IMPACT OF DRONE SPRAYING OF NUTRIENTS ON GROWTH AND YIELD OF MAIZE CROP

Abstract

This study aimed at utilizing unmanned aerial vehicle in place of a conventional hand sprayer for the smart delivery of agricultural inputs especially crop nutrients. A field experiment was conducted in the farms of Agricultural Research Station, Bhavanisagar, Tamil Nadu Agricultural University. There were nine treatments which were replicated thrice in a randomized block design. The treatments include NPK 19:19:19 along with liquid micronutrient, humic acid, and TNAU Maize maxim at two intervals *viz.,* 50% Tasselling, and Cob filling stage. These nutrients were applied as foliar spray through battery operated and fuel operated drones and were compared with knapsack hand sprayer. Biometric observations such as plant height, leaf area, dry matter accumulation and yield parameters such as cob yield and number of grains per cob were observed during the critical crop growth stages. Foliar application of nutrients through drones had a significant influence on the growth and yield of maize crop. TNAU Maize maxim applied using the fuel-operated drone with an atomizer nozzle (T_7) @ 30 lit/ac spray fluid recorded the maximum biometric and yield attributes than other treatments. Improved biometric attributes like plant height of 261.2 cm and 270.32 cm, LAI of 4.14 and 5.15, and DMP of 12354 kg/ha and 18564 kg/ha at 60 DAS and 90 DAS, respectively was recorded with drone spray. It also resulted in a grain and stover yield of 7195 kg/ha and 10942 kg/ha, respectively than hand sprayer.

Keywords: *Maize***,** *Drone spray, Water soluble nutrients, Foliar spray*

Introduction

Maize survives in several agricultural environments, and its capability to accommodate different habitats sets it apart from other crops (Murdia *et al.,* 2016). Maize is among the most widely consumed grains in the world, and it is a food source in many nations hence it is considered the "Queen of Cereals". It is a good source of vitamins A, B, and E, and a variety of minerals, as well as providing the essential calories for everyday metabolic activities. As the industrial revolution has begun, the localized usage of maize has shifted towards industrialized usage. Because of its high protein, oil, and carbohydrate content, maize are a superior choice for animal feed to other crops (66%).

Most industrialized countries have implemented cutting-edge technology like photogrammetry and remote sensing (RS) for precision agriculture with Unmanned Aerial Vehicles (UAVs) to create a good agriculture farm with less infection (Rejeb *et al.*, 2022). Aerial spraying by UAVs is not only used for crop protection but also for agricultural fertilization (del Cerro *et al.*, 2021). It will benefit farmers by increasing agricultural output, and quality, and most crucially, reducing their workload (KS and Sellaperumal, 2021). With the rising scarcity of agricultural workers, finding a good opportunity to finish a high-quality spraying operation through a traditional knapsack sprayer is becoming increasingly challenging.

NPK fertiliser application has long been one of the most practical and efficient ways to increase crop output and nutritional quality, particularly for maize (Nirere *et al.*, 2021). Plant growth regulators have been extensively used in the latest days to mitigate physiological limits, resulting in increased output in a wide range of crops (Krishnaveni *et al.,* 2004). The plant uses micronutrients not just to optimize its development and output, but also to increase its crude protein and fibre content (Raghuramakrishnan *et al.,* 2021). Nutrient application via foliar spray at critical stages of growth is becoming increasingly vital to effective nutrient utilization and improved crop production (Saleh *et al.,* 2020). With this in consideration, the current research was carried out with the objective of knowing the impact of spraying using drones with different nozzles and knapsack sprayer and also reading the biometric and yield parameters of the maize crop.

The United States ranks the first in the production of maize with 384 tonnes and China stands next to USA with 231 tonnes of maize production in the year 2021. India ranks seventh in the production of maize with the area of 9.89 million hectares, production of 31.64 million tonnes and production of 3199 kg/ha in 2021. The area, production and productivity of maize in Tamil Nadu are 0.40 million hectares, 2.56 million tonnes and 6408 kg/ha, respectively in 2021 (Indiastat, 2021). The area, production and productivity of India is given in Table 1.

Table 1: Maize Area, Production and Productivity of Tamil Nadu and India in 2019-2021

Year	Tamil Nadu			India		
	Area (Million hectares)	Production (Million tonnes)	Productivity (kg/ha)	Area (Million hectares)	Production (Million tonnes)	Productivity (kg/ha)
2021	0.40	2.56	6408	9.89	31.64	3199
2020	0.33	2.47	7424	9.56	28.76	3006
2019	0.39	2.83	7258	9.02	27.71	3070

Materials and Methods

Experimental Site

The field analysis was carried out in the summer of February 2022 at the Agricultural Research Station, Bhavanisagar with a latitude of 11° 48' N and a longitude of 77° 13' E and 256 m above mean sea level. The type of soil is largely Irugur or Chikkarasampalayam series, ranging from medium to deep reddish-brown.

Experimental design and treatment details

The experiment was laid out in a randomized block design with 9 treatments and 3 replications. The test crop used was maize hybrid COH (M) 8 with a spacing of 60 x 30 cm. The treatment details are as follows: T_1 - Drone spray (Battery operated)- Jet type nozzle: All 19 (NPK) + Liquid Micro Nutrient + Humic Acid (1%) T_2 - Drone spray (Fuel operated)- Jet type nozzle: All 19 (NPK) + Liquid Micro Nutrient + Humic Acid (1%) T_3 - Drone spray (Fuel operated)- Atomizer nozzle: All 19 (NPK) + Liquid Micro Nutrient + Humic Acid (1%) T_4 - Knapsack sprayer: All 19 (NPK) + Liquid Micro Nutrient + Humic Acid (1%) T_5 - Drone spray (Battery operated) - Jet type nozzle: Maize Maxim @ 6 kg/ac T_6 - Drone spray (Fuel operated) - Jet type nozzle: Maize Maxim @ 6 kg/ac T_7 - Drone spray (Fuel operated) - Atomizer nozzle: Maize Maxim @ 6 kg/ac T_8 - Knapsack sprayer: Maize Maxim @ 6 kg/ac T_9 - Control (Water Spray). The spray mixture of All 19 along with liquid micronutrient, humic acid, and TNAU Maize Maxim was sprayed twice at 50% tasselling and cob filling stage using drones with two types of nozzles *viz.*, flood jet type and atomizer type and knapsack sprayer.

Characteristics of spraying devices

Drone Parameters

The fuel and battery-operated drone with two types of nozzles namely flood jet and atomizer type was used for the spraying of boosters. The technical parameters of the drones were given in Table 2.

Table 2: Technical parameters of the fuel and battery-operated drones

Fuel Operated		Battery operated	
Classification	**Parameters**	**Classification**	**Parameters**
Dimensions(mm)	2160×2250×600	Dimensions(mm)	1520×1520×590
Nozzle type	Flood Jet & Atomizer	Nozzle type	Flood Jet
Tank capacity (L)	16	Tank capacity (L)	10
Fuel tank capacity (L)	4	Battery capacity	16000 mAh
Spraying width	4 m	Spraying width(m)	3.5 m
Flying height (Above crop canopy)	0.75 to 1 m	Flying height(m)	0.75 to 1 m
No. of nozzles	4	No. of nozzles	4

Knapsack Sprayer Parameters

Foliar nutrients were manually sprayed using a knapsack sprayer with a hollow cone nozzle. The knapsack sprayer had a loading capacity of 15 litres (Dayana *et al.,* 2021). The technical parameters of the knapsack sprayer are given in Table 3.

Table 3: Technical parameters of knapsack sprayer

Classification	Parameters
Dimension	41.9 cm × 17.8 cm × 53.3 cm
Nozzle type	Hollow cone
Tank capacity	15 liters
Spraying width	0.75 to 1 m
Spraying height	20 to 30 cm above the crop canopy
No. of nozzle	1

Observations

In all the 9 treatments randomly, 5 plants were selected in each replication and tagged for observing the biometric parameters like plant height and LAI, and dry matter production (DMP) at 30 days intervals. DMP was calculated by cutting the plants that fell inside a 1m × 1m quadrat in each replication of 9 treatments and recorded the fresh weight. Then these plants were oven-dried at 80°C ± 5°C until they reached a stable weight and were given in kg/ha. The yield parameters like length and girth of the cob, number of rows/cob, number of grains/row, number of grains/cob, grain yield, and stover yield were recorded.

Statistical Analysis

According to Gomez and Gomez (1984), the data acquired throughout the investigation were statistically analysed. If the critical difference was calculated at a confidence threshold of 5%, the variations in treatment were considered significant. The results are given in tables.

Results and Discussion

Growth parameters

Plant growth and development are the effects of superb coordination of multiple mechanisms working at various phases of plant growth. Different treatments led to considerable differences in plant height, which is an important component of maize growth. In 30 DAS, before spraying of crop booster and micronutrients the taller plants were recorded at the treatment T1 - Drone spray (Battery operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%) with 98.51 cm. But after the application of the crop booster, fuel-operated drone spray with atomizer nozzle T_7 has recorded the soaring plant heights 261.2 and 270.3 at 60 DAS and 90 DAS, respectively. Because micronutrients have a positive effect on crop development, fast cell division and cell elongation are intimately linked. Raghuramakrishnan *et al.*, (2021) published a report with a similar conclusion with a plant height of 287.31 cm. The plants were shorter in control (T_9) than in other treatments. The plant height values are given in Table 4.

Table 4 : Effect of foliar application of spray fluid through drone on plant height (cm) of maize

Treatments	Plant Height (cm)		
	30 DAS	60 DAS	90 DAS
T1 Drone spray (Battery operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%)	98.51	231.0	236.93
T2 Drone spray (Fuel operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%)	96.37	219.8	226.31
T3 Drone spray (Fuel operated)- Atomiser nozzle: All 19 (NPK) + LMN +HA (1%)	94.72	243.0	246.69
T4 Knapsack sprayer: All 19 (NPK) + LMN +HA (1%)	98.45	206.0	214.71

T5 Drone spray (Battery operated)- Jet type nozzle: Maize Maxim @ 6 kg/ac	95.67	249.0	257.36
T6 Drone spray (Fuel operated)- Jet type nozzle: Maize Maxim @ 6 kg/ac	98.54	259.33	269.33
T7 Drone spray (Fuel operated)- Atomiser nozzle: Maize Maxim @ 6 kg/ac	96.32	261.2	270.32
T8 Knapsack sprayer: Maize Maxim @ 6 kg/ac	98.31	208.0	215.29
T9 Control (Water Spray)	98.29	192.0	197.32
SE.d	1.823	4.465	4.581
CD (0.05)	3.865	9.465	9.712

The leaf area index is a favourable indicator that has a major impact on maize plant growth. The number of photosynthetic pigments produced does not have to be a role in higher yield. Rather, the distribution of those photosynthetic pigments to the shoot and root is crucial. It is determined by the leaf area index and other physiological characteristics. The foliar application of nutrients and crop boosters had a considerable impact on the leaf area index (LAI) at 60 DAS and 90 DAS. This could be because of the greater number of leaves, leaf area, and tillers. Among the treatments, the foliar spraying of TNAU Maize maxim twice using the fuel-operated drone with atomizer nozzle of spray volume 30 lit/ac has recorded the very high LAI value of 4.14 and 5.15 at 60 DAS and 90 DAS, respectively. The treatment, control (T_9) recorded the lowest LAI value of 1.95 and 2.8, where only water spray was given. This result was in similar with the report of Raghuramakrishnan *et al.,* (2021). The LAI values are given in Table 5.

Table 5: Effect of foliar application of spray fluid through drone on leaf area index (LAI) of maize

Treatments	LAI		
	30 DAS	**60 DAS**	**90 DAS**
T1 Drone spray (Battery operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%)	1.69	3.51	4.39
T2 Drone spray (Fuel operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%)	1.6	3.12	4.18
T3 Drone spray (Fuel operated)- Atomiser nozzle: All 19 (NPK) + LMN +HA (1%)	1.79	3.69	4.60
T4 Knapsack sprayer: All 19 (NPK) + LMN +HA (1%)	1.48	2.69	3.95
T5 Drone spray (Battery operated)- Jet type nozzle: Maize Maxim @ 6 kg/ac	1.89	3.93	4.82

T6 Drone spray (Fuel operated)- Jet type nozzle: Maize Maxim @ 6 kg/ac	2.01	4.12	5.13
T7 Drone spray (Fuel operated)- Atomiser nozzle: Maize Maxim @ 6 kg/ac	2.03	4.14	5.15
T8 Knapsack sprayer: Maize Maxim @ 6 kg/ac	1.49	2.71	3.96
T9 Control (Water Spray)	0.97	1.95	2.8
SE.d	0.033	0.067	0.085
CD (0.05)	0.070	0.143	0.180

Dry matter production (DMP) of a crop measures, how well it uses the resources it has. Noticeable changes in dry matter accumulation could be related to differences in general growth and development, as reflected by observations of several growth indices such as plant height and LAI. The dry matter was accumulated most in the treatment T_7 Drone spray (Fuel operated)- Atomiser nozzle: Maize Maxim @ 6 kg/ac with 12354 and 18564 with 30 lit/ac and the lowest dry matter accumulation was noticed in the treatment T_9 Control (Water Spray) with 7482 and 9645 at 60 DAS and 90 DAS, respectively. This result was in similar with the report of Raghuramakrishnan *et al.*, (2021).

The total chlorophyll content of leaves is measured by the SPAD value reading, which reveals the level of greenness in the leaves. The amount of chlorophyll, a green pigment, is one of the main elements that control the capacity for photosynthetic activity (Ramachandiran and Pazhanivelan, 2016). The SPAD value of the treatment T_5 recorded highest with the value 50.3 before spraying. But, after the spraying of the chemicals NPK 19:19:19, liquid Micronutrient and humic acid and TNAU Maize maxim, the SPAD values increased significantly. It recorded the values of 62.4 and 60.7 at 60 DAS and 90 DAS, respectively. Increased chlorophyll content and enhanced nutrient mobility within leaves led to a higher SPAD value for the degree of greenness in the leaf. This occurs as a result of the delay between treatment and crop uptake. The enhanced split application keeps SPAD values at higher levels as a result. The changes in dry matter production and SPAD values are given in Table 6.

Table 6: Effect of foliar application of spray fluid using an agricultural drone on dry matter production (DMP) (kg/ha) and SPAD values of maize

Treatments	Dry Matter Production (kg/ha)	SPAD Values

	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
T1 Drone spray (Battery operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%)	3258	10594	16017	43.5	51.2	50.1
T2 Drone spray (Fuel operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%)	3296	10098	15182	48.1	48.6	46.3
T3 Drone spray (Fuel operated)- Atomiser nozzle: All 19 (NPK) + LMN +HA (1%)	3258	11081	16742	45.8	53.9	52.5
T4 Knapsack sprayer: All 19 (NPK) + LMN +HA (1%)	3085	9598	11863	39.1	44.2	40.4
T5 Drone spray (Battery operated)- Jet type nozzle: Maize Maxim @ 6 kg/ac	3325	11592	17695	50.3	59.5	57.9
T6 Drone spray (Fuel operated)- Jet type nozzle: Maize Maxim @ 6 kg/ac	3296	12146	18459	35.2	56.7	55.3
T7 Drone spray (Fuel operated)- Atomiser nozzle: Maize Maxim @ 6 kg/ac	3314	12354	18564	41.3	62.4	60.7
T8 Knapsack sprayer: Maize Maxim @ 6 kg/ac	3208	9611	12134	37.2	45.7	43.6
T9 Control (Water Spray)	3307	7482	9645	32.8	39.4	31.5
SE.d	61.53	205.09	303.38	0.77	1.01	0.97
CD (0.05)	130.45	434.79	643.16	1.65	2.15	2.07

Yield parameters

The results on yield parameters of maize were greatly affected by the spray of micronutrients and crop boosters. The maximum cob length and cob girth were observed in treatment T_7 Drone spray (Fuel operated)- Atomiser nozzle: Maize Maxim @ 6 kg/ac 24.8 cm and 17.9 cm, respectively using 30 lit/ac spray fluid, and the lowest was observed in treatment T_9 Control with 15.8 cm and 13.1 cm, respectively. The test weight was also high in the treatment T_7 (27.86 g). The yield attribute values are given in Table 7.

Table 7: Effect of foliar application of spray fluid using an agricultural drone on yield attributes of maize

Treatments	Cob Length (cm)	Cob Girth (cm)	Test Weight (g)

T1 Drone spray (Battery operated)- Jet-type nozzle: All 19 (NPK) + LMN +HA (1%)	21.6	15.6	26.97
T2 Drone spray (Fuel operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%)	20.6	14.9	26.52
T3 Drone spray (Fuel operated)- Atomiser nozzle: All 19 (NPK) + LMN +HA (1%)	22.6	16.3	27.41
T4 Knapsack sprayer: All 19 (NPK) + LMN +HA (1%)	19.1	13.9	25.63
T5 Drone spray (Battery operated)- Jet-type nozzle: Maize Maxim @ 6 kg/ac	23.7	17.1	27.74
T6 Drone spray (Fuel operated)- Jet type nozzle: Maize Maxim @ 6 kg/ac	24.1	17.8	27.8
T7 Drone spray (Fuel operated)- Atomiser nozzle: Maize Maxim @ 6 kg/ac	24.8	17.9	27.86
T8 Knapsack sprayer:Maize Maxim @ 6 kg/ac	19.6	14.1	26.08
T9 Control (Water Spray)	15.8	13.1	25.14
SE.d	0.415	0.302	0.507
CD (0.05)	0.880	0.642	1.076

The highest grain and stover yield was achieved in treatment T_7 which sprayed 30 lit/ac spray fluid using the Drone (Fuel operated)- Atomiser nozzle: Maize Maxim @ 6 kg/ac with 7195 kg and 10942 kg per hectare, respectively. Treatment T_9 Control (Water Spray) with 3049 kg and 6623 kg per hectare of grain and straw yield recorded the lowest. The yield values are given in Table 8. The results of Kumar et al., (2018) were found similar with this work. The yield in drone spray when compared with the conventional knapsack sprayer was high due to the high absorption of TNAU Maize maxim. The geometry of maize plants, as well as the drone's downward airstream, provides the ideal circumstances for droplet deposition. The improvement in the growing season, active absorption, and transfer from source to sink as a result of physiological and biochemical processes.

Table 8: Effect of foliar application of spray fluid using an agricultural drone on grain and straw yield (kg/ha) of maize

Treatments	Yield (kg/ha)	
	Grain yield	Straw yield
T1 Drone spray (Battery operated)- Jet-type nozzle: All 19 (NPK) + LMN +HA (1%)	6013	9304
T2 Drone spray (Fuel operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%)	5692	8868
T3 Drone spray (Fuel operated)- Atomiser nozzle: All 19 (NPK) + LMN +HA (1%)	6294	9743

T4 Knapsack sprayer: All 19 (NPK) + LMN +HA (1%)	5271	8382
T5 Drone spray (Battery operated)- Jet-type nozzle: Maize Maxim @ 6 kg/ac	6619	10197
T6 Drone spray (Fuel operated)- Jet type nozzle: Maize Maxim @ 6 kg/ac	6912	10657
T7 Drone spray (Fuel operated)- Atomiser nozzle: Maize Maxim @ 6 kg/ac	7195	10942
T8 Knapsack sprayer:Maize Maxim @ 6 kg/ac	5389	8418
T9 Control (Water Spray)	3049	6623
SE.d	117.118	180.879
CD(0.05)	248.291	383.465

This research also shows that UAVs can be a significant tool for precision agriculture because of their low cost and advantageous vantage point and is also safer for farmers than an electric Knapsack Sprayer (Wang *et al.*, 2022). The advantages of drone spraying observed in the present experiment are:

(i) saving on quantity and cost of nutrients
(ii) the cost of spray is lesser than conventional spraying method
(iii) spray fluid requirement is also very less.

The spraying cost of drone was less (Rs. 1250 / ha) when compared with the spraying cost of knapsack sprayer (Rs. 2000 / ha). The nutrient requirement through drone spray was 0.25 kg/ha and 0.75 kg/ha for flood jet and atomizer nozzle drone spray, respectively. Whereas, for knapsack sprayer it was 5 kg/ha. The spray fluid was also 25 lit/ha and 75 lit/ha for flood jet and atomizer nozzle in drone spray, respectively as compared to conventional spray requirement of 200 lit/ha. Treatment wise input requirements and spraying cost details for both drone and knapsack sprayers are given in Table 9.

Table 9: Treatment wise input requirements and spraying cost for drone and knapsack spray

Treatments	**Nutrient Requirement (kg/ha)**	**Spray fluid (lit/ha)**	**Spraying cost (Rs/ha)**
T1 Drone spray (Battery operated)- Jet-type nozzle: All 19 (NPK) + LMN +HA (1%)	0.25 kg	25	1250
T2 Drone spray (Fuel operated)- Jet type nozzle: All 19 (NPK) + LMN +HA (1%)	0.25 kg	25	1250
T3 Drone spray (Fuel operated)- Atomiser nozzle:	0.75 kg	75	1250

All 19 (NPK) + LMN +HA (1%)			
T4 Knapsack sprayer: All 19 (NPK) + LMN +HA (1%)	5.0 kg	200	2000
T5 Drone spray (Battery operated)- Jet-type nozzle: Maize Maxim @ 6 kg/ac	0.25 kg	25	1250
T6 Drone spray (Fuel operated)- Jet type nozzle: Maize Maxim @ 6 kg/ac	0.25 kg	25	1250
T7 Drone spray (Fuel operated)- Atomiser nozzle: Maize Maxim @ 6 kg/ac	0.75 kg	75	1250
T8 Knapsack sprayer:Maize Maxim @ 6 kg/ac	5 kg	200	2000
T9 Control (Water Spray)	only water spray		

Conclusion

Thus, from the present experiment it is observed that, physiological features were modified by foliar application of nutrients and plant growth regulators. Foliar spray of TNAU Maize maxim using the fuel-operated drone with atomizer nozzle (T_7) with the spray fluid of 30 lit/ac has recorded enhanced biometric attributes *viz*., plant height, LAI, DMP, and yield attributes viz., cob length and girth, number of rows per cob, number of grains per row and cob. Hence, the drones cane be utilized for spraying any kind of nutrient applied through foliar spray for crops like maize where at some stage of the crop the use of hand sprayer is practically difficult. This would also help to minimize the demand for skilled labour for spraying and also it heavily reduces the requirement of chemical and well as spray fluid requirement.

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