Effect of Unmanned Aerial Vehicle Sprayed Herbicides on the soil properties and nutrient availability in *Rabi* Groundnut

ABSTRACT

Herbicides are applied by manually operated knapsack sprayers, which are laborious, uneven and prone to human mistakes. Unmanned aerial vehicles (UAVs) are a promising agricultural spraying alternative to manual operation. Drone herbicide spraying was compared to traditional and mechanical knapsack sprayers in this study. Hence, a two year field experiment was performed at Regional Agriculture Research Station, Research Farm, Palem, Nagarkurnool, Telangana during *rabi* 2022-23, 2023-24. A ready-mix post emergence herbicide with combination of Imazethapyr 3.75% + propaquizafop 2.5% ME was applied to groundnut at 20-25 DAS. The experiment consisted of 12 treatments to test the herbicide dose viz., 75% recommended dose (RD), 100%RD and 125% RD which were applied with drone using 20 and 40 L ha^{-1} spray fluid and sprayed from 2.0 and 2.5m drone nozzle height (from canopy), Checks (5) were also maintained (manual spray of 75% RD,100%RD and 125% RD, weedy check and weed free) in the experiment for comparative evaluation of drone applied and manually applied herbicides. The design opted was 3X2X2 Factorial RBD and all the treatments were replicated thrice. Results of the experiment showed that application of different doses of ready mix herbicide did not significantly influence the soil physical, chemical properties observed at harvest of the crop. Similarly, the available macro-nutrient status was also not significantly influenced y drone sprayed herbicide application compared to manual spraying using knapsack sprayer.

Commented [MP1]: If there was no significant influence by the application of different doses of ready mix herbicide and the available macro-nutrient status was also not significantly influenced by the drone sprayed herbicide application compared to manual spraying using knapsack sprayer, then what is the result and outcome of the experiment??. What are the benefits?

Keywords: Unmanned aerial vehicle, herbicide, soil properties, Available nutrients..

1. INTRODUCTION

Groundnut is an important oilseed crop grown in Southern Telangana agro-climatic zone. In groundnut, the loss in pod yield due to weeds ranges from 13 to 100% depending on the season, cultivars, weed composition and duration of crop weed competition, and the package of practices adopted (Jat *et al.,* 2011). Use of effective weed management options or efficient herbicides will provide lower competition from weeds to the crop. In Telangana, farmers rely on pre-emergence herbicides followed by manual weeding or pre-emergence application followed by post-emergence herbicides for managing the weeds. A ready-mix herbicide combination product of imazethapyr and propaquizafop provide control of broadleaf weeds, grasses and suppression of sedges when applied as post-emergence at 20-25 days after sowing and it is a popular herbicide used by farmers. This product is a selective post-emergence herbicide for broad spectrum control of weeds in groundnut (Barkani *et al.,* 2005).

Herbicide spray application using a knapsack sprayer is a conventional method usually adopted by most farmers. However, major disadvantages include its limited field capacity, exposure of applicator the herbicide, problem of accuracy of application etc. In this context, Spraying techniques continuously developed in recent decades, “Unmanned aerial vehicles (UAVs), or aerial drones, are an emerging technology with significant market potential” (Otto *et al.,* 2018) could contribute to the more sustainable use of pesticides; however, these potential benefits drones can help the farmers in avoiding the troubles of manual spray in conjunction with the benefits of green technology. The use of drone as a modern pesticide application technique would not only ensure accuracy, uniformity in spray across the fields, but also reduction in the overall use of the chemicals within the area and safety of the operators.

When applied with a knapsack sprayer, volatilization and drift losses are generally minimal as the nozzle is very close to the surface on which the pesticide is applied as compared to drone. Such changes may bring in a significant change in the quantity of the herbicide active ingredient that reaches the surface of the soil/ plant, which may significantly influence the soil pH, Physico-chemical properties and nutrient availability. Hence, the present experiment was conducted to steady the impact of herbicides applied using drones and knapsack sprayer on the soil physico - chemical properties and available nutrients during two year of experiment.

2. MATERIALS AND METHODS

A two years field experiment was conducted at Regional Agricultural Research Station Farm, Palem, Nagarkurnool, Telangana during *rabi* 2022-23, 2023-24. Field is situated at 16° 31' 8.0328'' N and 78° 14' 45.8628'' E for experimental field I and 16°31'05.9"N 78°14'50.4"E for experiment field II. The soil of the experimental field was sandy loam during both two years.

Bioefficacy and drift studies were carried out with AGRICOPTER AG 365 with UIN UA00132S1EX drone with a capacity of tank was 10L. Effective spraying width for treatments was adjusted to 4m.

A ready-mix post emergence herbicide with combination of (Imazethapyr 3.75% + propaquizafop 2.5% ME, Shaked manufactured by Adama India Ltd.) was applied.The experiment consisted of 12 treatments to test the herbicide dose viz., 75% recommended dose (RD), 100%RD and 125% RD which were applied with drone using 20 and 40 L/ha spray fluid and sprayed from 2.0 and 2.5m drone nozzle height (from canopy). Checks (5) were also maintained (manual spray and controls) in the experiment for comparative evaluation of drone applied and manually applied herbicides. The design opted was Factorial RBD and all the treatments were replicated thrice. Details of the treatments are provided in table 1.

Groundnut variety K-6, a bunch type released from Agricultural Research Station, Kadiri, ANGRAU was used as test variety. The duration of the variety is 120 days.The crop was supplied with fertilizers according to the recommendation of PJTAU, 20 kg N, 40 kg P_2O_5 and 50 kg K_2O in the form of urea, single super phosphate and muriate of potash respectively to all the plots and all the recommended package of practices were adopted in conducting the experiment

Table 1: Treatment details of the experiment at field

Treatment No.		Treatment Details
T_1	$D_1S_1H_1$	75% Recommended dose (56.25 g ha^{-1} + 37.5 g ha^{-1}) with spray volume 25 L ha^{-1} and spray height 2m above the crop canopy
T_2	$D_1S_1H_2$	75% Recommended dose (56.25 g ha^{-1} + 37.5 g ha^{-1}) with spray volume 25 L ha^{-1} and spray height 2.5m above the crop canopy
T_3	$D_1S_2H_1$	75% Recommended dose (56.25 g ha^{-1} + 37.5 g ha^{-1}) with spray volume 40 L ha^{-1} and spray height 2m above the crop canopy
T_4	$D_1S_2H_2$	75% Recommended dose (56.25 g ha^{-1} + 37.5 g ha^{-1}) with spray volume 40 L ha^{-1} and spray height 2.5m above the crop canopy
T_5	$D_2S_1H_1$	100% recommended dose (75 g ha^{-1} + 50 g ha^{-1}) with spray volume 25 L ha^{-1} and spray height 2m above the crop canopy
T_6	$D_2S_1H_2$	100% recommended dose (75 g ha^{-1} + 50 g ha^{-1}) with spray volume 25 L ha^{-1} and spray height 2.5 m above the crop canopy
T_7	$D_2S_2H_1$	100% recommended dose (75 g ha^{-1} + 50 g ha^{-1}) with spray volume 40 L ha^{-1} and spray height 2m above the crop canopy
T_8	$D_2S_2H_2$	100% recommended dose (75 g ha^{-1} + 50 g ha^{-1}) with spray volume 40 L ha^{-1} and spray height 2.5 m above the crop canopy
T_9	$D_3S_1H_1$	125% recommended dose (93.75 g ha^{-1}+ 62.5 g ha^{-1}) with spray volume 25 L ha^{-1} and spray height 2m above the crop canopy
T_{10}	$D_3S_1H_2$	125% recommended dose (93.75 g ha^{-1}+ 62.5 g ha^{-1}) with spray volume 25 L ha^{-1} and spray height 2.5m above the crop canopy
T_{11}	$D_3S_2H_1$	125% recommended dose (93.75 g ha^{-1}+ 62.5 g ha^{-1}) with spray volume 40 L ha^{-1} and spray height 2m above the crop canopy
T_{12}	$D_3S_2H_2$	125% recommended dose (93.75 g ha^{-1}+ 62.5 g ha^{-1}) with spray volume 40 L ha^{-1} and spray height 2.5m above the crop canopy
T_{13}	$KS_{(0.75x)}$	75% Recommended dose (56.25 g ha^{-1} + 37.5 g ha^{-1}) with Knapsack sprayer
T_{14}	$KS_{(1x)}$	100% Recommended dose (75 g ha^{-1}+ 50 g ha^{-1}) with Knapsack sprayer
T_{15}	$KS_{(1.25x)}$	125% recommended dose (93.75 g ha^{-1}+ 62.5 g ha^{-1}) with Knapsack sprayer
T_{16}	C	Unweeded check, control
T_{17}	WF	Weed Free check, (WF) (Manual weeding at 20, 40, 60 DAS)

Soil Chemical properties

The soil sample was collected from each plot before initiation of experiment, at flowering and harvest of the crop. Surface soil from 0-15 cm soil depth were collected at different spots from each plot. The composite soil samples collected were shade dried, pounded and passed through 2mm sieve, labeled and stored in polythene covers. The soil samples collected were analyzed for soil physico- chemical properties and available nutrients following standard procedures.

Soil Reaction (pH)

pH of the soil was determined by soil suspension (1:2.5 soil : water) by glass electrode method pH meter (ELICO pH analyser) after equilibrating soil with water for 30 minutes with occasional stirring (Jackson, 1973).

Electrical conductivity (EC)

EC was determined in soil suspension (1:2.5 soil: water) after equilibrium of soil with water and keeping the sample undisturbed till the supernatant solution was obtained and measured by a conductivity meter (ELICO CM EC-TDS analyser), (Jackson, 1973).

Organic carbon (%)

It was determined by the procedure given by Walkley and Black (1965). Soil samples passed through 0.5 mm sieve were used for determining Organic carbon. One gram of soil was taken in an Erlenmeyer flask to this 10 ml of 1N potassium dichromate and 20 ml of concentrated H_2SO_4 were added and was allowed for reaction to occur for 30 min. To this solution, 100 ml of distilled water were added followed by a pinch of NaF and few drops of diphenylamine indicator was added. The contents turn to violet colour. It was titrated against 0.5N ferrous ammonium sulphate till the colour changes to green colour.

$$\text{Organic carbon (\%)} = (\text{vol of } K_2Cr_2O_7 \times [(B-S)/B] \times 0.003 \times 100) / \text{weight of soil}$$

B= blank titre value S = sample titre value.

Cation Exchange Capacity (CEC)

Five grams of soil was taken in a centrifuge tube to which 1N sodium acetate (pH 8.2) was added and centrifuged at 8000 rpm for 5 minutes. The supernatant was discarded, and the procedure was repeated thrice. The excess sodium was removed by washing with 33 ml of isopropyl alcohol and the supernatant was discarded and repeated thrice. The adsorbed sodium was extracted by 1N ammonium acetate (pH 7) and the supernatant was collected and stored in a 100 ml volumetric flask. The sodium ions present in the extract were determined by a flame photometer (Bower, 1952).

Available Nitrogen

Available nitrogen in soil samples was determined by using alkaline permanganate method as described by Subbiah and Asija (1956).The procedure involved distilling the soil with alkaline potassium permanganate solution and determining the ammonia liberated by titrating against standard sulphuric acid (0.02 N).

$$\text{Available N (kg ha}^{-1}\text{)} = \frac{2.24 \times 10^{6} \times 100 \times Y \times 0.00028}{20 \times 100}$$

1 ml of 0.02 *N* H_2SO_4 = 0.00028

Y = volume of 0.02 *N* H_2SO_4 utilized for neutralizing of NH_3 in ml.

Available phosphorus

The Available phosphorus in soil samples was extracted with 0.5 M $NaHCO_3$ at pH 8.5 as described by Olsen *et al.* (1954) in neutral and alkali soils. The phosphorus in the extract was estimated colorimetrically using ascorbic acid as the reductant. The blue colour developed was measured by using the spectrophotometer at 660 nm wavelength. The available phosphorus content was calculated and expressed as kg ha^{-1}.

$$\text{Available } P_2O_5 \text{ (kg ha}^{-1}\text{)} = \frac{\text{Graph ppm} \times \text{Vol. of extractant} \times \text{volume made} \times 2 \times 2.29\times10^{6}}{10^{6} \times \text{aliquot taken} \times \text{weight of sample}}$$

Available potassium

Available potassium was extracted from soil using neutral normal ammonium acetate and potassium present in the extracts was determined by using Flame photometer (Elico CL 378) as described by Jackson (1973) and expressed as kg K_2O ha^{-1}.

$$\text{Available K (kg ha}^{-1}\text{)} = \frac{\text{Concentration of K} \times \text{volume made} \times 100 \times 2.24 \times 10^{6}}{10^{6} \times \text{weight of sample} \times 100}$$

Available K_2O = K x 1.2

3. RESULTS AND DISCUSSION

Effect of the drone sprayed herbicides in comparison with knapsack sprayer on the soil physico-chemical properties

Soil pH varied from 7.27 to 7.71 in T_2 and T_5 in 2022-23 and initial pH was 7.20. In 2023-24 it ranged between 7.30 to 7.76 in T_8 and T_9, initial pH was 7.78 as shown in Table 2. Soil reaction (pH) was not significantly impacted by the different doses, spray volume and spray height of the herbicide sprayed by the UAV (drone) and knapsack sprayer for the two years of experimentation. Similarly, soil EC (table 2) was also non significantly influenced by the herbicides applied at different doses, spray volume and spray height in drone spray and knapsack spray. EC values of soil at harvest in 2022-23 was 0.46 to 0.59 dS m^{-1} was noticed in T_5 and KS $_{(1.0X)}$ were slightly higher as compared to initial EC (0.45 dS m^{-1}). In 2023- 24, it was varied from 0.46 -0.56 dS m^{-1} in T_3 and KS $_{(1.25X)}$ compared to initial (0. 51 dS m^{-1}) which might be due to repeated irrigation of the field with groundwater.

The soil CEC in 2022-23 ranged from 18.73 -20.98 c.mol (P^+) kg^{-1} soil in T_6 and weed free treatment and initial 18.19 c.mol (P^+) kg^{-1} soil and in 2023-24 it was 17.58 to 20.40 c.mol (P^+) kg^{-1} soil in KS $_{(1.25x)}$ and weed free, initial value 17.34 c.mol (P^+) kg^{-1} soil as shown in table 2. The initial soil organic carbon was 0.41% and 0.44% during 2022-23 and 2023-24 respectively. At harvest stage, soil organic carbon in 2022-23 was in the range of 0.42-0.53% in KS $_{(1.25X)}$ and weed free and in 2023-24 the SOC was 0.40-0.50% in T_2 and weed free.

Soil physic-chemical properties like pH, EC, OC did not show any significant changes with the application of the herbicides with drone and knapsack sprayer. They are not affected with the herbicide dose , spray volume and spray height in both the years. A study reported by sudharshana *et al.,* (2014) found that imazethapyr and penimethalin application in groundnut has found non significant effect on soil properties. Studies conducted at DWSRC, 2010 reported that application of imazethapyr @100 g a.i ha^{-1} or 200 g a.i ha^{-1} or 400 g a.i ha^{-1} did not significantly change the soil physical, physiochemical and fertility properties at the time of harvest of groundnut crop. Several studies conducted in India and abroad have also reported minimal or insignificant influence of various herbicides on soil physical and physic-chemical properties in view of the low volume/quantity application compared to the soil mass.

Effect of the drone sprayed herbicides in comparison with knapsack sprayer on the Macronutrient status of the soil

In the year 2022-23 From table 3 and 4, at the reproductive stage of the crop the highest available soil N among all the treatments was recorded in the weed free (248.66 kg ha^{-1}) and lowest was noticed in the weedy check (218.23 kg ha^{-1}). Among the drone treatments, the highest available N was in T_{12} (241.58 kg ha^{-1}) and lowest was recorded in T_8 (218.66 kg ha^{-1}). However, they were below the initial soil available nitrogen of 258.20 kg ha^{-1}. At the time of the harvest of the crop, soil available N was ranged from 237.00 to 258.66 kg ha^{-1} in weedy check and weed free. In the drone treatments, highest was in T_8 (255.00 kg ha^{-1}) and lowest was in T_4 (237.66 kg ha^{-1}). Similarly, in 2023-24, at reproductive stage the soil N was ranged from 219.76 to 237.26 kg ha^{-}

^{1}. In the drone sprayed treatments, the soil N recorded was (223.46 and 233.13 kg ha^{-1}) in T_9 and T_{10}. The highest soil N among all was observed in the weed free (237.26 kg ha^{-1}) and lowest was recorded in the weedy check (219.76 kg ha^{-1}). At the harvest stage there was an increase in the available N and it was (229.33 and 247.10 kg ha-1) in T_9 and T_{12} whereas in manual spray it was (225.66 to 256.43 kg ha^{-1}) in weedy check and weed free treatment.

Soil available P at the reproductive stage varied from 48.01 to 55.35 kg ha^{-1} which was lower than the initial P_2O_5 (55.40 kg ha^{-1}) in 2022-23. Similarly in 2023-24, the available P_2O_5 ranged from 51.50 to 59.30 kg ha^{-1} which was lower than initial value (60.40 kg ha^{-1}). In the two years, highest available $P_2O_5$was in the weed free treatment and lowest was in the weedy check. Among the drone treatments highest Soil P was noticed in T_4 (54.66 kg ha^{-1}) and lowest in T_9 (48.41 kg ha^{-1}) in 2022-23. In 2023-24, highest was in T_6 (54.25 kg ha^{-1}) and lowest was in T_{12} (46.20 kg ha^{-1}) as shown in table 3.

At harvest stage, soil available P_2O_5 range was (46.10 to 55.16 kg ha^{-1}) in weedy check and weed free and in drone treatments it was highest in T_5 (55.80 kg ha^{-1}) and lowest in T_7 (51.80 kg ha^{-1}) as in 2022-23. Similarly, in 2023-24, the soil P_2O_5 of 46.76 to 54.22 kg ha^{-1} was recorded in T_4 and T_{10}. Among all treatments, available P_2O_5 was noticed highest in weed free (56.33 kg ha^{-1}) and lowest in weedy check (45.83 kg ha^{-1}).

The available soil potassium was estimated in different treatments at reproductive stage in 2022-23, the drone sprayed available K was high in T_6 (309.89 kg ha^{-1}) and lowest in T_7 (279.00 kg ha^{-1}). Among all treatments, lowest was in the weedy check (272.38 kg ha^{-1}) and highest was in weed free (314.68 kg ha^{-1}). In 2023- 24, soil K of 279.00 to 309.89 kg ha^{-1} was recorded in T_7 and T_6. Among all treatments, lowest available soil K was in weedy check (272.38 kg ha^{-1}) and highest in weed free (314.68 kg ha^{-1})as in table 3 which was slightly less than the initial soil K (318.33 kg ha^{-1}).

At harvest stage the soil K_2O in drone herbicide application treatments ranged from 258.61 to 301.55 kg ha^{-1} in T_1 and T_3. Among all lowest in weedy check (257.71 kg ha^{-1}) and highest in weed free (309.33 kg ha$^{-1)}$ in 2022-23. The herbicide has a non significant effect on the available soil K_2O. Similar trend was observed in the 2023-24. Compared to other drone treated plots, lowest was seen in T_5 (265.55 kg ha^{-1}) and highest was in T_6 (308.58 kg ha^{-1}) among all the weedy check recorded lowest (264.83 kg ha^{-1}) and weed free noticed highest (307.00 kg ha^{-1}).

From the above results, it was noticed that in both the years, a non significant effect with respect to soil available nutrients was found among the treatments in both the manual and drone sprayed plots applied with different doses and spray volume and spray height. Among all, highest nutrients were recorded in weed free and lowest was in weedy check. This could be attributed to differences in weed control efficiency of the used herbicides allowing variations in crop growth and uptake of the nutrient by weeds flora and crop. The present findings are in line with that of Mukhopadhyay and Biswas (2019) who reported that application of the Imazethapyr @ 100, 150, 200 and 300 g a.i/ha have not resulted in any remarkable change in soil properties after application of this herbicide. Janaki *et al.,*(2019) also reported that herbicides application did not influence soil properties, pH, EC, organic C, available N, P, K in Tamil Nadu. Similarly, Ramprakash *et al.,* (2015) also reported that there were no significant changes in soil physico-chemical (pH, EC, CEC, OC) and fertility properties of the soil (available N, P_2O_5 and K_2O) due to application of bispyribac sodium.

Table 2 Effect of the UAV applied herbicides on the physico-chemical properties of the soil at harvest stage of crop in 2022-23 and 2023-24.

TrtNo.	2022-23				2023-24			
	P^H	EC (d Sm^{-1})	Soil OC (%)	Soil CEC [c.mol (P^+) kg^{-1} soil]	P^H	EC (d Sm^{-1})	Soil OC (%)	Soil CEC [c.mol (P^+) kg^{-1} soil]
T_1	7.36	0.52	0.44	19.11	7.43	0.48	0.42	18.00
T_2	7.27	0.53	0.45	19.88	7.50	0.53	0.40	19.22
T_3	7.69	0.47	0.45	19.65	7.63	0.46	0.44	19.65
T_4	7.45	0.51	0.45	18.76	7.59	0.50	0.40	18.06
T_5	7.71	0.46	0.44	19.21	7.53	0.49	0.47	19.21
T_6	7.37	0.54	0.45	18.73	7.49	0.53	0.43	18.06
T_7	7.57	0.52	0.45	18.58	7.53	0.51	0.45	18.67
T_8	7.43	0.53	0.46	19.71	7.30	0.53	0.45	19.71
T_9	7.68	0.53	0.44	19.13	7.76	0.53	0.43	19.13
T_{10}	7.41	0.51	0.44	19.04	7.52	0.50	0.46	17.98
T_{11}	7.60	0.53	0.42	19.28	7.46	0.53	0.40	19.28
T_{12}	7.61	0.53	0.47	19.58	7.45	0.51	0.49	19.60
T_{13}	7.64	0.53	0.42	20.19	7.61	0.54	0.45	18.74
T_{14}	7.40	0.59	0.44	19.37	7.46	0.54	0.45	18.30
T_{15}	7.57	0.57	0.41	18.93	7.40	0.55	0.44	17.58
T_{16}	7.39	0.56	0.47	18.75	7.66	0.56	0.45	18.56
T_{17}	7.50	0.50	0.53	20.98	7.72	0.55	0.50	20.40
Initial	7.20	0.45	0.41	18.19	7.78	0.51	0.44	17.34
SE(m)±	**0.4**	**0.47**	**0.0**	**1.0**	**0.4**	**0.0**	**0.0**	**2.9**
CD(p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 3 Effect of the UAV applied herbicides on the soil fertility status at reproductive stage at 2022-23 and 2023-24.

Trt No.	2022-23	2023-24

	Available N (Kg ha^{-1})	Available P (P_2O_5) (kg ha^{-1})	Available K (K_2O) (kg ha^{-1})	Available N (kg ha^{-1})	Available P (P_2O_5) (kg ha^{-1})	Available K (K_2O) (kg ha^{-1})
T_1	231.00	50.56	286.33	232.10	52.40	310.99
T_2	220.90	52.79	294.33	225.26	52.40	292.74
T_3	226.00	54.66	298.85	226.16	55.00	285.01
T_4	219.20	54.23	287.34	225.40	55.30	307.33
T_5	231.66	48.43	304.04	232.06	55.80	292.45
T_6	233.59	48.60	309.89	236.63	53.90	288.98
T_7	228.42	50.61	279.00	228.42	51.80	285.79
T_8	218.66	49.72	301.33	226.86	52.70	308.94
T_9	237.77	48.41	289.94	233.13	54.30	308.08
T_{10}	233.93	48.83	302.74	223.46	51.90	310.59
T_{11}	222.46	51.49	280.39	233.00	54.40	284.26
T_{12}	241.58	53.53	285.36	228.16	52.50	313.84
T_{13}	219.83	49.53	296.96	232.90	51.90	326.95
T_{14}	223.49	53.24	293.66	229.96	53.40	301.00
T_{15}	227.68	51.86	276.00	230.43	51.70	313.02
T_{16}	218.23	48.01	272.38	219.76	51.50	280.66
T_{17}	248.66	55.35	314.68	237.26	59.30	333.00
Initial	258.20	55.40	318.33	238.33	60.40	338.80
SE(m)±	**11.6**	**2.7**	**18.2**	**12.2**	**2.8**	**18.3**
CD(p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table 4 Effect of the UAV applied herbicides on the soil fertility status at harvest stage at 2022-23 and 2023-24.

Trt No.	2022-23			2023-24		
	Available N (Kg ha^{-1})	Available P (P_2O_5) (kg ha^{-1})	Available K (K_2O) (kg ha^{-1})	Available N (Kg ha^{-1})	Available P (P_2O_5) (kg ha^{-1})	Available K (K_2O) (kg ha^{-1})
T_1	241.66	47.72	258.61	238.8	49.20	290.70
T_2	239.33	53.87	270.76	243.36	50.48	296.03
T_3	241.00	49.33	301.55	233.00	47.67	277.62
T_4	237.66	53.93	260.04	238.10	46.76	287.45
T_5	247.34	49.30	278.26	231.11	48.69	265.51
T_6	253.80	54.25	300.23	243.65	52.01	308.58

T_7	249.00	51.60	265.33	236.22	47.36	293.79
T_8	255.00	47.23	287.46	245.14	50.66	283.60
T_9	255.10	48.64	281.57	229.33	51.54	308.08
T_{10}	254.30	52.03	287.41	229.66	54.22	291.93
T_{11}	254.47	53.93	260.96	242.52	47.44	285.25
T_{12}	254.32	46.20	272.36	247.10	52.20	282.00
T_{13}	251.66	50.93	280.60	241.33	47.26	277.94
T_{14}	253.00	48.28	267.27	235.19	51.52	297.33
T_{15}	253.00	47.36	285.77	247.00	48.76	295.66
T_{16}	237.00	46.10	257.71	225.66	45.83	264.83
T_{17}	258.66	55.16	309.33	256.43	56.33	307.00
SE(m)±	**13.5**	**3.3**	**18.1**	**12.7**	**3.1**	**16.9**
CD(p=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

4. CONCLUSION

In conclusion, Using drones for herbicide application in groundnut, or the use of a knapsack sprayer, showed no significant effect on the chemical properties of the soil *viz*., pH, electrical conductivity, soil organic carbon, and cation exchange capacity. Similarly, the availability of soil macronutrients was not significantly impacted by herbicide application, whether applied using a drone or a knapsack sprayer.

Commented [MP2]: When a research study finds no significant difference, it could mean that there is no effect, or that the data is inconclusive.

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