*Indian Journal of Agricultural Sciences* **94** (11): 1165–1170, November 2024/Article
https://doi.org/10.56093/ijas.v94i11.150525

# Drone-assisted herbicide optimization for energy efficiency, weed control and economics in transplanted rice (*Oryza sativa*)

NARAYANASWAMY JEEVAN[1], SELLAPERUMAL PAZHANIVELAN[2]*, RAMALINGAM KUMARAPERUMAL[1], A P SIVAMURUGAN[2] and MRUNALINI KANCHETI[3]

*Agricultural Research Station (Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu), Bhavanisagar, Tamil Nadu 638 451, India*

Received: 10 April 2024; Accepted: 06 September 2024

ABSTRACT

The experiment was conducted during summer and rainy (*kharif*) seasons of 2021 and 2022 at Agricultural Research Station (Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu), Bhavanisagar, Tamil Nadu to evaluate the efficiency, economics and energetics of drone-based herbicide spray (fluid) application in transplanted rice (*Oryza sativa* L.). During the experiment the application of pre-emergence and post-emergence herbicides was done using drone and knapsack sprayer to assess the weed control efficiency (WCE). Treatments included 3 herbicide combinations, viz. pyrazosulfuron ethyl as pre-emergence (PE); pyrazosulfuron ethyl as pre-emergence (PE) *fb* bispyribac sodium as PoE; and pyrazosulfuron ethyl as PE *fb* metsulfuron methyl + chlorimuron ethyl as PoE; and 4 spray fluids applied using drone and knapsack sprayer (25, 37.5, 75 and 500 litre/ha). Weed free and unweeded check plot were used as reference for calculating WCE. Application of pyrazosulfuron ethyl *fb* bispyribac sodium using knapsack sprayer reduced weed density from 77.74–86.45% and weed dry weight from 89.60–91.40% over unweeded plot. Moreover, it was found on par with drone application of 37.5 litre/ha using herbicides during both the seasons. Interaction effect between herbicides and drone spray fluids was found to be non-significant. Pyrazosulfuron ethyl *fb* bispyribac sodium application through knapsack sprayer (500 litre/ha) and drone (37.5 litre/ha) produced higher grain yield and straw yield. Higher net return, benefit: cost ratio (2.49 and 2.40), energy-use efficiency (13.44 and 13.40 MJ) and energy productivity (0.414 and 0.416 kg/MJ) were noticed with drone application of pyrazosulfuron ethyl *fb* bispyribac sodium using 37.5 litre/ha spray fluid in both the seasons. From the experiment, drone application of pyrazosulfuron ethyl *fb* bispyribac sodium with spray volume of 37.5 litre/ha was found as an effective strategy to manage weeds in transplanted rice and more advantageous in terms of energy-use efficiency and profitability.

**Keywords**: Drone, Herbicide, Rice, UAV, Weed control efficiency

The availability of resources such as water, energy, labour, and capital significantly impacts crop production. With agricultural labour increasingly transitioning to non-agricultural sectors (Srivastava *et al*. 2020), the agricultural workforce has decreased by 30.7 million (12% reduction), leading to a 9.3% increase in labour wages (Vaishnavi and Manisankar 2022). Therefore, the development of drone technologies for pesticide application is crucial for efficiently managing scarce resources while achieving profitable energy, yield, and returns. Weeds pose significant biological challenges to maximizing rice (*Oryza sativa* L.) production potential. However, using a single herbicide is often insufficient to effectively manage the diverse range of weed species in transplanted rice. Therefore, it is crucial to employ a judicious and appropriate combination of herbicides to achieve better weed control. Further, utilizing highly efficient spraying equipment is crucial to enhance the efficacy of agrochemicals (Yang *et al*. 2018). There will be decreased value of net returns and B: C ratio without weed management practices as reported by Kumari *et al*. (2021). Although knapsack sprayers and spray guns are commonly used, they are inefficient as they require extensive labour and expose workers to more pesticides. Additionally, applying pesticides at high volumes with hand sprayer and knapsack sprayer results in reduced efficiency. There is a lack of research comparing backpack sprayers with UAVs (Unmanned aerial vehicles) for pest application (Garcera *et al*. 2011). Drones or UAVs apply pesticides with reduced spray volumes compared to conventional airborne

[1]Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu; [2]Centre for Water and Geospatial Studies (Tamil Nadu Agricultural University), Coimbatore, Tamil Nadu; [3]ICAR-Indian Institute of Pulses Research, Kanpur, Uttar Pradesh. *Corresponding author email: pazhanivelans@gmail.com

or ground-based spraying methods, and they operate at higher flight heights than ground-based treatments using manual knapsack sprayers (Fritz *et al*. 2006). Drones are well-suited for this task because they can fly at lower altitudes, hover effectively, and maintain precise control at various heights and flight velocities close to plant canopies (Xiao *et al*. 2020). Furthermore, conventional sprayers require significant time, energy, water, labour, and exertion for herbicide application. To mitigate the excessive use of resources, drones offer an alternative technology for herbicide application with limited resources. However, there has been limited research on the effectiveness of herbicides when applied via drones. Thus, the current study was carried out to assess the effectiveness of drone-based herbicide spray fluid application for weed control, and to compare the economics and energy implications of weed control using drones in transplanted rice.

## MATERIALS AND METHODS

The experiment was conducted during summer (December to May, 2021–22) and rainy (August to December, 2022) (*kharif*) seasons of 2021 and 2022 at Agricultural Research Station (Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu), Bhavanisagar ($11.4734^0$ N, $77.1389^0$ E), Tamil Nadu. The experiment was laid-out in a strip-plot design (SPD) with 3 replications. The main plot treatments consisted of 3 different herbicide combinations, viz. Pyrazosulfuron-ethyl @25 g/ha on 3 DAT (days after transplanting) (PE) ($H_1$); Pyrazosulfuron-ethyl @25 g/ha on 3 DAT (PE) *fb* Bispyribac-sodium @25 g/ha on 25 DAT (PoE) ($H_2$); and Pyrazosulfuron-ethyl @25 g/ha on 3 DAT (PE) *fb* Metsulfuron methyl + Chlorimuron ethyl @4 g/ha on 25 DAT (PoE) ($H_3$) and sub-plot included 4 spray fluids applied using drone, viz. Drone spray volume of 25 L/ha ($D_1$); Drone spray spray volume of 37.5 L/ha ($D_2$); Drone spray spray volume of 75 L/ha ($D_3$); and Manual knapsack spray volume of 500 L/ha ($D_4$). Further, two treatments (unweeded check and weed free) were taken for reference for calculating WCE. The pre-emergence pyrazosulfuron-ethyl was applied at 3 DAT and post-emergence herbicides such as bispyribac-sodium and metsulfuron methyl + chlorimuron ethyl at 25 DAT. Flat fan nozzle was used in both sprayer.

Flight height, flight speed and effective spray width of drone application for 25 g/ha and 37.5 L/ha were 2 m, 4 m/s and 4 m, respectively and 1 m, 3 m/s and 3.5 m, respectively. The drone was flown twice with same operational parameters of 37.5 L/ha spray fluid to achieve spray volume of 75 L/ha. The knapsack sprayer's operational parameters included speeds of 0.34 to 0.41 m/s for pre-emergence and 0.26 to 0.37 m/s for post-emergence herbicides, with a 2 m effective spray width. Heights varied from 0.42 to 0.50 m for pre-emergence and 0.44 to 0.56 m for post-emergence herbicides. The cultivated land was annual rice-rice rotation. The soil in the field was sandy clay loam with a neutral reaction. The test material was rice variety ASD-16. During the application of herbicide, plant spacing and planting density were 25 cm × 25 cm and 1,60,000 plants/ha, respectively. The recommended dose of fertilizer i.e. 150:50:50 kg/ha of N: $P_2O_5$: $K_2O$ was adopted. The weed density and weed dry weight were observed at 60 DAT. Weed density was recorded in 4 quadrants (0.5 m × 0.5 m) placed randomly in each plot. Weed control efficiency (WCE) was calculated as (Mani *et al*. 1973):

$$\text{WCE (\%)} = \frac{\text{Weed dryweight in control plot- Weed dryweight in treated plot}}{\text{Weed dryweight in control plot}} \times 100$$

Yield parameters (grain and straw) were measured per hectare at 14% moisture content. Economic indices such as gross return, net return, and benefit-cost ratio (BCR) were calculated based on input and output prices. Energy values for input and output were determined using published conversion coefficients (Devasenapathy *et al*. 2009). Energy output from produce was calculated by multiplying quantity of production by its energy equivalent. Energy efficiency was calculated as output energy divided by input energy. Energy productivity was determined as the ratio between yield and energy. Net energy was calculated as the difference between output and input energy.

*Statistical analysis*: The data from two seasons were statistically analyzed following the guidelines of Gomez and Gomez (1984). Statistical significance was determined using an F-test with a critical difference (CD) of 0.05 probability level. Weed density and weed dry weight data underwent square root transformation $\sqrt{X+0.5}$ before analysis. Linear regression analysis was employed using IBM SPSS Statistics software version 26.0 to assess the relationship between grain yield and weed dry weight.

## RESULTS AND DISCUSSION

*Weed flora of experimental field*: The predominant weed flora observed during summer was *Cynodon dactylon*, *Echinochloa colonum* and *Leptochloa chinensis* in grasses, *Cyperus difformis* and *Cyperus iria* in sedges and *Sphenoclea zeylanica, Bergia capensis, Marsilea quadrifolia* and *Monochoria vaginalis* among broad-leaf weeds. Further, weed flora found during *kharif* was *Echinochloa crusgalli*, *Echinochloa colonum* and *Leptochloa chinensis* in grasses, *Cyperus difformis* and *Cyperus iria* in sedges and *Bergia capensis, Marsilea quadrifolia* and *Monochoria vaginalis* among broad-leaf weeds.

*Weed density, weed dry matter and weed control efficiency*: The relative density of the experimental site was dominated by grasses (59.63%) followed by broad-leaf weeds (23.85%) and sedges (16.51%) during summer season. Meanwhile, *kharif* season was dominated by grasses (48.23%) followed by broad-leaf weeds (25.89%) and sedges (25.81%).

Pre-emergence and post-emergence herbicides application using drone and knapsack sprayer showed a good effect on the total weed density, weed dryweight and WCE during both the seasons (Table 1). The highest total weed density (72.67 and 57.33 weeds/$m^2$ during summer and *kharif*, respectively) and weed dry weight (118.82 and 174.53 g/m$^2$ during summer and *kharif*, respectively) were recorded in unweeded check. All herbicide treatments significantly reduced the total weed density and weed dry weight compared with unweeded control. Among herbicide combination, the lowest total weed density was recorded with application of pre-emergence pyrazosulfuron ethyl followed by post-emergence bispyribac sodium using both drone spraying of 37.5 litre/ha and knapsack spraying of 500 litre/ha, with no significant interaction between them. Priya *et al*. (2022) revealed that weed management practice involving the application of pyrazosulfuron ethyl followed by bispyribac sodium was found to be effective in controlling weeds in transplanted rice fields. Among different spray fluids, the lowest total weed density (9.78 and 12.56 weeds/m$^2$ during summer and *kharif*, respectively), weed dry weight (12.37 and 14.90 g/m$^2$ during summer and *kharif*, respectively) and highest weed control efficiency were recorded with application of herbicides with spray fluid of 500 litre/ha using knapsack sprayer and it was on par with drone application of 37.5 litre/ha in both the seasons. In both seasons, higher weed density, weed dry weight and reduced weed control was recorded significantly under spray fluid of 75 litre/ha. Further, greater weed control might be due to better spray uniformity, higher droplet density, deposition and penetrability obtained under the drone application of 37.5 litre/ha, which resulted in greater control of weeds and obtaining higher WCE (Wang *et al*. 2019). No significant difference was found between applying 37.5 litre/ha of spray fluid using a drone and 500 litre/ha using a knapsack sprayer across all herbicide combinations, indicating that reducing carrier volume did not affect herbicide efficacy. The similar control efficacy of the drone was attributed to increased droplet deposition on the underside of weed foliage compared to conventional sprayers (Martin *et al*. 2020). Chen *et al*. (2019) reported that herbicide mixtures (isoproturon + clodinafop-propargyl + mesosulfuron) applied via drone on wheat demonstrated comparable WCE to conventional knapsack sprayers.

The different herbicide spray fluids had significant influence on grain yield and straw yield (Fig. 1). Rice grain yield recorded in all herbicide spray fluids applied using drone and knapsack sprayer ranged from 4508–6532 and 4411–6405 kg/ha, while unweeded plot yielded 1657 and 1456 kg/ha during summer and *kharif*, respectively. The highest grain yield (6532 kg/ha and 6405 kg/ha during summer and *kharif*, respectively) was recorded in the plots treated with pre-emergence pyrazosulfuron ethyl followed by post-emergence bispyribac sodium using knapsack sprayer with 500 litre/ha and it was on par with pre-emergence pyrazosulfuron ethyl followed by post-emergence bispyribac sodium using 37.5 litre/ha application of drone spray fluid. Grain yield obtained from pre-emergence pyrazosulfuron ethyl followed by post-emergence metsulfuron methyl + chlorimuron ethyl was found to be lower compared drone and knapsack application of bispyribac sodium in both the seasons. Swain *et al*. (2023) revealed that post-emergence application of bis-pyribac sodium @25 g/ha was found to

Table 1 Effect of herbicides and drone spray fluids on weed control in rice

| Treatment | Weed density (Weeds/m$^2$) | | Weed dry matter (g/m$^2$) | | Weed control efficiency (%) | |
|---|---|---|---|---|---|---|
| | Summer | *Kharif* | Summer | *Kharif* | Summer | *Kharif* |
| Herbicides (H) | | | | | | |
| $H_1$, PE pyrazosulfuron-ethyl | 5.15 (26.42) | 5.46 (29.75) | 5.65 (31.96) | 6.18 (38.39) | 73.10 | 78.00 |
| $H_2$, PE pyrazosulfuron-ethyl *fb* PoE bispyribac sodium | 2.68 (6.92) | 3.16 (9.67) | 2.99 (8.52) | 3.26 (10.22) | 92.83 | 94.15 |
| $H_3$, PE pyrazosulfuron ethyl *fb* PoE metsulfuron methyl + chlorimuron ethyl | 3.03 (9.25) | 3.56 (12.33) | 3.18 (9.76) | 3.48 (11.76) | 91.79 | 93.26 |
| SEd | 0.19 | 0.11 | 0.13 | 0.25 | | |
| CD (*P*=0.05) | 0.52 | 0.29 | 0.37 | 0.68 | | |
| Drone spray fluids (D) | | | | | | |
| $D_1$, Drone spray-25 litre/ha | 3.93 (16.00) | 4.28 (18.67) | 4.26 (19.21) | 4.60 (23.12) | 83.84 | 86.75 |
| $D_2$, Drone spray-37.5 litre/ha | 3.27 (11.33) | 3.71 (14.22) | 3.59 (13.62) | 3.91 (16.36) | 88.53 | 90.63 |
| $D_3$, Drone spray-75 litre/ha | 4.31 (19.67) | 4.75 (23.56) | 4.47 (21.79) | 4.88 (26.12) | 81.66 | 85.03 |
| $D_4$, Manual spray-500 litre/ha | 3.04 (9.78) | 3.62 (12.56) | 3.45 (12.37) | 3.78 (14.90) | 89.59 | 91.46 |
| SEd | 0.13 | 0.18 | 0.17 | 0.29 | | |
| CD (*P*=0.05) | 0.34 | 0.43 | 0.41 | 0.71 | | |
| H × D (SEd) | $0.20^{NS}$ | $0.23^{NS}$ | $0.26^{NS}$ | $0.50^{NS}$ | | |
| Unweeded check | 8.55 (72.67) | 7.60 (57.33) | 10.92 (118.82) | 13.23 (174.53) | | |
| Weed free | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | 0.71 (0.00) | | |

Data in the parenthesis are original value, which was transformed into $\sqrt{X+0.5}$ before analysis. NS, Non-significant.

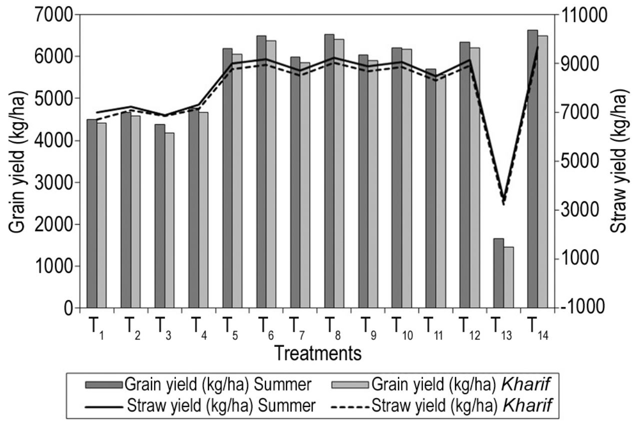


Fig. 1 Effect of herbicide spray fluids applied using drones on grain and straw yield of rice.
Treatment details are given under Materials and Methods.

be the most effective in suppressing weeds and increasing yield when compared to post-emergence application of metsulfuron methyl + chlorimuron ethyl, hand weeding and weed check treatment. Similarly, employing herbicides in a sequential manner led to superior straw yield compared to alternative treatments across both application methods. The highest straw yield (9238 and 9027 kg/ha during summer and *kharif*, respectively) was recorded in the plots treated with pyrazosulfuron ethyl followed by bispyribac sodium using knapsack sprayer with 500 litre/ha and it was on par with pyrazosulfuron ethyl followed by bispyribac sodium using 37.5 litre/ha application of drone spray fluid. These results were corroborated with the findings of Mahajan and Chauhan (2015).

*Correlations between weed dry weight and grain yield*: In both the seasons, a significant negative linear correlation was observed between weed dry weight and grain yield. These results are in accordance with the findings of Ansari *et al*. (2017), indicating a strong relationship between weed dry weight and grain yield compared to weed density (Fig. 2). The relationship represented that, rice grain yield was reduced more than 30% if the weed dry matter was more than 100 g/m$^2$ during both the seasons. Sequential application of pyrazosulfuron *fb* bispyribac sodium through knapsack sprayer and drone resulted in better weed control and grain yield than other treatments. The weed dry weight was more than 118 g/m$^2$, and grain yield was reduced to 74–77% in unweeded plot. The findings indicate that weeds posed high competition to rice crops for the resources and resulted in poor yield in unweeded plot. The results are in accordance with Kumar *et al*. (2018), who reported that weed-related yield reduction exceeds 56% in weedy plots in rice crop.

*Economics*: The highest additional cost for weed control was recorded in weed-free plot (₹26100/ha for summer and ₹27000/ha for *kharif*) and lowest with drone spray fluid application of pyrazosulfuron ethyl (₹1256/ha for summer and ₹2156/ha for *kharif*) (Table 2). The cost varied for the different herbicide application from 1256–4786 ₹/ha

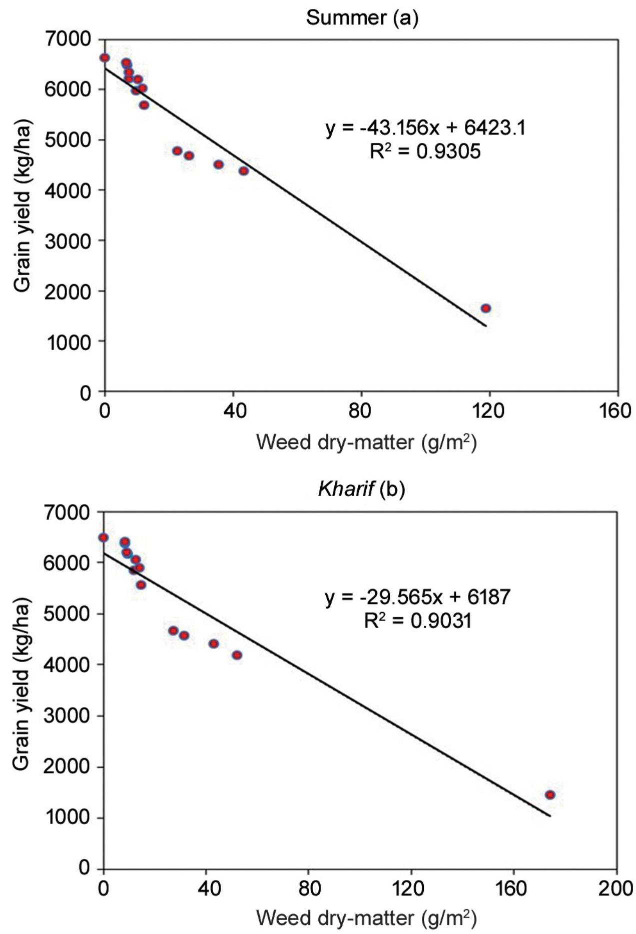


Fig. 2 Correlation studies between weed dry-matter and grain yield in rice.

for drone spray fluid application and 1406–5086 ₹/ha for knapsack sprayer. The result observed that the application cost was comparatively more for knapsack (>6%) than drone application. It was attributed to increased labour cost for herbicide application. According to Garre and Harish (2018), the utilization of drones for pesticide application has the potential to lower production costs by as much as 20%. Application of PE pyrazosulfuron ethyl followed by PoE bispyribac sodium with the spray fluid of 37.5 litre/ha resulted in the highest net return of ₹79,325/ha and ₹75,947/ha during the summer and *kharif* seasons, respectively. Additionally, the benefit-cost ratio (BCR) was 2.49 and 2.40 during the summer and *kharif* seasons, respectively (Patel *et al*. 2018). The lowest BCR and net return were observed in unweeded check because of poor grain and straw yield.

*Energy analysis*: Various weed management treatments exhibited significant differences in energy balance indices (Table 3). The highest input energy for different herbicide spray fluids applied using drone and knapsack sprayer ranged from 5,624–9,763 MJ/ha for drone application and 6,454–10,168 MJ/ha for knapsack sprayer application in summer and *kharif* seasons. Notably, knapsack sprayer application required comparatively more input energy than drone application. The drone application of PE pyrazosulfuron

Table 2 Effect of herbicide spray fluids applied using drones on economics of rice

| Treatment | Additional cost (₹/ha) | | Gross returns (₹/ha) | | Net returns (₹/ha) | | Benefit cost ratio | |
|---|---|---|---|---|---|---|---|---|
| | Summer | *Kharif* | Summer | *Kharif* | Summer | *Kharif* | Summer | *Kharif* |
| $H_1D_1$ | 1256 | 2156 | 91977 | 89997 | 41371 | 38491 | 1.82 | 1.75 |
| $H_1D_2$ | 1256 | 2156 | 95442 | 93387 | 44836 | 41881 | 1.89 | 1.81 |
| $H_1D_3$ | 1256 | 2156 | 89374 | 85415 | 38768 | 33909 | 1.76 | 1.66 |
| $H_1D_4$ | 1406 | 2306 | 97453 | 95356 | 46697 | 43700 | 1.92 | 1.85 |
| $H_2D_1$ | 3886 | 4786 | 126412 | 123568 | 73176 | 69432 | 2.38 | 2.28 |
| $H_2D_2$ | 3886 | 4786 | 132561 | 130083 | 79325 | 75947 | 2.49 | 2.40 |
| $H_2D_3$ | 3886 | 4786 | 122007 | 119264 | 68771 | 65128 | 2.29 | 2.20 |
| $H_2D_4$ | 4186 | 5086 | 133271 | 130663 | 79735 | 76227 | 2.48 | 2.40 |
| $H_3D_1$ | 2506 | 3406 | 123066 | 120347 | 71210 | 67591 | 2.37 | 2.28 |
| $H_3D_2$ | 2506 | 3406 | 126746 | 125927 | 74890 | 73171 | 2.44 | 2.39 |
| $H_3D_3$ | 2506 | 3406 | 116158 | 113513 | 64302 | 60757 | 2.24 | 2.15 |
| $H_3D_4$ | 2806 | 3706 | 129404 | 126611 | 77248 | 73555 | 2.48 | 2.38 |
| Unweeded check | 0 | 0 | 33803 | 29702 | -15547 | -19648 | 0.68 | 0.60 |
| Weed free | 26100 | 27000 | 135230 | 132583 | 59780 | 56233 | 1.79 | 1.74 |

Fixed cost for summer and *kharif* ₹49350. Treatment details are given under Materials and Methods.

followed by PoE bispyribac sodium using spray fluid of 37.5 litre/ha recorded the highest output energy (2,10,066 MJ/ha and 2,05,632 MJ/ha), energy use efficiency (13.44 and 13.42), and energy productivity (0.414 and 0.416 kg/MJ) during the summer and *kharif* seasons, respectively. Lowest output energy, energy productivity, energy use efficiency and energy productivity was observed in PE pyrazosulfuron ethyl application of 75 litre/ha using drone. Energy savings of 6.04% in summer and 8.89% in *kharif* were recorded by the application of PE pyrazosulfuron followed by PoE bispyribac sodium using spray fluid of 37.5 litre/ha over PE pyrazosulfuron ethyl application of 75 litre/ha using drone. This was attributed to the effective reduction of excess energy inputs such as water, electricity, and labour for weed control through drones compared to knapsack sprayers.

The study showed that using drones for applying pre-emergence pyrazosulfuron followed by post-emergence

Table 3 Effect of herbicide application using drone on energy analysis of rice

| Treatment | Output energy (MJ/ha) | | Additional input energy (MJ/ha) | | Energy productivity (kg/MJ) | | Energy use efficiency (MJ) | |
|---|---|---|---|---|---|---|---|---|
| | Summer | *Kharif* | Summer | *Kharif* | Summer | *Kharif* | Summer | *Kharif* |
| $H_1D_1$ | 153834 | 148916 | 5876 | 5856 | 0.392 | 0.396 | 13.36 | 13.37 |
| $H_1D_2$ | 159395 | 155876 | 6291 | 6383 | 0.392 | 0.392 | 13.36 | 13.36 |
| $H_1D_3$ | 150399 | 147137 | 5624 | 5753 | 0.389 | 0.379 | 13.35 | 13.34 |
| $H_1D_4$ | 161642 | 158075 | 6454 | 6542 | 0.395 | 0.395 | 13.37 | 13.37 |
| $H_2D_1$ | 203523 | 198892 | 9554 | 9564 | 0.408 | 0.408 | 13.40 | 13.40 |
| $H_2D_2$ | 210066 | 205632 | 9998 | 10047 | 0.414 | 0.416 | 13.44 | 13.42 |
| $H_2D_3$ | 196940 | 192460 | 9066 | 9087 | 0.407 | 0.407 | 13.39 | 13.39 |
| $H_2D_4$ | 212010 | 206992 | 10168 | 10165 | 0.415 | 0.415 | 13.41 | 13.40 |
| $H_3D_1$ | 199645 | 195127 | 9396 | 9415 | 0.401 | 0.401 | 13.28 | 13.28 |
| $H_3D_2$ | 204520 | 201320 | 9752 | 9763 | 0.404 | 0.410 | 13.29 | 13.38 |
| $H_3D_3$ | 189908 | 185553 | 8674 | 8709 | 0.398 | 0.398 | 13.27 | 13.26 |
| $H_3D_4$ | 207512 | 202864 | 9981 | 9987 | 0.406 | 0.406 | 13.29 | 13.29 |
| Unweeded check | 66201 | 60746 | 0 | 0 | 0.294 | 0.276 | 11.74 | 11.50 |
| Weed free | 218415 | 214028 | 10669 | 10697 | 0.407 | 0.407 | 13.39 | 13.40 |

MJ, Mega joule; Common input energy for summer = 5637 MJ/ha and *kharif* = 5281 MJ/ha. Treatment details are given under Materials and Methods.

bispyribac sodium significantly reduced weed density and weed dry weight and higher WCE, while achieving the highest grain and straw yield in transplanted rice. Moreover, drone application resulted in higher net return, benefit-cost ratio, output energy, energy use efficiency, and energy productivity compared to knapsack sprayer application. Therefore, it is recommended to apply pyrazosulfuron-ethyl @25 g/ha on 3 DAT as pre-emergence *fb* bispyribac-sodium @25 g/ha on 25 DAT as post-emergence using drones with a spray fluid volume of 37.5 litre/ha for increased productivity and more remunerative energy, and income in transplanted rice cultivation.

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