INTERCOMPARISON OF DRONE AND CONVENTIONAL SPRAYING OF NUTRIENTS ON CROP GROWTH AND YIELD IN BLACK GRAM

Abstract

An experiment was conducted to reveal the effect of drone spraying of foliar nutrients on the crop growth and yield in black gram at Agricultural Research Station, Bhavanisagar in a Randomized block design with 12 treatments and 3 replications. The biometric parameters *viz.*, plant height, leaf area, dry matter production and yield parameters *viz.*, no. of pods plant^{-1}, haulm yield were influenced by drone spaying treatments than the conventional method of knapsack spraying. The results revealed that Fuel operated drone spray of 2% pulse wonder with spray fluid of 75 L ha^{-1} using an atomizer nozzle recorded the highest growth and yield attributes values. The treatment which registered the highest grain and haulm yield of 784 and 1525 kg ha^{-1} and performed better than foliar spraying of All 19 solution with fuel operated drone and the lowest yield was noticed in control. From this study, it is concluded that fuel operated drone spray of 2% pulse wonder using the atomizer nozzle with spray fluid of 75 L ha^{-1} is adopted to enhance the growth and grain yield of black gram.

Keywords: Pulse wonder, Drone spray, Black gram, Crop booster

Introduction

Pulses are an amazing gift of nature with incomparable abilities like a deep root system, biological nitrogen fixation, and mobilization of insoluble soil nutrients. They are called soil fertility restorers as they bring qualitative variations in soil properties (Kumar, 2018a). Pulses are an important component of the food and economy of the Indian subcontinent. India is the largest producer, consumer and importer of pulses in the world. The area under the cultivation of pulses is 28.8 million hectares with a total production of 25.72 million metric tons and productivity of 892 kg ha^{-1} in 2021.

The Black gram [*Vigna mungo* (L.)] is one of the most important pulse crops farmed in the country. In India, black gram is grown in various cropping systems such as mixed crop, catch crop, and sequential crop. Black gram seed has a protein, carbohydrate and fat content of 25, 60 and 1.5 per cent, respectively with minerals, amino acids and essential vitamins. Black gram is grown extensively in Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Uttar Pradesh, West Bengal, Punjab, Haryana, and Karnataka in India (Kumar, 2018b)

The fertilizer All 19 combination provides all the macro nutrients N, P, K in the balanced ratio of 19:19:19 that aids crop growth. On the other hand, the foliar spraying of crop boosters especially pulse wonder at peak flowering stage, induces the pod formation and reduces the flower drop and thereby increases the yield (Mir *et al.*, 2010). Foliar application of nutrients aid in improved nutrient translocation and utilization in plants and enhanced 8 to 20 times more absorption of nutrients than applied to the soil. It nourishes plants, enhances photosynthetic efficiency, minimizes nutrient losses and increases production (Smoleń, 2012; Vijay Kumar *et al.*, 2020).

The conventional foliar spraying approach necessitates more labour and a high input cost and nowadays, farmers are facing serious challenges such as labour shortages and hike in labour costs. Agricultural drones are utilized for foliar nutrient spraying to overcome this situation and give the best solution to reduce the labour requirement and production cost and enhance productivity and fasten the application rate thereby covering the larger areas. Drones are unmanned aerial vehicle systems (UAVs) that are operated remotely and used to spray agrochemicals using an automated pre-programmed GPS system (Pathak *et al.*, 2020). UAVs have the advantage of replacing traditional large-volume mass locomotive spray technology with low-volume spray technology (Liu *et al.*, 2018). Foliar application of nutrients using drone needs to be studied thoroughly for its feasibility. The experiment was conducted with the objective of standardizing nutrient concentration and selection of suitable type drone with nozzle for spraying nutrient and crop booster to improve the yield of black gram var. VBN 8 and the hence the foliar application of nutrients and crop boosters is to be studied for its feasibility and applicability.

Materials and Methods

Experimental site

The experiment was carried out at the Northern block (N block) of Tamil Nadu Agricultural Research Station (ARS), Bhavanisagar. The site is located at a latitude of 11° 29' N and a longitude of 77° 80' E at 256 m above mean sea level. The soil type is predominantly medium to deep reddish brown belonging to the Irugur soil series.

Experimental design and treatment details

The field experiment was laid out in a randomized block design with twelve treatments and three replications. The treatment details were:

Table.1. Treatment details of the experiment

T1	Battery operated Drone spray of 1 % All 19 with jet type nozzle and a spray fluid of 25 L ha^{-1}
T2	Fuel operated Drone spray of 1 % All 19 with jet type nozzle and a spray fluid of 25 L ha^{-1}
T3	Fuel operated Drone spray of 1 % All 19 with Atomiser nozzle and a spray fluid of 75 L ha^{-1}
T4	Manual spray of 1 % All 19 with knapsack sprayer and a spray fluid of 500 L ha^{-1}
T5	Battery operated Drone spray of 1 % TNAU pulse wonder with jet type nozzle and a spray fluid of 25 L ha^{-1}
T6	Fuel operated Drone spray of 1 % TNAU pulse wonder with jet type nozzle and a spray fluid of 25 L ha^{-1}
T7	Fuel operated Drone spray of 1 % TNAU pulse wonder with Atomiser nozzle and a spray fluid of 75 L ha^{-1}
T8	Battery operated Drone spray of 2 % TNAU pulse wonder with jet type nozzle and a spray fluid of 25 L ha^{-1}
T9	Fuel operated Drone spray of 2 % TNAU pulse wonder with jet type nozzle and a spray fluid of 25 L ha^{-1}
T10	Fuel operated Drone spray of 2 % TNAU pulse wonder with Atomiser nozzle and a spray fluid of 75 L ha^{-1}
T11	Manual spray of 2 % All 19 with knapsack sprayer and a spray fluid of 500 L ha^{-1}
T12	Control (Water spray)

Seeds were sown at a spacing of 30 x 10 cm in a large sized plot dimension of 50 X 8 m. The experiment was laid out in a randomized block design with three replications. Pulse wonder was sprayed at the peak flowering stage of the crop i.e., 45 days after sowing (DAS) using a manual knapsack sprayer and agricultural drones with flat jet and atomizer nozzles.

Two types of drones *viz.*, Battery operated, and Fuel operated drones, were used for foliar spraying of nutrients (All 19) and the crop boosters (pulse wonder) with two different nozzles, i.e., Flood jet nozzle and Atomizer nozzle.

Drone parameters

The technical parameters for different types of spraying drones for the foliar spray of nutrients and crop boosters are as given below:

Table.1. Technical parameters of the fuel and battery operated drones

Parameters	Fuel Operated	Battery operated
Dimensions (mm)	2160×2250×600	1520×1520×590
Nozzle type	Flood Jet & Atomiser	Flood Jet
Tank capacity (L)	16	10
Fuel tank capacity (L)	4	Not available
Spraying width (m)	4	4
Flying height (m) (Above crop canopy)	1	1
No. of nozzles	4	4

Observations

One hundred plants were selected randomly for each treatment to record the growth and yield parameters regularly. Biometric observations viz., plant height and leaf area index (LAI) and dry matter production were recorded at 15 days intervals regularly. SPAD meter chlorophyll readings (SMCR) were recorded at different stages of the black gram crop, viz., 30, 45 and 60 DAS. Yield parameters such as the number of pods plant^{-1}, grain yield and haulm yield were also observed at the harvest stage.

Statistical analysis

The observations recorded are statistically analyzed by the method outlined by Panse and Sukhatme (1967). The critical difference was calculated for all the treatments at the probability level ($\alpha = 0.05$).

Results and Discussion

Growth parameters

Plant Height

Plant height was significantly influenced by foliar spraying of Pulse wonder and nutrients through drones than conventional spraying during 45 DAS and harvest. Among the treatments, foliar spraying through drones registered the highest plant height than conventional spraying. Among the nutrient solutions, foliar spraying of crop boosters accounted for the highest plant height than All 19 solution (Karthikeyan *et al.*, 2020).

Fuel operated drone spraying of 2% TNAU pulse wonder with spray fluid volume of 75 L ha^{-1} using atomizer nozzle (T10) significantly recorded the highest plant height of 50.3 cm and 59.2 at 45 DAS and harvest than battery operated and manual spraying however, this was on par with Fuel operated drone spray of 2 % pulse wonder with (T9) and battery operated drone spray of 2 % pulse wonder (T8) using Jet type nozzle. The spray using an atomizer recorded a slightly higher plant height than the flood jet nozzle. The drone spray of 1 % pulse wonder using fuel operated with atomizer and flood jet, battery operated with flood jet type nozzles treatments are on par with each other.

Foliar application of pulse wonder might have increased the availability of iron, boron, and plant growth hormones for black gram, resulting in more vigorous root, cell wall, plasma membrane, cell division, tissue differentiation, nucleic acid, carbohydrate, and shoot initiation, resulting in increased crop growth and establishment in terms of plant height (Balaji *et al.*, 2019; Srinivasan *et al.*, 2019). The control treatment (water spray) registered the lowest plant height of 36.6 and 41.9 cm during 45 DAS and harvest (Table 3), respectively and these findings were in accordance with Dayana *et al.* (2021)

LAI

The foliar application of pulse wonder results in higher plant height and greater number of leaves which might further produced higher LAI. The LAI was found to be at its peak at 45 DAS and further starts to decrease at harvest due to the fall of matured leaves (Islam *et al.*, 2010). The Fuel operated drone spray of 2% TNAU pulse wonder with spray fluid of 75 L ha^{-1} using an atomizer nozzle (T10) has resulted in higher LAI (3.79) than conventional knapsack spraying (T4 and T11) and control (T12). The treatments viz., fuel operated (T9) and battery operated (T8) drone spray of 2% TNAU pulse wonder with flood jet nozzles were on par with each other, which recorded the LAI of 3.61 and 3.59, respectively.

The control (T12) recorded the lowest LAI (1.47) (Table 3). The higher LAI might be due to the beneficial effects of foliar nutrient spraying on cell division and cell elongation, resulting in improved crop growth and development and higher growth characteristics (Meena, 2004). Foliar application of TNAU Pulse wonder aided in the supply of photosynthates for development of pods and grains and intensification of metabolic activity (Sridhar *et al.*, 2020).

Table.3. Effect of foliar spray on growth parameters of black gram

Treatments	Plant height (cm)			LAI		
	30 DAS	45 DAS	At harvest	30 DAS	45 DAS	At harvest
T1	34.1	41.8	48.2	0.93	2.46	0.99
T2	34.5	42.3	48.2	0.75	2.52	1.06
T3	34.0	43.3	49.8	0.91	2.66	1.13
T4	33.9	38.3	44.1	0.90	1.82	0.63
T5	33.8	45.3	52.9	0.88	3.12	2.36
T6	34.0	46.0	53.6	0.92	3.28	2.47
T7	36.1	46.9	54.6	0.76	3.33	2.50
T8	36.3	48.7	57.7	0.84	3.59	2.68
T9	34.3	49.6	58.7	0.91	3.61	2.73
T10	36.8	50.3	59.2	0.66	3.79	2.78
T11	34.2	40.1	46.1	0.76	2.10	0.81
T12	33.4	36.6	41.9	0.74	1.47	0.44
SE.d	1.16	0.83	0.97	0.03	0.11	0.08
CD (0.05)	NS	1.72	2.01	NS	0.23	0.17

Dry matter production

The significant difference in dry matter production among the treatments was noticed due to drone spraying of pulse wonder using an atomizer nozzle (Table 4). The pulse wonder is composed of the nutrients and growth regulators which is required for plants for growth and yield enhancement. The Fuel operated drone spray of 2% pulse wonder with spray fluid of 75

L ha^{-1} using atomizer (T10) has recorded the highest dry matter production (3536 kg ha^{-1}) at harvest. It might be due to the foliar application of 2% pulse wonder at the peak flowering stage (45 DAS). The control treatment (T12) recorded the lowest dry matter production (1632 kg ha^{-1}) which might be due to the presence of a lesser amount of growth components (Nautiyal and Chatterjee, 2004). The results were similar to the findings of Balaji *et al.* (2019).

Table.4. Effect of foliar spray on dry matter production and SPAD meter values of black gram at different growth stages

Treatments	Dry matter production (kg ha^{-1})			SPAD meter chlorophyll values		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T1	1338	1860	2598	22.5	48.8	35.7
T2	1260	1920	2680	21.2	49.0	35.8
T3	1328	1998	2768	22.4	50.7	36.9
T4	1302	1490	1996	21.6	38.2	27.2
T5	1250	2200	2987	21.7	53.0	38.6
T6	1286	2256	3083	22.2	53.6	39.2
T7	1320	2285	3115	21.8	54.5	39.6
T8	1325	2489	3336	21.5	56.6	41.5
T9	1266	2536	3426	21.3	56.9	41.9
T10	1300	2600	3536	22.4	58.3	42.3
T11	1298	1660	2220	21.8	40.8	32.5
T12	1282	1328	1632	22.3	36.2	25.2
SEd	43.06	36.2	50.4	0.73	0.64	0.18
CD (0.05)	NS	75.2	104.6	NS	1.33	0.37

SPAD meter chlorophyll values

The SPAD meter chlorophyll readings seemed to be enhanced due to the foliar spray of nutrients and crop boosters. The results of the chlorophyll values revealed an increasing trend up to the pod formation stage and then a substantial decrease at maturity. The drone spray of 2% pulse wonder using atomizer (T10) recorded the highest chlorophyll value (58.3) and the control plot

(T12) recorded the lowest chlorophyll value (36.2) at 45 DAS. Due to the foliar nutrient spray of the pulse wonder and all 19, it is noted that the leaf senescence has been delayed causing the increase in chlorophyll content values. These findings were similar to that of Nithila (2018); Sivakumar *et al.* (2020).

Though the All 19 provide the balanced macronutrients, i.e., NPK in the 19:19:19 ratio, the pulse wonder on the other hand, provides the nutrients and the plant growth regulators required for plant growth and yield enhancement. Thus, The foliar spray of 2% pulse wonder (T10, T9, T8) seemed to record the highest chlorophyll values (58.3,56.9 and 56.6) than the All 19 spray (50.7,49.0,48.8).

Yield parameters

Pods/plant

The significant and the maximum number of pods plant^{-1} (15.8) was recorded by fuel operated drone spray of 2% pulse wonder using atomizer (T10) and the minimum number of pods plant^{-1} (8.2) was registered in control (T12) (Table 5). Higher nutrient availability throughout the flowering and pod formation stages of crop growth might have resulted in efficient photosynthate transfer from source to sink. More number of pods plant^{-1} and decreased flower drop are due to the prolonged assimilatory activity of leaves (Solaiappan *et al.* (2002).

Among the treatments, more number of pods plant $^{-1}$ were registered by the foliar spray of crop boosters using than the foliar spray using the conventional knapsack sprayer. The maximum number of pods plant^{-1} were observed in the foliar spray of the pulse wonder than in the All 19 spray. The increase in the number of pods might be due to the additive effect of foliar spray of macronutrients and crop boosters. (Karthikeyan *et al.*, 2020).

100 seed weight

The highest 100 seed weight (4.67 g) was observed by the fuel operated drone spray of 2% pulse wonder using an atomizer (T10) and the lowest 100 seed weight was observed in the control plot (T12). The foliar spray of the nutrients and crop booster resulted in the increase in dry matter production, thereby increasing the number of pods plant^{-1} that might cause an

increase in the 100 seed weight. The results were in agreement with the findings of Kumar *et al.* (2015); Gowsalya *et al.* (2016)

Haulm yield and seed yield

The fuel operated drone spray of 2% pulse wonder with spray fluid quantity of 75 L ha^{-1} using atomizer nozzle (T10) registered the highest haulm yield (1525 kg ha^{-1}) and grain yield (754 kg ha^{-1}) at harvest and was followed by fuel operated drone spray of 2% pulse wonder with spray fluid of 25 L ha^{-1} using flood jet nozzle (T9) and registered the haulm yield (1446 kg ha^{-1}) and grain yield (784 kg ha^{-1}). The manual spray of nutrients (T4) and crop boosters (T11) have recorded a higher haulm yield than the control plot but lesser haulm yield than the foliar spray of nutrients and crop boosters using drones. The control treatment recorded the haulm yield (811 kg ha^{-1}) and grain yield (313 kg ha^{-1}) (Table 5).

Higher yield might be attributed due to enhanced yield parameters such as number of pods $plant^{-1}$, number of seeds $pods^{-1}$, and greater nutrient uptake via effective transfer of nutrients from the sink to the reproductive area of the crop, which resulted in increased black gram seed yield (Pandey and Gupta (2013); Kunjammal and Sukumar (2019); Sachin *et al.* (2019).

The reason for the higher yield under drone spray over manual spray was due to enhanced absorption of pulse wonder. The propellers induced turbulence that caused a downwash air flow that fluttered and turned the leaves over, resulting in enhanced deposition of pulse wonder on the active site of the leaf from top to bottom of the crop canopy. The efficient translocation of nutrients might also be improved by the uniform distribution of finer spray droplets with increased penetration compared to manual spray. All of these elements together resulted in higher growth and improved physiological parameters, which led to improved crop growth and yield.

Table.5. Effect of foliar spray on yield of black gram

Treatments	No. of pods $plant^{-1}$	100 seed weight	Haulm yield (Kg ha^{-1})	Grain yield (Kg ha^{-1})
T1	11.4	3.82	1094	565
T2	11.6	3.88	1118	578

T3	11.9	3.98	1130	593
T4	9.3	3.65	904	414
T5	13.0	4.10	1225	641
T6	13.3	4.16	1277	656
T7	13.6	4.28	1313	682
T8	14.9	4.46	1412	733
T9	15.2	4.53	1446	737
T10	15.8	4.67	1525	784
T11	10.4	3.73	999	500
T12	8.2	3.60	811	313
SE.d	0.46	3.82	24.5	18.6
CD (0.05)	NS	3.88	50.9	38.6

In comparison to a hydraulic nozzle, i.e., Flood jet nozzle, a rotary atomization sprayer adjusts spraying parameters in real time without stopping the machine because the droplet size is controlled by the pump's flow rate and rotating speed of the disk which could be changed instantly. When wind speed or other environmental factors might cause s the variation instantly, the spraying may adjust automatically to achieve accurate and variable spraying (Gong *et al.*, 2019). Thus, the growth attributes and yield attributes of atomizer spray seemed to be the best compared to flood jet nozzle spray.

Conclusion

Crop growth and yield of a black gram could be enhanced by the application of crop booster, *viz*., All 19 and pulse wonder. The drone spraying proved to be efficient compared to the manual knapsack sprayers. The drone spraying using an atomizer proved to be better than flood jet nozzle and 2 % pulse wonder spray produced a better yield compared to 1% spay of both pulse wonder and All19. From this study, it is concluded that e fuel operated drone spray of 2% pulse wonder using an atomizer nozzle with spray fluid of 75 L ha^{-1} is recommended to enhance the growth and grain yield of black gram.

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