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Feasibility of using drone for foliar spraying of nutrients in irrigated green gram (*Vigna radiata* L.)

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ABSTRACT

An experiment was conducted at Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli during *summer*, 2021 to study the feasibility of using drone for foliar spray of nutrients on growth attributes, yield and economics of green gram. Experiment was laid out in randomized block design with 7 treatments and three replications. The treatments consisted two levels of TNAU pulse wonder (1% and 2%), two levels of drone spray fluid requirement (30 and 50 liters ha^{-1}) along with manual spray (1% and 2% of TNAU pulse wonder with 500 liters ha^{-1} spray fluid) and control. The results revealed that significantly higher growth characters such as plant height (56.2), number of branches $plant^{-1}$ (4.12), leaf area index (4.48), dry matter production (2961 kg ha^{-1}), yield attributes *viz.,* number of pods $plant^{-1}$ (39.2), number of seeds pod^{-1} (11.0), pod length (8.33 cm), pod weight (0.64 g), grain yield (747 kg ha^{-1}), haulm yield (1684 kg ha^{-1}) and economics such as gross returns (Rs. 53784 ha^{-1}), net returns (Rs. 28648 ha^{-1}), benefit cost ratio (2.14) were recorded with spray of 2% TNAU pulse wonder using drone with spray fluid of 50 litres ha^{-1} compared to manual spray and control. Thus, it is concluded that agricultural drone could be feasibly used for spraying of 2% pulse wonder with spray fluid of 50 litres ha^{-1} at peak flowering stage to increase productivity and profitability of green gram.

***Key words**: Drone, Foliar spray, Green gram, Pulse wonder, Spray fluid, Unmanned aerial vehicle (UAV)*

Introduction

Green gram is known as mung bean, significant short duration legume crop in India. It contains protein (24%), fat (1.5%) and carbohydrate (60%). It also contains 460 mg g^{-1} of lysine, 60 mg g^{-1} of tryptophan, 21 mg $100g^{-1}$ of riboflavin and calorific value of 334 calories per 100 g (Praveena *et al.,* 2018). It fixes atmospheric nitrogen of about 35 kg ha^{-1} through root nodules and enriches soil fertility. Being early maturing crop with a period of 65 to 70 days and due to its photo-thermo insensitivity nature it suits well in different cropping system and can be grown under all seasons (*kharif, rabi* and *summer*). It is also considered as erosion resisting and drought resistant crop that can be grown as catch crop in between two main crops (Movalia *et al.,* 2020). The total area of green gram in India was 47.55 lakh ha with a production of 24.55 lakh tonnes and productivity of 516 kg ha^{-1} (Anonymous, 2019). The poor yield performance of green gram was attributed to various physio-biochemical factors along

with inadequate management practices.

Foliar nutrition offers a suitable method to increase the yield potential of green gram, as it is associated with 8 to 20 times more efficient utilization of nutrients than soil applied nutrients (Smolen, 2012). The potential benefits of foliar spraying are timely supplying of nutrients with reduced nutrient loss, thus boosting crop productivity. Tamil Nadu Agricultural University, Coimbatore developed pulse wonder, a water soluble foliar nutrition product especially for pulses to reduce flower shedding and increase yield (CPG, 2020). It contains macro and micro nutrients that enhance several metabolic process of the plant. Conventionally, nutrients are sprayed manually using knapsack sprayer. At current scenario, farmers are facing and struggling for agricultural spraying due to non-availability of labour and hike of labour cost. To overcome the prevailing crisis, automated controlled system of spraying of fertilizers is required. Drone is an exuberant contraption for applying fertilizers in an efficient and appropriate manner. Drones are known as (UAV) system that is remotely controlled used for spraying of agro-chemicals with an automated preprogrammed GPS system (Pathak *et al.*, 2020). Foliar application of nutrients using drone needs to be studied thoroughly for its feasibility. Hence, this experiment was conducted with the objective of standardizing nutrient concentration and amount of spray fluid required for spraying using drone to improve the yield and economics of green gram.

Materials and Methods

Experimental site

The experimental trail was conducted at Anbil Dharmalingam Agricultural College and Research Institute situated in Tiruchirappalli, Tamil Nadu during *summer*, 2021. The site was geographically located at central part of Tamil Nadu with latitude of 10º45′ N, longitude of 78º36′ E and 85 m above mean sea level. The soil type of the experimental site was sandy clay loam with moderate drainage system. The soil was sodic in nature with a pH of 8.9. The soil has 0.42% of organic carbon, 189 kg ha^{-1} of nitrogen, 17.8 kg ha^{-1} of phosphorus and 246.1 kg ha^{-1} of potassium.

Experimental design and treatment details

A field experiment was laid out in a randomized block design with seven treatments, replicated thrice. The test area of each treatment was 200 m^2 (20mx10m). Green gram VBN (4) is the test variety used for trial. Seeds were dibbled at a spacing of 30x10 cm. Recommended dose of fertilizers at a rate of 25:50:25 kg ha^{-1} was applied as basal before sowing. Pulse wonder was sprayed once at peak flowering stage using manual knapsack sprayer and agricultural drone. The treatment details were: T_1 - Drone spray of 1% TNAU pulse wonder with spray fluid of 30 litres ha^{-1}, T_2 - Drone spray of 1% TNAU pulse wonder with spray fluid of 50 litres ha^{-1}, T_3 - Drone spray of 2% TNAU pulse wonder with spray fluid of 30 litres ha^{-1}, T_4 - Drone spray of 2% TNAU pulse wonder with spray fluid of 50 litres ha^{-1}, T_5 - Manual spray of 1% TNAU pulse wonder with spray fluid of 500 litres ha^{-1}, T_6 - Manual spray of 2% TNAU pulse wonder with spray fluid of 500 litres ha^{-1}, T_7 - Control.

Spray equipment

The Knapsack sprayer was operated with 15 litres tank capacity. Flat fan type of nozzle was used for spraying. The agricultural drone used in the study was AD610D model. The flight height, flight velocity and GPS were pre-determined for the experimental site and controlled by a well-trained operator. The loading capacity of the spraying system was 10 litres. The discharge rate of the flat fan nozzle was adjustable with 15 and 30 ml/sec. The spraying drone and knapsack sprayer was shown in Figure 1 and 2. The detailed specifications of the drone are presented in Table 1:

Table 1. Technical parameters of Agricultural spraying drone

Classification	Parameters
Drone model	AD610D
Dimensions (mm)	1365x1365x480
Motor (Kv)	6215-100
Maximum tilt angle	15®
Nozzle type	Flat fan standard nozzle
Tank capacity (Litres)	10
Spraying width (m)	3.5
Flight height (m)	1.5

Observations

Ten plants were tagged randomly from each plot and used to record growth and yield parameters. Plant height was recorded by measuring from base of the plant to its growing tip and was expressed in

cm. Number of branches plant^{-1} was recorded and expressed in numbers. Dry matter production was recorded by oven drying of samples at 65± 5ºC and expressed in kg ha^{-1}. Leaf area index was recorded at 15 days after spray and calculated using the formula given by Palanisamy and Gomez (1974). The yield attributes such as number of pods plant^{-1}, number of seeds pod^{-1}, pod length (cm), pod weight (g), test weight (g), grain yield (kg ha^{-1}) and haulm yield (kg ha^{-1}) were recorded at harvest stage. Cost of cultivation, gross return, net returns and benefit cost ratio were calculated and expressed in Rs. ha^{-1}.

Statistical analysis

Experimental data collected was statistically analysed as outlined by Panse and Sukhatme (1967). Critical difference at 5 per cent probability level was calculated for the treatments with significant difference.

Results and Discussion

Growth parameters

The results revealed that drone spray of 2% TNAU pulse wonder with spray fluid of 50 litres ha^{-1} significantly recorded taller plants (56.2 cm), more number of branches plant^{-1} (4.12), higher leaf area index (4.48) and dry matter production (2961 kg ha^{-1}) than manual spray and control (Table 2). However, this was on par with drone spray of 2% TNAU pulse wonder with spray fluid of 30 litres ha^{-1} and drone spray of 1% TNAU pulse wonder with spray fluid of 50 litres ha^{-1}. Presence of micro and macro nutrients in pulse wonder have supplemented the crop at its peak stage and boosted plant vitality and enhanced cell division, cell elongation, strengthened cell wall, improved shoot growth that leads to better growth of plant might be reason for the increased plant height, more number of branches plant^{-1}, higher leaf area index and dry matter production. These results were in accordance with findings of Balaji *et al.* (2019).

Fig. 1. Spraying of pulse wonder using knapsack sprayer

Fig. 2. Spraying of pulse wonder using agricultural drone

Table 2. Effect of foliar spray of pulse wonder using drone on growth parameters of green gram

Treatments	Plant height (cm)	Number of branches plant^{-1}	Leaf area index	Dry matter Production (kg ha^{-1})
T_1- Drone spray of 1% pulse wonder with 30 litres ha^{-1}	50.7	2.75	3.78	2616
T_2-Drone spray of 1% pulse wonder with 50 litres ha^{-1}	52.9	3.85	4.21	2831
T_3-Drone spray of 2% pulse wonder with 30 litres ha^{-1}	54.3	3.96	4.36	2896
T_4-Drone spray of 2% pulse wonder with 50 litres ha^{-1}	56.2	4.12	4.48	2961
T_5-Manual spray of 1% pulse wonder with 500 litres h^{-1}	50.4	2.67	3.65	2564
T_6-Manual spray of 2% pulse wonder with 500 litres ha^{-1}	51.1	2.89	3.96	2681
T_7-Control	45.2	1.68	3.24	2249
SEd	2.15	0.12	0.17	119
CD (P=0.05)	4.68	0.28	0.38	261

Yield parameters

Yield attributes *viz.*, number of pods plant^{-1} (39.2), number of seeds pod^{-1} (11.0), pod length (8.33 cm), pod weight (0.64 g) were significantly higher with drone spray of 2% TNAU pulse wonder with spray fluid of 50 litres ha^{-1} than manual spray and control (Table 3). This was comparable with drone spray of 2% TNAU pulse wonder with spray fluid of 30 litres ha^{-1} and drone spray of 1% TNAU pulse wonder with spray fluid of 50 litres ha^{-1}. Manual spray of 1% pulse wonder with 500 litres ha^{-1} registered significantly lesser number of pods plant^{-1}, number of seeds pod^{-1}, pod length and pod weight than drone spray. The lowest yield attributes were recorded with control. There was no significant difference in test weight. Application of pulse wonder using drone have supplemented nutrient at critical stage of growth, decreased flower dropping and increased floral bud without causing stress to the plants which enhanced better translocation of nutrients from source to sink which in turn increased yield attributes. These results were in conformity with the work of Kunjammal and Sukumar (2019).

Yield

Application of drone spray of 2% TNAU pulse wonder with spray fluid of 50 litres ha^{-1} registered higher grain yield (747 kg ha^{-1}) and haulm yield (1684 kg ha^{-1}) (Table 3). However, this was on par with drone spray of 2% TNAU pulse wonder with spray fluid of 30 litres ha^{-1} and drone spray of 1% TNAU pulse wonder with spray fluid of 50 litres ha^{-1} over other treatments and control. The increased grain and haulm yield were attributed to increased number of pods plant^{-1}, number of seeds pod^{-1}, pod length and pod weight. It was due to balanced supply of nutrients from pulse wonder have improved partitioning of assimilates and overall transport efficiency with the ability of biotic and abiotic tolerance, reduced flower shedding and increased seed setting percentage.

Delayed senescence resulted in continuous translocation of photosynthates which was also an important reason for increased yield. Similar results were obtained by Kunjammal and Sukumar (2019) and Sachin *et al.* (2019). The reason behind higher yield under drone spray than manual spray was recorded due to increased absorption of pulse wonder. The rotation of the propellers and the interaction of air generates a downwash air flow that fluttered and flipped the leaves over, thus facilitating maximum deposition of spray droplets from top to bottom of the crop canopy. Finer droplet size under low spray volume application facilitates maximum spray coverage. This was attributed to 4-fold increase of droplet deposition and droplet penetration on active site of leaves (abaxial surface). The flight operating parameters also played a significant role in droplet deposition, distribution and penetration. The flight height operated at 1.5 m above the ground exhibited uniform distribution of nutrients with high efficiency than manual spray. All the factors together

Table 3. Effect of foliar spray of pulse wonder using drone on yield attributes and yield of green gram

Treatments	Number of pods plant^{-1}	Number of seeds pod^{-1}	Pod length (cm)	Pod weight (g)	Test weight (g)	Grain yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1-Drone spray of 1% pulse wonder with 30 litres ha^{-1}	29.1	9.2	7.44	0.55	3.66	668	1523
T_2-Drone spray of 1% pulse wonder with 50 litres ha^{-1}	37.2	10.2	7.86	0.61	3.76	700	1575
T_3-Drone spray of 2% pulse wonder with 30 litres ha^{-1}	38.1	10.5	8.12	0.62	3.78	723	1625
T_4-Drone spray of 2% pulse wonder with 50 litres ha^{-1}	39.2	11.0	8.33	0.64	3.79	747	1684
T_5-Manual spray of 1% pulse wonder with 500 litres h^{-1}	28.5	9.0	7.32	0.53	3.65	666	1519
T_6-Manual spray of 2% pulse wonder with 500 litres ha^{-1}	30.2	9.3	7.59	0.57	3.74	677	1543
T_7-Control	21.3	8.0	6.62	0.45	3.56	574	1398
SEd	1.39	0.43	0.31	0.02	0.18	30	54
CD (P=0.05)	3.04	0.93	0.68	0.05	NS	65	118

Table 4. Effect of foliar spray of pulse wonder using drone on economics of green gram

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Benefit cost ratio
T_1- Drone spray of 1% pulse wonder with 30 litres ha^{-1}	24996	48096	23100	1.92
T_2-Drone spray of 1% pulse wonder with 50 litres ha^{-1}	25036	50400	25364	2.01
T_3-Drone spray of 2% pulse wonder with 30 litres ha^{-1}	25056	52056	27000	2.08
T_4-Drone spray of 2% pulse wonder with 50 litres ha^{-1}	25136	53784	28648	2.14
T_5-Manual spray of 1% pulse wonder with 500 litres h^{-1}	25886	47952	22066	1.85
T_6-Manual spray of 2% pulse wonder with 500 litres ha^{-1}	26886	48744	21858	1.81
T_7-Control	23686	41328	17642	1.74

resulted in higher absorption of nutrients by the crop canopy, thus reflected in increased physiological parameter that leads to better crop growth and yield. These results were in accordance with the findings of Qin *et al.* (2016), Yang *et al.* (2018) and Martin *et al.* (2020). Between two concentrations used in drone, 2% concentration performed better than 1% concentration which might be due to increased dosage resulted in increased droplet deposition density with better absorption. Whereas, between spray fluids used in drone, 50 litres ha^{-1} was found to be better than 30 litres ha^{-1}. The reason might be due to higher spray liquid deposited on leaves with maximum spray coverage enhanced better absorption and translocation of pulse wonder which resulted in better growth and yield.

Economics

Higher cost of cultivation (Rs. 26886 ha^{-1}) was recorded with manual spraying of pulse wonder 2% with 500 litres ha^{-1} whereas least cost of cultivation (Rs. 23686 ha^{-1}) was recorded with control. Maximum gross returns (Rs. 53784 ha^{-1}), net returns (Rs. 28648 ha^{-1}) and benefit cost ratio (2.14) were recorded with drone spray of 2% pulse wonder with a spray fluid of 50 litres ha^{-1} (Table 4). The least gross returns, net returns and BC ratio were registered with control. The higher returns and BCR were mainly due to increased grain yield, reduced labour cost and input requirement under drone spray of pulse wonder. These results were in accordance with Qin *et al.* (2016).

Conclusion

The best way to improve the productivity of green gram was application of nutrients as foliar spray which absorbs, utilize and translocate nutrients efficiently. Labour shortage has become a serious issue now-a-days. From the research evidence, it is concluded that agricultural drone could be effectively used for spraying of 2% pulse wonder with spray fluid of 50 litres ha^{-1} at peak flowering stage for improving productivity and profitability of green gram.

Conflict of Interest

The authors declare that there is no conflict of interest.

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