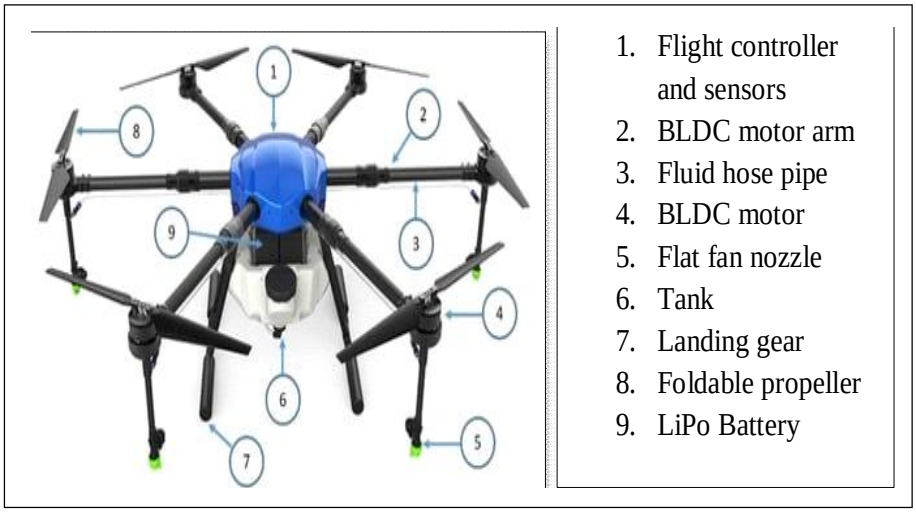

Fig 2: Six-rotor electric autonomous UAV sprayer.

Table 2: Effect of nutrients application through drone and manual spray on growth parameters, growth analysis and yield of black gram.

Treatments	Plant height (cm)	Number of branches $plant^{-1}$	Dry matter production (kg ha^{-1})	No. of root nodules $plant^{-1}$	No of pods $plant^{-1}$	No of seeds pod^{-1}	100 Seed weight (g)	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index
T_1	30.4	7.1	3377	22.3	26.2	6.20	5.32	595	2397	0.199
T_2	32.2	7.2	3462	22.5	27.2	6.20	5.37	625	2485	0.201
T_3	29.4	6.8	3248	21.9	23.6	5.80	5.23	555	2248	0.198
T_4	29.3	7.0	3317	22.0	25.4	5.90	5.29	598	2352	0.203
T_5	34.6	7.2	3713	23.3	31.5	6.50	5.49	650	2618	0.199
T_6	38.1	7.8	3952	25.4	34.6	6.70	5.53	745	2835	0.208
T_7	31.8	7.2	3507	22.7	29.3	6.30	5.40	610	2570	0.192
T_8	33.4	7.4	3731	23.0	30.8	6.40	5.46	635	2630	0.194
SE.d	0.85	0.24	105.4	0.71	1.3	0.18	0.19	21.5	91.0	-
CD (p=0.05)	3.05	0.49	218.5	1.47	2.6	0.36	1.02	46.5	196.2	-

Note: T_1 - Drone spray of Poly feed @ 1%, T_2 - Drone spray of Pulse wonder @ 1%, T_3 - Manual spray of Poly feed @ 1%, T_4 - Manual spray of Pulse wonder @ 1%, T_5 - Drone spray of Poly feed @ 2%, T_6 - Drone spray of Pulse wonder @ 2%, T_7 - Manual spray of Poly feed @ 2%, and T_8 - Manual spray of Pulse wonder @ 2%.

droplets with increased penetration can improve nutrient translocation efficiency compared to manual spraying and thus increased growth parameters (Nandhini *et al.*,2022).

Likewise, Drone spray of 2% TNAU pulse wonder also recorded higher number of root nodules per plant (25.4) over other treatments (Table 2). Manual spray of 1% poly feed recorded lesser number of root nodules per plant (21.9). The higher number of root nodule in Drone spray of Pulse wonder @ 2% might be due to the increased nitrogen fixation capacity of the pulse crop. The higher N fixation might have helped in better plant growth and higher biomass production which intern resulted in better development of yield attributes like pods plant^{-1}, seeds pods^{-1} and seed weight (Das and Jana, 2015).

Growth analysis

The foliar spray of TNAU pulse wonder and poly feed under different concentrations using drone and manual spray significantly influenced the LAI (Fig 3) and Crop Growth Rate at 45 DAS (Fig 4). Drone spray of 2% TNAU pulse wonder significantly recorded 17 per cent higher CGR during 30-45 DAS and 36.7 per cent during 45 DAS to harvest over other foliar nutrition treatments. Besides, the same treatment also recorded higher LAI of 2.0 and 3.54 during 30 and 45 DAS, respectively and it was 9.0 and 7.0 per cent higher than the LAI recorded under 1.0% pulse wonder applied through drone as well as 12 and 10 per cent higher than the 1% pulse wonder applied manually during the respective periods of observation. This could be

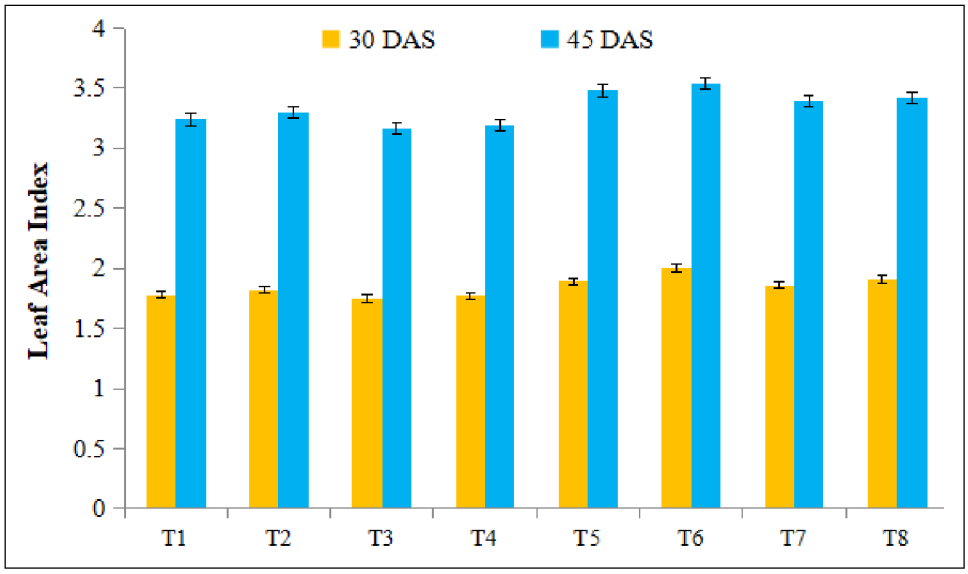

Fig 3: Effect of nutrients application through drone and manual spray on LAI of black gram.

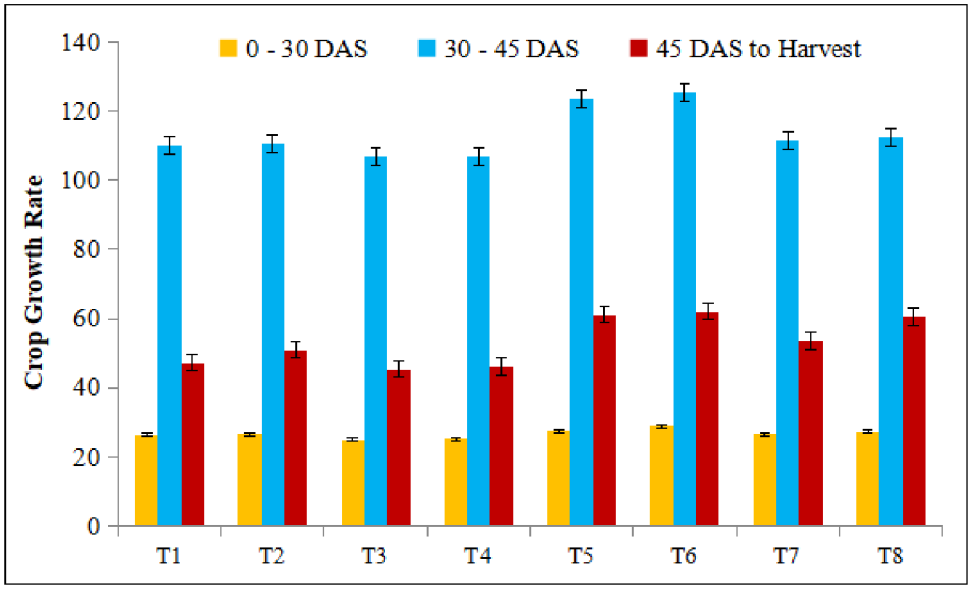

Fig 4: Effect of nutrients application through drone and manual spray on CGR of black gram.

because of the greater number of leaves, leaf area and branches attained by the drone nutrition with pulse wonder. The foliar nutrients might have supplemented the nutrient demand of the crop at the critical stage, resulting in better growth and development of the crop and ultimately the plant physiological parameters. (Manivannan *et al*., 2002).

Yield attributes

Spraying of TNAU pulse wonder @ 2% using drone recorded significantly more number of pod plant^{-1} (34.6), number of seed pod^{-1} (6.7) and 100 seed weight (5.53g) however it was followed by foliar spray of polyfeed @ 2.0% recorded the next best yield attributes of blackgram which recorded 31.5 number of pod plant^{-1}, 6.5 number of seed pod^{-1} and 5.49gof 100 seed weight (Table 2). Manual spray of 1.0 % poly feed with spray fluid of 500 litre ha^{-1} recorded lesser number of pods plant^{-1} (23.60), number of seed pod^{-1} (5.80) and 100 seed weight (5.23). The increased number of flowers and pods were due to pulse wonder application using drone supplemented nutrient at critical stage of growth, decreased flower dropping and increased floral bud by increasing the metabolic activity of the plant and finally more number of pods. Similar findings were reported by Kunjammal and Sukumar (2019). The yield attributes in drone spray when compared with conventional knapsack sprayer was high due to the high absorption of TNAU Pulse wonder. The improvement in the growth phases, active absorption and transfer from source to sink as a result of physiological and biochemical processes (Kaniska *et al.,* 2022).

Yield

Growth promoting substances applied at different concentration either by drone or manually cause significant variation in yield of irrigated blackgram. Higher grain yield of 745 kg ha^{-1} and haulm yields of 2835 kg ha^{-1} as well as a harvest index (0.208) were significantly recorded with a drone spray of 2% TNAU pulse wonder using spray fluid of 75 litres per hectare (Table 2 and Fig 5). It was followed by foliar application of polyfeed @ 2.0% recorded the next best grain and haulm yield of blackgram. With 1.0 % poly feed through hand spray, a lower grain yield of 555 kg ha^{-1} and haulm yield of 2248 kg ha^{-1}. A pulse wonder foliar spray retarded senescence and provided the crop with balanced nutrients that enhanced overall transport and partitioning efficiency. This led to continuous source-to-sink translocation, which was manifested in a higher number of pods per plant and seeds per pod as well as a higher yield. These results were in conformity with the work Sachin *et al.,* (2019). Moreover Pulse wonder was better absorbed when it was sprayed by drone than with hand spray. Reduced deposition of pulse wonder from top to bottom of the crop canopy on the active site of the leaf occurred as a result of the propeller-induced turbulence, which flipped and fluttered the leaves. The translocation of nutrients may have been enhanced more effectively by uniform dispersion of finer spray droplets with higher penetration than by manual spraying. Better crop growth and production were the outcome of higher physiological parameters brought about by the combination of all the factors. These results were in line with the work of Yang *et al.,*(2018) and Martin *et al.,* (2020). Application of 2% concentration performed better than 1% due to increased droplet deposition density; spray fluid 75 liters ha^{-1} performed better spray coverage under drone spray.

Economics

Among the treatment results, Table 3 shows that the cost of cultivation ranged between Rs. 19,800 ha^{-1} and Rs. 21,680 ha^{-1}. Higher cost of cultivation was registered in manual spray of TNAU Pulse wonder @ 2% (Rs. 21,680 ha^{-1}). Whereas, Drone spray of Poly feed @ 1% (T_1) recorded lowest cost of cultivation which was on par with manual spray of Poly feed @ 1% (T_3). Conversely, higher gross return (Rs. 46,435 ha^{-1}) was determined in drone spray of TNAU Pulse wonder @ 2% (T_6) and It was followed by foliar application of polyfeed @ 2.0% through drone accounting Rs. 41,880 ha^{-1}. Lower gross income of Rs.35, 648 ha^{-1} was obtained in manual spray of Poly feed @ 1% (T_3). similarly Superior net return of Rs.25,335 ha^{-1} and B: C ratio of 2.20 was recorded in drone spray of TNAU Pulse wonder @ 2% (T_6) which was followed by drone spray of Poly feed @ 2% (T_5) registered net return and B: C ratio of Rs. 21,380 ha^{-1} and

Fig 5: Best treatment: Drone spray of Pulse wonder @ 2% (T_6).

Table 3: Effect of nutrients application through drone and manual spray on economics of black gram.

Treatments	Cost of cultivation (Rs.ha^{-1})	Gross income (Rs.ha^{-1})	Net income (Rs.ha^{-1})	B:C ratio
T_1	19800	38197	18397	1.93
T_2	20100	40085	19985	1.99
T_3	19800	35648	15848	1.80
T_4	20680	38322	17652	1.85
T_5	20500	41880	21380	2.04
T_6	21100	46535	25435	2.21
T_7	21080	39270	18190	1.86
T_8	21680	40830	19150	1.88

Note: T_1 - Drone spray of Poly feed @ 1%, T_2 - Drone spray of Pulse wonder @ 1%, T_3 - Manual spray of poly feed @ 1%, T_4 - Manual spray of Pulse wonder @ 1%, T_5 - Drone spray of Poly feed @ 2%, T_6 - Drone spray of Pulse wonder @ 2%, T_7 - Manual spray of Poly feed @ 2%, and T_8 - Manual spray of Pulse wonder @ 2%.

2.04, respectively. The higher returns and BCR were primarily due to increased grain yield, lower labour costs and reduced input requirements under application of TNAU pulse wonder through drone. These findings were consistent with Dayana *et al.* (2022). Minimum net return of Rs.15,848 ha^{-1} and B: C ratio of 1.80 was recorded in manual spray of Poly feed @ 1% (T_3).

CONCLUSION

Foliar application of TNAU pulse wonder at 2% through drone using spray fluid of 75 litres per hectare could increase the growth and yield of irrigated black gram. In consideration of the current workforce crisis, it is determined that spraying 2% TNAU pulse wonder at 30 and 45 DAS with 75 litres ha^{-1} of spray fluid using agricultural drones could be a feasible way to boost KKM 1 black gram growth and production. Using drones to apply nutrients is beneficial since they perform better than manual spraying.

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Conflict of interest

All authors declared that there is no conflict of interest.

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