



Drone based herbicide application in greengram (*Vigna radiata*)

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Received: 26 October 2023; Accepted: 08 December 2023

Keywords: Dosage, Drone, Grain yield, Greengram, Pendimethalin, Spray fluid, Weed control efficiency

Greengram [*Vigna radiata* (L.) R. Wilczek] is one of the most significant and widely cultivated pulses in India. It is grown in an area of 5.13 mha, producing 3.08 million tonnes with an average yield of 601 kg/ha in India. In Tamil Nadu, it is grown in around 1.61 lakh ha with a production of 0.59 lakh tonnes and productivity of 367 kg/ha (Anonymous 2021). It is a short-duration pulse crop suited in any type of cropping system. Crop weed competition is the key contributing factor for reduced productivity of greengram. The most common weeds observed in greengram fields include *Trianthema portulacastrum* (L.), *Amaranthus viridis* (L.), *Phyllanthus niruri* as a broad-leaf weed; *Cynodon dactylon* (L.), *Echinochloa colonum* (L.), and *Eleusine indica* as grasses (Ramesh and Rathika 2020). Weeds reduce greengram grain production by 30 to 50% and the critical period for crop-weed competition ranges from 15 to 30 DAS (Khan *et al.* 2011).

Weeding operation done manually and mechanically in greengram is tedious, expensive and time-consuming. In such cases, chemical weed management may be a feasible and cost-effective option for greengram. The conventional method of manual herbicide spraying requires more labour, expensive and needs more input. Further, manual spraying causes serious health issues for human beings. Hence, it is highly essential to identify an alternative method of herbicide application with less cost, time and health issues. In this situation, use of unmanned aerial vehicles or agricultural drones can be employed to spray herbicides for controlling weeds (Zhang *et al.* 2020).

An agricultural drone is an unmanned aircraft used in agriculture, helps in spraying pesticides. It covers large areas quickly, potentially increasing productivity and reducing labour costs (Dayana *et al.* 2022). When drones are used for herbicide application, the quantity of spray fluid and herbicide dose have to be optimized before commercial

recommendation, which are completely lacking. Hence, the present study was carried out with the objectives of optimizing herbicide dosage and spraying fluid for effective weed control in greengram through drone application.

The present study was carried out during winter (*rabi*) season of 2023 at Anbil Dharmalingam Agricultural College and Research Institute, (Tamil Nadu Agricultural University), Tiruchirappalli (10°45'N, 78°36'E and at an altitude 85 m amsl), Tamil Nadu. The soil of experimental field was sandy loam, moderately drained with pH 8.6 (sodicity). The nutrient status of soil was low in N (190.2 kg/ha) and medium in available P (17.6 kg/ha) and K (243.1 kg/ha). The field trial was laid out in a randomized block design (RBD) with 12 treatments and 3 replications. The area of each treatment was 137.5 m² (25 × 5.5). The greengram variety VBN 2 (GG) was sown with a spacing of 30 cm × 10 cm. The treatments consisted of 2 doses of pendimethalin (0.75 and 1.0 kg/ha); 5 levels of spray fluids (40, 50, 60, 70 and 80 litre/ha) for drone spray compared with conventional manual spray of pendimethalin at 1.0 kg/ha with 500 litre/ha spray fluid and control.

The agricultural drone (AD610D model) with a dimension of 1365 mm × 1365 mm × 480 mm was used. During herbicide spray, the flight height (1.0 m), swath (1.8 m), velocity, and GPS were pre-determined and controlled by a well-trained operator. The loading capacity of drone was 10 ls. As per the treatment schedule, the spray fluid was adjusted by pulse width modulation signal's duty cycle (Agurob *et al.* 2023). Spraying was carried out by using a flat fan nozzle, both manually and by drone.

Total weed density and weed dry weight were recorded using 0.25 m² quadrat at four places randomly in each plot at 15 and 30 DAS (days after sowing), sun dried and oven dried at 80°C for 72 h and expressed in g/m². Weed control efficiency (WCE) was calculated using the formula as suggested by Mani *et al.* (1973). Plant height at harvest, leaf area index (LAI) at 25 DAS and dry-matter production (DMP) at harvest were recorded. Yield attributes, viz. no. of pods/plant, seeds/pod, grain yield and haulm yield (kg/ha) were recorded at harvest stage. Data on weed

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density and weed dry weight were subjected to square root transformation ($\sqrt{x+0.5}$). The energetics advantages of using drones for herbicide application were calculated by taking in account of energy conversion coefficients of inputs and outputs (Devasenapathy *et al.* 2009). Additional energy used for weed management and additional yield obtained due to weed management were taken as input and output energy. Energy use efficiency was calculated from the ratio of additional output and input energy. All the recorded data were statistically examined as applicable to randomized block design (RBD) (Gomez and Gomez 1984).

Weed flora of the experimental site: The predominant weed flora found in the experimental field were *Trianthema portulacastrum* in broad-leaf weeds, *Echinochloa colona* (L.), *Cynodon dactylon* and *Eleusine coracana* in grasses and *Cyperus rotundus*, *Cyperus iria* in sedges. Similar weed flora in greengram field were reported by Udhaya *et al.* (2021).

Weed density, weed dry weight and weed control efficiency: Drone spray of pendimethalin 1.0 kg/ha with spray fluid of 60 litre/ha recorded significantly lower weed density (10.77 and 47.89/m²), dry weight (6.78 and 27.21

g/m²) and higher WCE (82.4 and 72.6%) at 15 and 30 DAS respectively than other treatments (Table 1). However, this was on par with pendimethalin 0.75 kg/ha with spray fluid of 60 litre/ha (WCE of 81.8 and 68.6%), pendimethalin 1.0 kg/ha with spray fluids of 50 and 70 l/ha and manual spray. The reason behind the reduced weed density, dry weight and higher WCE under drone spray was owing to that spraying of optimum dose of herbicide and spray fluid provided wider area coverage, greater number of droplet deposits on the soil surface and uniform dissipation of pendimethalin resulted in reduced weed germination through inhibition of cell division or mitosis (Sinchana *et al.* 2023). These results were in conformity with the findings of Jeevan *et al.* (2023) who reported that drone application of pyrazosulfuron-ethyl at 25 g/ha recorded higher WCE in rice. These results were well supported by the findings of Shan *et al.* (2021) who reported that the spray volume of 15.0 litre/ha and the droplet size of 150 µm under drone spray produced higher WCE in winter wheat.

Growth parameters: Drone application of pendimethalin 1.0 kg/ha with spray fluid of 60 litre/ha registered

Table 1 Effect of herbicide application using drone on total weed density, dry weight and weed control efficiency in greengram

Treatment	Total weed density (No./m ²)		Total weed dry weight (g/m ²)		Weed control efficiency (%)	
	15 DAS	30 DAS	15 DAS	30 DAS	15 DAS	30 DAS
T ₁ , DS pendimethalin 0.75 kg/ha + SF 40 litre/ha	4.53 (20.50)	8.14 (66.21)	3.35 (10.73)	7.03 (48.87)	72.1	50.8
T ₂ , DS pendimethalin 0.75 kg/ha + SF 50 litre/ha	4.18 (17.46)	7.86 (61.77)	3.17 (9.56)	6.47 (41.34)	75.2	58.4
T ₃ , DS pendimethalin 0.75 kg/ha + SF 60 litre/ha	3.39 (11.46)	6.96 (48.38)	2.74 (7.01)	5.40 (28.69)	81.8	71.1
T ₄ , DS pendimethalin 0.75 kg/ha + SF 70 litre/ha	4.30 (18.53)	7.94 (63.04)	3.21 (9.81)	6.66 (43.87)	74.5	55.8
T ₅ , DS pendimethalin 0.75 kg/ha + SF 80 litre/ha	4.68 (21.92)	8.36 (69.29)	3.86 (14.39)	7.44 (54.91)	62.6	44.7
T ₆ , DS pendimethalin 1.0 kg/ha + SF 40 litre/ha	4.35 (18.95)	8.04 (64.59)	3.32 (10.50)	6.85 (46.41)	72.7	53.2
T ₇ , DS pendimethalin 1.0 kg/ha + SF 50 litre/ha	3.49 (12.21)	7.00 (48.99)	2.79 (7.27)	5.63 (31.21)	81.1	68.6
T ₈ , DS pendimethalin 1.0 kg/ha + SF 60 litre/ha	3.28 (10.77)	6.92 (47.89)	2.70 (6.78)	5.26 (27.21)	82.4	72.6
T ₉ , DS pendimethalin 1.0 kg/ha + SF 70 litre/ha	3.57 (12.78)	7.09 (50.28)	2.83 (7.51)	5.76 (32.69)	80.5	67.1
T ₁₀ , DS pendimethalin 1.0 kg/ha + SF 80 litre/ha	4.57 (20.91)	8.23 (67.72)	3.41 (11.1)	7.20 (51.41)	71.2	48.2
T ₁₁ , MS pendimethalin 1.0 kg/ha + SF 500 litre/ha	3.61 (13.03)	7.12 (50.74)	2.88 (7.79)	5.80 (33.16)	79.8	66.6
T ₁₂ , Unweeded control	6.75 (45.62)	10.28 (105.77)	6.25 (38.51)	9.99 (99.26)	-	-
SEm±	0.18	0.40	0.16	0.43	-	-
CD (P=0.05)	0.38	0.83	0.34	0.89	-	-

Data given in parentheses are original values which were transformed to $\sqrt{x+0.5}$. DS, Drone spray; MS, Manual spray; SF, Spray fluid.

significantly taller plants (56.1 cm), higher LAI (1.21) at 25 DAS and DMP (3350 kg/ha) than control (Table 2). It was comparable with the drone spray of pendimethalin 0.75 kg/ha with spray fluid of 60 l/ha, pendimethalin 1.0 kg/ha with spray fluids of 50 and 70 litre/ha and manual spray of pendimethalin 1.0 kg/ha. The reason behind the higher growth attributes is the uniform coverage of optimum pendimethalin dosage with spray fluid applied by a drone, controlling the weeds effectively during the critical period of crop weed competition resulted in less weed competition by weeds for nutrients, space and light, and ultimately higher growth parameters. These findings were in accordance with Sudesh *et al.* (2019), who reported that application of pendimethalin 30 EC + Imazethapyr 2 EC 1.0 kg/ha reduced the weed competition and increased the growth attributes of greengram.

Yield attributes and yield: Significantly a greater number of pods/plant (34.1), seeds/pod (12.0), higher grain yield (747 kg/ha) and haulm yield (1662 kg/ha) were obtained under drone spray of pendimethalin 1.0 kg/ha with spray fluid of 60 litre/ha over other treatments (Table 2). However, this was statistically comparable with the drone

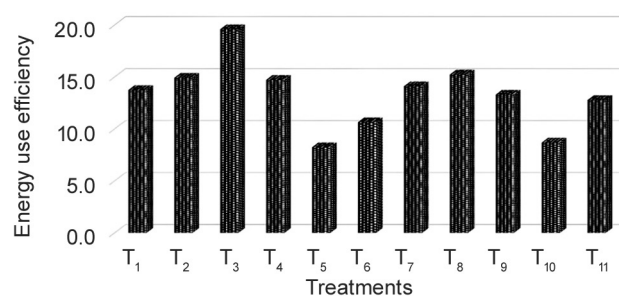


Fig. 1 Effect of herbicide application using drone on energy use efficiency in greengram.

Treatment details are given under Table 1.

spray of pendimethalin 0.75 kg/ha with spray fluid of 60 litre/ha, pendimethalin 1.0 kg/ha with spray fluids of 50 and 70 litre/ha and manual spray of pendimethalin 1.0 kg/ha. Application of pendimethalin, either by drone or manual spray, controlled the broad spectrum of weeds at critical periods resulted in less crop weed competition, increased nutrient availability to crops favoured better source sink relationship and ultimately produces a greater number

Table 2 Effect of herbicide application using drone on growth, yield parameters, yield and economics of greengram

Treatment	Plant height (cm)	LAI at 25 DAS	DMP (kg/ha)	Pods/plant (Nos.)	Seeds/pod (Nos.)	Grain yield (kg/ha)	Haulm yield (kg/ha)	Net returns (₹/ha)	BCR
T ₁ , DS pendimethalin 0.75 kg/ha + SF 40 litre/ha	48.9	0.77	2545	26.5	9.90	596	1520	20271	1.74
T ₂ , DS pendimethalin 0.75 kg/ha + SF 50 litre/ha	49.7	0.96	2615	29.6	10.50	642	1525	23947	1.87
T ₃ , DS pendimethalin 0.75 kg/ha + SF 60 litre/ha	55.5	1.18	3300	33.2	11.80	727	1655	30747	2.12
T ₄ , DS pendimethalin 0.75 kg/ha + SF 70 litre/ha	49.7	0.89	2600	29.5	10.50	635	1523	23387	1.85
T ₅ , DS pendimethalin 0.75 kg/ha + SF 80 litre/ha	47.5	0.56	2119	19.8	9.10	512	1349	13547	1.49
T ₆ , DS pendimethalin 1.0 kg/ha + SF 40 litre/ha	49.2	0.84	2579	27.1	10.30	610	1522	21040	1.76
T ₇ , DS pendimethalin 1.0 kg/ha + SF 50 litre/ha	54.3	1.16	3211	31.5	11.50	697	1645	27974	2.01
T ₈ , DS pendimethalin 1.0 kg/ha + SF 60 litre/ha	56.1	1.21	3350	34.1	12.00	747	1662	31974	2.15
T ₉ , DS pendimethalin 1.0 kg/ha + SF 70 litre/ha	54.5	1.13	3149	31.1	11.10	681	1612	26694	1.96
T ₁₀ , DS pendimethalin 1.0 kg/ha + SF 80 litre/ha	48.2	0.71	2515	25.2	9.40	567	1445	17600	1.63
T ₁₁ , MS pendimethalin 1.0 kg/ha + SF 500 litre/ha	54.2	1.11	3088	30.8	10.90	680	1612	26514	1.95
T ₁₂ , Unweeded control	44.6	0.31	2095	15.8	8.90	370	1112	4562	1.18
SEm±	2.43	0.05	137	1.91	0.59	37	67	-	-
CD (P=0.05)	5.02	0.10	284	3.96	1.23	77	139	-	-

DS, Drone spray; MS, Manual spray; SF, Spray fluid; LAI, Leaf area index; DAS, Days after sowing; DMP, Dry matter production; BCR, Benefit cost ratio.

of plant/pods and seeds/pod (Muthuram *et al.* 2018). Use of the drone for spraying pendimethalin either 1.0 or 0.75 kg/ha with spray fluid of 60 litre/ha performed better than the other treatments because of the number of spray droplets and uniform coverage of pendimethalin over the soil surface which considerably reduced the crop weed competition for resources, ultimately increased the plant growth and yield parameters and grain yield. Similarly, increased WCE and grains of maize under drone spray of atrazine with spray fluid of 80 l/ha was reported by Supriya *et al.* (2021).

Energy use: Energy use efficiency of drone usage for herbicide application revealed that application of pendimethalin at 0.75 kg/ha with spray fluid of 60 litre/ha registered higher energy use efficiency (19.6) than other treatments (Fig. 1) mainly due to reduced use of energy inputs, viz. herbicide, water and labour for weed control than manual spray of pendimethalin 1.0 kg/ha with spray fluid of 500 litre/ha (12.8). Similarly, Paul *et al.* (2023) also reported the energetic advantages of drone usage in herbicide application in rice.

Economics: Higher net returns of ₹31974/ha and benefit cost ratio (BCR) of 2.15 were obtained with drone spray of pendimethalin 1.0 kg/ha with spray fluid of 60 litre/ha than manual spray. This was closely followed by pendimethalin 0.75 kg/ha with spray fluid of 60 litre/ha (₹30747/ha net returns and 2.12 BCR). The higher net returns and BCR were mainly due to better weed control, higher grain yield, reduced input and labour cost under drone spray. The results were corroborated by findings of Paul *et al.* (2023) who reported that application of herbicide through the drone can reduce the labour wages and production cost of rice. The lowest net return of ₹4562/ha and BCR of 1.18 were obtained with control.

SUMMARY

An experiment was conducted during winter (*rabi*) season of 2023 at Anbil Dharmalingam Agricultural College and Research Institute, (Tamil Nadu Agricultural University), Tiruchirappalli, Tamil Nadu to assess the effect of drone based herbicide application in greengram. Results showed that drones could be effectively used for spraying of pre-emergence herbicide to control weeds and increase the yield of greengram. Further, application of pendimethalin 0.75 kg/ha with spray fluid of 60 litre/ha precisely through drones controlled the weeds effectively (WCE of 81.8%), increased grain yield, saved herbicide dose and spray fluid to the tune of 6.9%, 25% and 88% respectively than manual spray of pendimethalin 1.0 kg/ha with spray fluid of 500 litre/ha. Thus, application of pendimethalin 0.75 kg/ha with spray fluid of 60 litre/ha was considered as the optimum dosage and spray fluid for drone spray to control weeds, increase grain yield and profit in greengram, considering the reduced dose of herbicide as well as the labour scarce situation.

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