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UAV-based Herbicide Application for Efficient Weed Management in Direct-seeded Rice

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ABSTRACT

Background: Weeds are the key pest, which reduce crop productivity. Direct-seeded rice is very prone to early-stage weed infestation during initial crop development. Cultural and mechanical methods are difficult due to unavailability of labour and poor work efficiency. Hence, use of herbicides is an effective method for timely weed control. However, the efficacy of agrochemicals depends on the efficiency of spraying equipment. Conventional knapsack sprayers are used most often to spray herbicides but they are highly time-consuming, labour intensive and labour drudgery practices. Hence, the current experiment was aimed to study the efficiency of unmanned aerial vehicles (UAVs) on weed management.

Methods: A field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore during *summer*, 2022 to evaluate the efficacy of UAV-based herbicide application in direct-seeded rice. The study comprised of five weed management treatments such as pre emergence application of pretilachlor with safener and pyrazosulfuron through both UAV and knapsack sprayer and unweeded check as control. The experimental plot was laid out in a randomized block design with four replications.

Result: The experimental findings showed that the application of pre-emergence pretilachlor significantly reduced the density and dry weight of grasses, sedges and broad leaved weeds in knapsack application. Moreover, it was found on par with UAV application of same herbicide without any phytotoxicity to rice seedlings. From the experiment, the application of pre-emergence pretilachlor through UAV is found to be more effective for timely weed control during early stages in direct-seeded rice, which reduce the labour intensity and drudgery than knapsack application.

Key words: Direct-seeded rice, Herbicide, UAV, Weed control efficiency.

INTRODUCTION

Rice is an important food grain crop and mostly cultivated in conventional transplanting method. However, there is a trend shifting towards direct-seeded rice due to climate variability and resource constraints (Goswami *et al*., 2018). Weeds are the notable barriers to rice that reduce crop productivity. Direct-seeded rice is very prone to early-stage weed infestation during initial crop development. Cultural and mechanical methods are used often to control the weeds but it is difficult due to labour unavailability and poor work efficiency. Hence, use of herbicide is an effective method for timely weed control and application of pre-emergence herbicides can offer a broad spectrum of weed control at the initial stage, contributing to higher grain yield. However, the efficacy of agrochemicals depends on the efficiency of spraying equipment. Conventional knapsack sprayers are used most often to spray agrochemicals but they are highly time-consuming, labour intensive and labour drudgery practices. In addition, application of pre-emergence herbicides through the conventional knapsack method immediately after sowing leads to an uneven crop stand due to pressing the seeds into the mud during herbicide application by spraying person (Vijayakumar *et al*., 2022). Moreover, conventional methods possess a high risk of pesticide exposure to the labour (Cao *et al*., 2017) and are highly time-consuming and need high spray volume to cover the entire field. Therefore, conventional methods are being replaced by increasingly adopted unmanned aerial vehicles (UAVs). UAVs are high-handedly used to deliver the pesticides to inaccessible places such as steep and mountainous terrains where the conventional spraying system is not possible (Arthanari and Paul, 2022). It has the ability to deliver pesticides at different application heights and lower altitudes closer to plant canopies with reduced carrier volume in a more precise and safe manner than conventional methods (Fritz *et al*., 2006). Wang *et al*. (2019), reported that aerial application of insecticide with fungicide combination recorded a comparable control of wheat aphids and powdery mildew than knapsack spraying system. The adoption of UAVs is progressively increased to substitute the conventional knapsack spraying system. Nevertheless,

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numerous experiments were conducted to study the efficiency of UAVs on insect and disease control but there is a lack of research evidence on weed control. Hence, a field experiment was conducted to study the efficacy of low volume application of suitable pre-emergence herbicides using UAV in direct-seeded rice.

MATERIALS AND METHODS

The field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore, India to screen the suitable pre-emergence herbicides and their efficacy for UAV application. The experimental field was geographically situated between 11°.24′N latitude and 76°.92′E longitude with an altitude of 426.7 meters above the mean sea level. The experimental field was fairly uniform and the soil is clay loam in nature with a pH of 7.95. The organic carbon content of the soil was 0.60%. The initial soil contain low amount of nitrogen (262.1 kg ha^{-1}), medium amount of phosphorus (20.5 kg ha^{-1}) and high amount of potassium (615.7 kg ha^{-1}).

In summer 2022 (February-March), sprouted seeds of CO 51 rice variety were sown on puddled soil using a drum seeder by adopting a spacing of 20 × 10 cm. The recommended fertilizer dose of 150:50:50 kg/ha of nitrogen, phosphorus and potassium was supplied in the form of urea, single super phosphate and muriate of potash.

Equipment

The unmanned aerial vehicle used in the present study was a hexacopter system. The UAV was embedded with a spraying system with four nozzles. The knapsack sprayer used in the present study was battery operated system. A flat fan nozzle was used in both the spraying system.

Herbicide application

The experimental treatments were laid out in randomized block design with four replications to overcome field heterogeneity. The treatments comprised five weed management practices T_1- Pretilachlor with safener (30.7% EC) @ 450 g a.i/ha UAV spray, T_2- Pretilachlor with safener (30.7% EC) @ 450 g a.i/ha knapsack spray T_3- Pyrazosulfuron (10% WP) @ 25 g a.i/ha UAV spray, T_4- Pyrazosulfuron (10% WP) @ 25 g a.i/ha knapsack spray and T_5- Unweeded check. The pre-emergence herbicides were applied at 3 days after sowing (DAS). The pre-emergence herbicides were applied using 40 L ha^{-1} and 500 L ha^{-1} spray volume for drone and knapsack system, respectively. The application of herbicide by UAV spraying system is illustrated in Fig 1.

Biometric observations on weed

Data on density (number per m^2) and dry weight (g m^{-2}) of the grasses, sedges and broad-leaved weeds were recorded for each experimental unit from a randomly selected unit area using quadrants (0.25 m^2) at 20 days after sowing. In order to record the weed dry weights, the weeds were cut at ground level, shade dried and then oven-dried at 78±2°C until a constant dry weight was recorded.

Summed dominance ratio (SDR)

The SDR of the weed species was computed using the following formula suggested by Janiya and Moody (1989).

$$SDR = \frac{\text{Relative weed denisty + Relative weed dry weight}}{2}$$

Whereas the relative weed density and relative weed dry weight were calculated by using the following formula.

$$\text{Relative weed denisty} = \frac{\text{Denisty of a spices}}{\text{Total denisty of all spices}} \times 100$$

$$\text{Relative weed dry weight} = \frac{\text{Dry weight of a spices}}{\text{Total dry weight of all spices}} \times 100$$

Weed control efficiency (WCE)

Weed control efficiency was calculated as per the procedure given by Mani *et al.* (1973) and expressed in percentage.

$$WCE = \frac{\text{Weed dry weight in control plot - Weed dry weight in treated plot}}{\text{Weed dry weight in control plot}} \times 100$$

Statistical analysis

The data on weed density and weed dry weight were analyzed statistically by adopting Fisher's method of ANOVA suggested by Gomez and Gomez (1984). The data on weed density and weed dry weight were subjected to square root transformation $\sqrt{(X + 0.5)}$ before analysis. Statistical significance was tested by the F test at a critical difference (CD) of 0.05 level of probability.

RESULTS AND DISCUSSION

The predominant weed flora observed in the experimental plots were Barnyard grass (*Echinochloa crus-galli*) and Chinese sprangletop (*Leptochloa chinensis*) in grasses, Variable flatsedge (*Cyperus difformis*) in sedges and European waterclover (*Marsilea quadrifolia*), Cape ash (*Bergia capensis*) and Heart shape false pickerel weed (*Monochoria vaginalis*) in broad leaved weeds. Similar weed flora was previously reported by Yogananda *et al.* (2017). The application of pre-emergence herbicides caused a substantial reduction in relative weed density and dry weight over unweeded check (Table 1). The relative weed density of the experimental site was dominated by grasses (65.33%) followed by sedges (20.72%) and broad leaved weeds (13.95%). The relative weed dry weight was dominated by grasses (47.40%) followed by sedges (29.56%) and BLW (23.05%) under unweeded check (T_5). Similarly, in all the treatments relative density and dry weight of grasses were higher than sedges and BLW. Data on summed dominance ratio (Fig 2) also confirmed that in all the treatments grasses were more dominant than sedges and BLW. These result were corroborated with earlier findings of Ravisankar *et al.* (2008).

Weed density and weed dry weight

Data on weeds were grouped into grasses, sedges and broad leaved weeds and presented in Table 2. The application of pre-emergence pretilachlor caused 73.91% and 65.30% reduction in the density of grasses in knapsack (T_2) and UAV (T_1) treatments, respectively. The lowest density (32.08 No./m^2) of grasses was recorded in knapsack application of pre-emergence pretilachlor (T_2) and it was closely followed by UAV application of same herbicides (T_1). The lowest sedge population (10.00 No./m^2) was recorded in knapsack application of pre-emergence pretilachlor (T_2) and pyrazosulfuron with 74.36% and 67.72% reduction respectively, over unweeded check. The density of broad leaved weeds was significantly reduced by pre-emergence herbicides and the reduction of BLW was 51.43% and 49.52% for pretilachlor application through knapsack and UAV treatments and pyrazosulfuron recorded 38.13% and 32.34% reduction of BLW on UAV and knapsack plots, respectively. The wide spectrum control of grasses, sedges and BLW were recorded in pre-emergence application

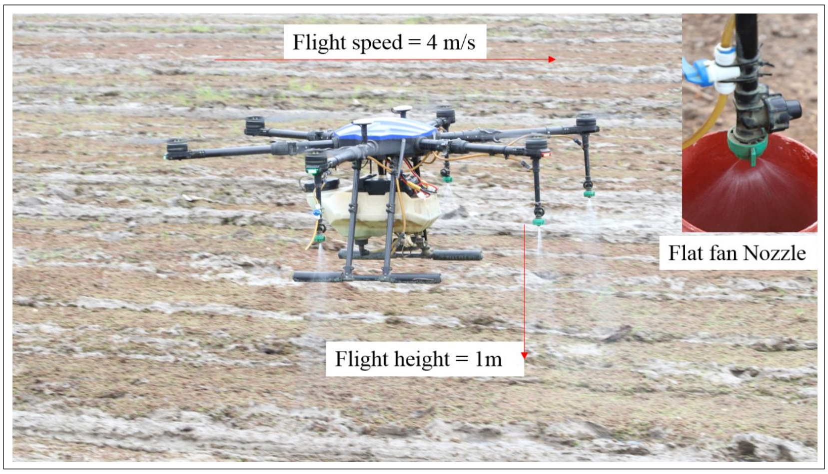

Fig 1: Spray operation of UAV at rice field.

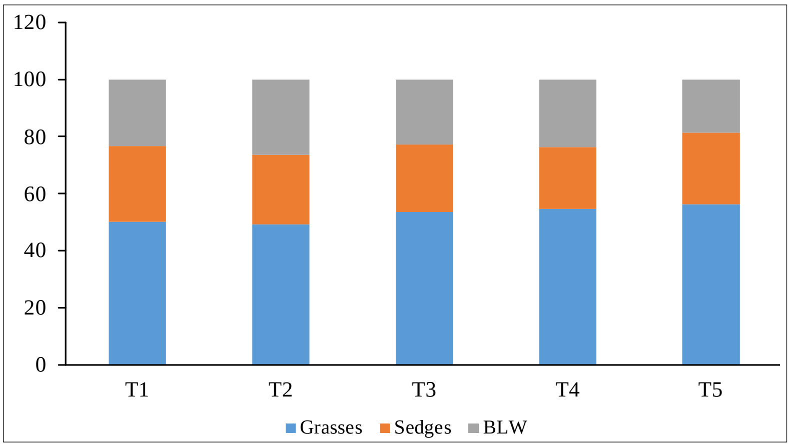

Fig 2: Effect of different pre-emergence herbicides applied through UAV on summed dominance ratio.

Table 1: Effect of different pre-emergence herbicides applied through UAV on relative weed density and weed dry weight.

Treatments	Relative density (%)			Relative dry weight (%)		
	Grasses	Sedges	BLW	Grasses	Sedges	BLW
T_1	57.93	24.09	17.98	42.44	29.16	28.40
T_2	58.51	18.24	23.25	40.00	30.59	29.41
T_3	63.03	19.18	17.79	44.21	28.21	27.57
T_4	62.39	15.60	22.01	46.98	27.84	25.18
T_5	65.33	20.72	13.95	47.40	29.56	23.05

Data was not statistically analyzed.

pretilachlor in both application without any phytotoxicity to rice seedlings. This might be due to the application of pretilachlor at 3 DAS which effectively controlled the germinating weeds at the plumule-initiation stage by inhibiting the cell division and the presence of fenclorim protects the crop from phytotoxicity under low spray volume of 40 L/ha. The results were in line with the findings of Suganthi *et al.* (2005). The density of grasses, sedges and BLW was significantly higher in the unweeded check (T_5).

All the applied pre-emergence herbicides caused significant reductions in dry weight of grasses, sedges and BLW (Table 2). The pretilachlor application reduced the weed dry weight over control by 72.83%, 66.77% and 58.91% for grasses, sedges and BLW respectively, for knapsack treatment (T_2) and it was comparable with UAV application of same herbicides (T_1). This might be due to application of pretilachlor was more effective in controlling grasses, BLW and sedges at early stages (Sunil *et al*., 2010). There was no significant difference between UAV and knapsack application and confirmed that carrier volume was not influenced the herbicide efficacy under saturated soil conditions. Similar results were reported by Paul *et al.* (2023). Chen *et al.* (2019) also reported that the application of pre-emergence herbicides through UAV had similar weed control efficiency with conventional knapsack sprayer.

Weed control efficiency

Weed control efficiency was worked out based on the weed dry weight and was significantly influenced by weed management practices at 20 DAS (Fig 3). The highest WCE (67.83%) was recorded in the pre-emergence application of pretilachlor by knapsack sprayer (T_2) and was followed by UAV application of same herbicides (64.43%) (T_1). The UAV-based herbicide application used low spray volume and recorded similar control efficiency of knapsack application.

Correlations between weed dry weight and rice dry matter production

A strong negative correlation was observed between weed dry matter and dry matter production of rice (Fig 4). The relationship indicated that the increased weed dry weight in unweeded check significantly reduced the dry matter production of rice up to 21.8% at 30 DAS. Application of

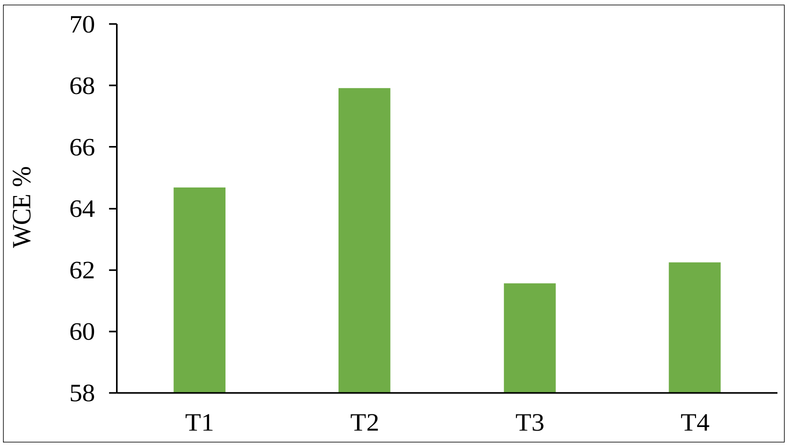

Fig 3: Effect of different pre-emergence herbicides applied through UAV on weed control efficiency.

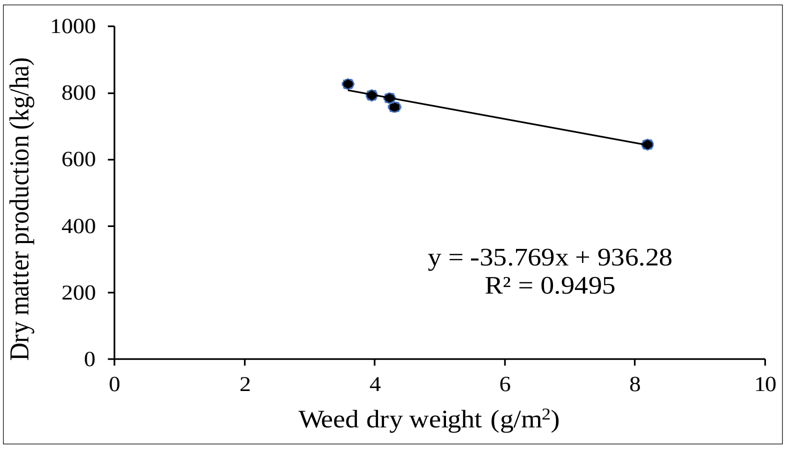

Fig 4: Correlation between weed dry weight and rice dry matter production.

Table 2: Effect of different pre-emergence herbicides applied through UAV on weed density and weed dry weight.

Treatment	Grasses				Sedges				BLW			
	Density (No./m^2)	% of control	Dry weight (g/m^2)	% of control	Density (No./m^2)	% of control	Dry weight (g/m^2)	% of control	Density (No./m^2)	% of control	Dry weight (g/m^2)	% of control
T_1	6.57 (42.68)	65.30	1.47 (1.69)	68.11	4.27 (17.75)	54.49	1.29 (1.16)	64.95	3.63 (13.25)	49.52	1.28 (1.13)	56.20
T_2	5.70 (32.08)	73.91	1.39 (1.44)	72.83	3.23 (10.00)	74.36	1.29 (1.10)	66.77	3.63 (12.75)	51.43	1.25 (1.06)	58.91
T_3	7.61 (57.53)	53.22	1.54 (1.90)	64.15	4.24 (17.51)	55.10	1.31 (1.21)	63.44	4.06 (16.24)	38.13	1.30 (1.19)	53.88
T_4	7.12 (50.35)	59.06	1.56 (1.98)	62.64	3.58 (12.59)	67.72	1.26 (1.18)	64.35	4.25 (17.76)	32.34	1.25 (1.06)	58.91
T_5	11.11 (122.98)	-	2.40 (5.30)	-	6.46 (39.00)	-	1.67 (3.31)	-	5.17 (26.25)	-	1.44 (2.58)	-
SEd	0.22	-	0.14	-	0.28	-	0.04	-	0.36	-	0.03	-
CD (p=0.05)	0.49	-	0.30	-	0.61	-	0.09	-	0.79	-	0.07	-

Data in the parenthesis are original value, which was transformed into $\sqrt{(X + 0.5)}$.

pre-emergence herbicides had better weed control and dry matter production than unweeded plot and pretilachlor applied plots recorded the highest dry matter production. The research outcomes indicated that weed competition significantly affected rice crop in the early stages of growth, leading to a reduced accumulation of dry matter production in unweeded check. The results were corroborated with the findings of Ravishankar *et al.* (2008).

CONCLUSION

From the experiments, it is concluded that the application of pre-emergence pretilachlor significantly reduced the density and dry weight of broad-spectrum weeds and recorded the highest weed control efficiency in direct-seeded rice through both UAV and knapsack application. In addition, UAV application used lesser spray volume than knapsack sprayer and recorded comparable weed control to conventional knapsack sprayer. Hence, the application of pre-emergence pretilachlor through UAV might be recommended to obtain timely weed control during early stages of crop growth without any phytotoxicity and more advantages than the conventional spraying method.

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Conflict of interest: None.

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