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DRONE BASED HERBICIDE SPRAY IN TRANSPLANTED RICE USING DIFFERENT NOZZLES IN COMPARISON TO KNAPSACK SPRAYER

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ABSTRACT

The information on efficacy of herbicide spray with drone using different nozzle is very limited. An experiment was conducted, on comparative study of knapsack and drone spraying of herbicide using different nozzles to study the efficacy of herbicide in transplanted rice at Rajendra Nagar, Hyderabad. Among the herbicide spray treatments lower total weed density and weed dry weight was recorded with triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using knapsack sprayer with flat fan nozzle and it was at par with triafamone 20% + ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with multiple solid stream (SJ7A015VP) nozzle and drones with air induction extended range flat spray (AIXR110015VS) nozzle. There was a 55 % higher yield in triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using knapsack sprayer with flat fan nozzle over the unweeded check.
***Keywords* :** Drone, nozzle, transplanted rice, weed control efficiency, weed density, weed dry weight.

Introduction

Rice (*Oryza sativa* L.) production occupies a very important position in agriculture, particularly in Asian countries. Area, production and productivity of rice in India are 47.8 m ha, 135.8 m t and 2838 kg ha^{-1} respectively (www.indiastat.com, 2022-2023). Rice productivity in India is very low compared to other rice growing countries like China (4.3 t ha^{-1}), Australia (10.1 t ha^{-1}), U.S (7.5 t ha^{-1}) and Russia (5.2 t ha^{-1}) Yadav *et al.* (2019). Weeds are one of the most important yield-limiting biological constraints in rice production worldwide. The diverse weed flora under transplanted conditions (grasses, sedges and broad-leaved weeds) can cause yield reduction up to 76% Singh *et al.* (2004). Globally, about 10% of the total production of rice is lost due to weed infestation Oerke E.C. and Dehne H.W. (2004). Effective control of weeds increases grain yield by 85 per cent Dhanapal *et al.* (2018). Therefore, timely weed control is crucial to realize higher productivity. About 300–400-man hours per hectare are required to remove weeds from transplanted rice field. The acute shortage of labour is one of the major challenges.

To address these challenges, advanced technology is inevitable in agriculture in order to save time and energy. Drone being a modern technology can be one of the solutions for farmers. Advancing drone technologies for chemical application is crucial to optimize scarce resource utilization while ensuring energy efficiency, higher yields, and profitable returns Paul *et al.* (2023). Agricultural use of unmanned aerial vehicles (UAVs) for herbicide application offers a new high-tech tool for weed management. Labour costs were reduced by half with UAVs compared to conventional machines Umeda *et al.* (2022).

The nozzle serves as the key component in a spraying system, directly influencing both the herbicide's efficacy and the overall effectiveness of the application. Spray drift resulting from aerial chemical applications remains a significant challenge in modern agriculture. In UAV-based herbicide spraying, the choice of an appropriate nozzle is essential to ensure uniform spray distribution over target plants and to minimize drift losses. Droplet size, which is closely linked to the nozzle's volume median diameter, affects both the deposition and penetration of droplets in the target zone as well as their unintended dispersion in non-target areas Chen *et al.* (2020). However, available technical literature addressing aerial drift-reduction performance is limited, as most prior studies have concentrated on ground-based spraying systems Wang *et al.* (2018).

Therefore, the choice of an optimal nozzle is critical to ensure precise and efficient herbicide delivery in drone-based spraying operations and as there are relatively few studies focusing on injection systems and nozzle optimization technology in agricultural drones. This study helps in understanding the type of nozzle to be selected for spray fluid application to increase the efficiency of weed management by selection of proper nozzle by using drone vs-a-vis knapsack sprayer.

Materials and Methods

A field experiment was carried out at Military farm, Institute of rice research, Rajendra Nagar, Hyderabad during *kharif*, 2023. The farm is located geographically at 17 ^{0}19' 16.4" North latitude and 78^{0} 24' 43" East longitude and at an altitude of 542.3 m above mean sea level. The mean maximum weekly temperature ranged from 27^{0} C to 33.1^{0} C with an average of 30 ^{0}C during the crop growth period (July to November, 2023). The weekly mean minimum temperature ranged from 16.1^{0} C to 23.8^{0} C with an average of 19.9 ^{0}C. The average relative humidity during the crop growth season fluctuated from 93 to 81% in the morning and 83.1 to 30 % in the afternoon respectively.

The soil at the experimental site was characterized by a clay loam texture with pH of 7.56, low in available nitrogen (218.5 kg/ha), medium in available phosphorus (36.8 kg/ha) and high in available potassium (439.7 kg/ha) contents. The experiment consisted of 8 treatments and the design used was randomized block design and replicated thrice. 'RNR–15048' (Telangana sona) variety was transplanted in main field at the age of 21 days old seedlings with a spacing of 15× 15 cm. Pre-emergence herbicide was applied at three days after transplanting and post-emergence herbicides were applied at 2–3 leaf stage of weeds (20 DAT).

At sampling density of weeds, viz. grasses, sedges and broad-leaved weeds were recorded using a 50 × 50 cm quadrat, and their dry weight was determined from the same area through destructive sampling. The samples were first shade-dried and then oven-dried at 65 ± 2°C for 48 hours to obtain the dry weight.

The nozzles used in the experimental study for drone spraying and droplet size parameters of the nozzles were XR11002VP (Fine), AIXR110015VS (Coarse), DG110015VS (Fine), DG95015EVS (Medium) and SJ7A-015VP (Extremely coarse). The herbicide used in the study triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE has both contact and systemic activity (foliage and soil active).

Weed control efficiency (WCE) was calculated based on weed dry weight. Treatment imposition of post emergence herbicide was done at 20 DAT. The data on weed density and dry weight for all the categories were computed using square root transformation, before analysis. However, for better understanding, original values are given in the parenthesis.

Results and Discussion

Weed flora

The weed flora of the experimental field was among the grasses *Paspalum distichum* L., *Echinochloa colona*, *Echinochloa crusgalli, Cynodon dactylon* and among the sedges found were *Cyperus difformis, Schoenoplectiella juncoides* Among the broad-leaved weeds *Alternanthera paronychioides, Limnophila heterophylla, Ottelia alismoides, Monochoria vaginalis, Ammania baccifera* and *Marsilea quadrifolia* were predominant.

Weed density

Significantly lower weed density 10 days after treatment imposition (*i.e.,* at 30 DAT) was recorded with Hand weeding (20 and 40 DAT) and was followed by triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using knapsack sprayer with nozzle (flat fan nozzle) and it was at par with drones with multiple solid stream (SJ7A015VP) nozzle and drones with air induction extended range flat spray (AIXR110015VS) nozzle. This might be due to lower drift in case of knapsack sprayer and drone using multiple solid stream (SJ7A015VP) nozzle. As the solid stream nozzle have extremely coarse spray pattern there was no drift losses of the herbicide spray fluid and the herbicide used was having both contact and systemic activity (soil and foliage active) due to production of coarser droplets the herbicide reached the ground and through soil activity controlled the weeds effectively. Higher weed density recorded with drone using XR11002VP was due to higher loss of the spray fluid through drift. These results are in tune with the findings of Hunter *et al.* (2020) and Supriya *et al.* (2021). All the weed management practices significantly reduced weed density and weed dry weight over the unweeded check (Table 1).

Weed dry matter

Similar to weed density lower weed dry matter at 30 DAT was also recorded in case of Hand weeding (20 and 40 DAT) and it was followed by triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using knapsack sprayer with nozzle (flat fan nozzle) and it was at par with drones with multiple solid stream (SJ7A015VP) nozzle, drones with air induction extended range flat spray (AIXR110015VS) nozzle and drones with drift guard even flat spray (DG95015EVS) nozzle. Among the herbicidal treatments knapsack sprayer has recorded the lowest total weed dry weight which is due to higher bio efficacy and no losses of drift. Among the drone-based herbicide treatments, solid stream nozzle and air induction nozzle was found to record lower total weed dry weight due to reduced drift owing to production of coarser droplets as the herbicide has both contact and systemic activity (soil and foliage active) these nozzles have shown higher bioefficacy due to herbicide entry through the soil and controlled the weeds effectively. Similar findings were recorded by Wang *et al.* (2018), Paul *et al.* (2023), Hiremath *et al.* (2024) and Meesaragandla *et al.* (2024) (Table 1)

Weed control efficiency and weed index

Among the chemical treatments higher weed control efficiency (WCE) and lower weed index (WI) was recorded with using knapsack sprayer with nozzle (flat fan nozzle) and followed by drones with multiple solid stream (SJ7A015VP) nozzle (Table 2).

Effect on yield

Higher grain and straw yield were recorded with Hand weeding (20 and 40 DAT) and it was at par with drones with multiple solid stream (SJ7A015VP) nozzle, drones with air induction extended range flat spray (AIXR110015VS) nozzle and drones with drift guard even flat spray (DG95015EVS) nozzle. There was 55.2 % reduction in grain yield under unweeded control over hand weeding. Weed management practices not only decreased weed density and biomass but also enabled crops to utilize available resources more effectively, leading to higher yields compared to the unweeded control. Comparable findings were observed by Choudhary and Dixit (2018) and Kashid (2019) (Table 3) and (Figure 1 and 2).

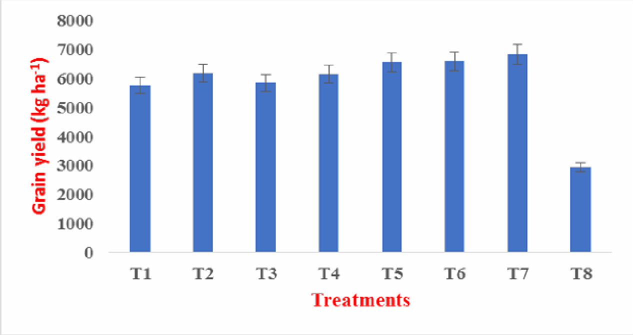

Fig. 1 : Grain yield (kg ha^{-1})

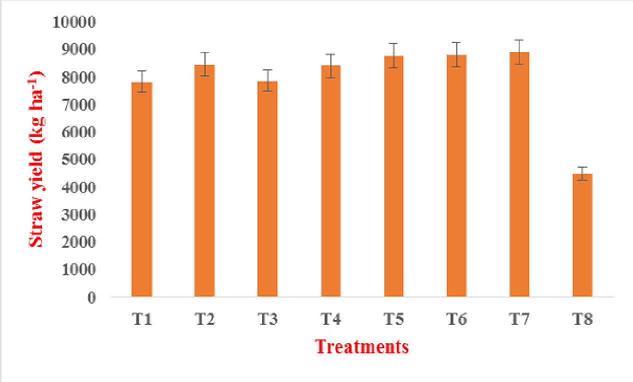

Fig. 2 : Straw yield (kg ha^{-1})

Conclusion

The application of post-emergence herbicides using both knapsack sprayers and drones equipped with different nozzle types namely the multiple solid stream (SJ7A015VP), air induction extended range flat spray (AIXR110015VS), and drift guard even flat spray (DG95015EVS) resulted in statistically similar weed density and weed dry matter. This indicates that the performance of drone-based spraying was comparable to that of the conventional knapsack sprayer. The findings clearly demonstrate that drones fitted with these nozzle configurations can effectively and uniformly deliver PoE herbicides, ensuring adequate coverage and weed control. Therefore, drones can be efficiently employed as an alternative to manual spraying methods for PoE herbicide applications, offering advantages such as reduced labour, greater operational efficiency, and potential for precision in field management.

Table 1 : Total weed density (no. m^{-2}) and weed dry weight (g m^{-2}) before (20 DAT) and 10 days after treatment (30 DAT) imposition

Treatments	Total Weed density (no. m^{-2})		Total weed dry weight (g m^{-2})	
	20 DAT (Before treatment imposition)	30 DAT (10 days after treatment imposition)	20 DAT (Before treatment imposition)	30 DAT (10 days after treatment imposition)
T_1 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with extended range flat spray (XR11002VP) nozzle.	6.68 (43.7)	5.53 (29.6)	5.54 (29.7)	4.77 (21.8)
T_2 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with air induction extended range flat spray (AIXR110015VS) nozzle.	6.08 (36.3)	4.65 (20.6)	5.56 (29.9)	4.06 (15.5)
T_3 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with drift guard flat spray (DG 110015VS) nozzle.	5.91 (34.0)	5.26 (26.7)	5.53 (29.6)	4.64 (20.6)
T_4 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with drift guard even flat spray (DG95015EVS) nozzle.	6.04 (35.7)	4.72 (21.3)	5.56 (29.9)	4.14 (16.2)
T_5 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with multiple solid stream (SJ7A015VP) nozzle.	6.19 (37.3)	4.46 (19.0)	5.43 (28.5)	4.02 (15.1)
T_6 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using knapsack sprayer with nozzle (flat fan nozzle).	6.21 (37.7)	4.24 (17.0)	5.52 (29.5)	3.88 (14.0)
T_7 : Hand weeding (20 and 40 DAT).	6.27 (38.3)	3.04 (8.3)	5.54 (29.7)	3.27 (9.7)
T_8 : Unweeded check.	6.16 (37.0)	7.90 (61.3)	5.67 (31.1)	8.06 (64.0)
SE(m) ±	0.20	0.16	0.05	0.10
CD (P=0.05)	NS	0.47	NS	0.29

Table 2 : Weed control efficiency (%) and weed index (%) as influenced by herbicide application with drones using different nozzles

TREATMENTS	WCE		WI
	20 DAT (Before treatment imposition)	30 DAT (10 days after treatment imposition)	
T_1 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with extended range flat spray (XR11002VP) nozzle.	1.4	65.9	15.6
T_2 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with air induction extended range flat spray (AIXR110015VS) nozzle.	1.2	75.7	9.3
T_3 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with drift guard flat spray (DG 110015VS) nozzle.	1.5	67.8	14.3
T_4 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with drift guard even flat spray (DG95015EVS) nozzle.	1.2	74.6	10.3
T_5 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with multiple solid stream (SJ7A015VP) nozzle.	2.6	76.3	3.9
T_6 : Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using knapsack sprayer with nozzle (flat fan nozzle).	1.6	78.0	3.5
T_7 : Hand weeding (20 and 40 DAT).	1.4	84.7	-
T_8 : Unweeded check.	-	-	56.9

Table 3 : Grain and straw yield (kg ha^{-1}) as influenced by herbicide application with drones using different nozzles

Treatments	Grain yield	Straw yield	Harvest index
T_1: Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with extended range flat spray (XR11002VP) nozzle.	5763	7809	42.5
T_2: Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with air induction extended range flat spray (AIXR110015VS) nozzle.	6190	8455	42.2
T_3: Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with drift guard flat spray (DG 110015VS) nozzle.	5850	7843	42.7
T_4: Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with drift guard even flat spray (DG95015EVS) nozzle.	6137	8396	42.2

T_5: Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using drones with multiple solid stream (SJ7A015VP) nozzle.	6564	8770	42.8
T_6: Triafamone 20%+ ethoxysulfron 10%WG 44+22.5 g ha^{-1} PoE using knapsack sprayer with nozzle (flat fan nozzle).	6597	8802	42.8
T_7: Hand weeding (20 and 40 DAT).	6834	8896	43.4
T_8: Unweeded check.	2955	4484	39.7
SE(m) ±	230	291	0.99
CD (P=0.05)	699	884	NS

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