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RESEARCH ARTICLE

Harnessing the full potential of low-dose high-potency (LDHP) herbicide molecules by standardized spraying technique in rice and wheat

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ABSTRACT

Efficient and effective methods of weed control are needed to ensure higher crop productivity and profitability. Herbicides use is becoming popular amongst farmers because of ease, efficiency and lesser cost involved. The efficacy of herbicide depends on the proper spraying technique. Recently, the new generation effective low-dose high-potency (LDHP) herbicide molecules are being introduced but their compatibility to the existing spraying techniques and practices is unknown. Hence, it is necessary to standardize existing spraying technique for LDHP molecules. Thus, to standardize the existing spraying technique with two LDHP molecules (bispyribac-Na and clodinafop + metsulfuron), a field experiment was conducted for two years (2016-18) in rice during *Kharif* season and wheat *Rabi* season. The post-emergence (PoE) application of LDHP molecules, *viz.* bispyribac-Na at 25 g/ha in rice and clodinafop + metsulfuron at 60 + 4 g/ha in wheat were tested with flat fan (FF) and floodjet (FJ) nozzles using spraying volume of 250 and 500 l/ha. The weed control efficiency (WCE) obtained with different spray volume and nozzles usage was on par. The maximum WCE of 76% in rice and 89% in wheat was observed. A spray volume of 250 l/ha with either FF or FJ nozzle effectively controls the weeds and increases the field capacity by 60-100%.

Keywords: Bispyribac-Na, Clodinafop + metsulfuron, Low-dose high-potency (LDHP), LDHP herbicide, Rice, Spraying technique, Weed control efficiency, Wheat

INTRODUCTION

Weed control is one of the costliest and laborious practice in crop production (Rao and Nagamani 2010, Chethan and Krishnan 2017, Chethan *et al.* 2018a, Gharde *et al.* 2018, Singh *et al.* 2018). Chemical method of weed control in agriculture has become more popular because of its ease, efficient and effectiveness in controlling the weeds (Rao and Chauhan 2015, Chethan *et al.* 2019). Efficient and effective methods of weed control are the need of the hour as they invariably ensure higher crop productivity (Tewari and Chethan 2018, Kumar 2019). The usage of higher doses of the herbicides *i.e.* more than 1.0 kg/ha was a more common practice in chemical weed control during earlier days. Currently new generation low-dose-high-potency (LDHP) herbicide molecules are being introduced as they are effective and efficient in managing weeds control (Chethan *et al.* 2019) compared to higher dose molecules. In order to harness full potential of these molecules, their application must be accurate and uniform.

The selection of the pesticide spray application technique should be proper for the pesticide to be effective (Zhu *et al.* 2004). Spray nozzle used decides the spray quality, amount of spray applied per unit area, spray uniformity, spray coverage, amount of drift occurrences, application and pesticide efficacy (Grisso *et al.* 2013, Slocombe and Sharda 2015, Chethan *et al.* 2018b). A reliable uniform spray can be obtained in conventional flat fan (FF) nozzles at operating pressure of 140-420 kPa, but spray drift (Giles *et al.* 2002, Piggott and Matthews 1999) and requirement of proper spray overlap is a major problem. Thus, it is not recommended to use in single nozzle sprayers instead, even flat fan nozzles are recommended for the purposes as it produces uniform distribution of spray particles throughout spray pattern and spraying operation completed within a single pass. The flood nozzles are popular to apply the pesticides and fertilizers where clogging is a problem and it requires a hundred percent overlap and also special care has to be taken for nozzle orientation (Grisso *et al.* 2013, Slocombe and Sharda 2015, Chethan *et al.* 2018b). A perfect nozzle-pressure combination with proper amount of spray volume influences the spraying efficiency and

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herbicide efficacy (Smith *et al.* 2000). Using a spray volume of 400 to 500 liters per hectare for herbicide application is common practice followed in India. However, after introduction of LDHP herbicide molecules, no study as such was conducted with respect to standardizing the spraying techniques, spraying volume and nozzle types. Further, the suitability of existing spraying techniques to LDHP herbicide molecules is unknown. Thus, the trend of shifting the herbicide use from higher doses to LDHP molecules necessitates standardization of existing spraying technique. Hence, an experiment was carried out at Jabalpur to assess the suitability of popularly used knapsack sprayer for spraying LDHP herbicide molecules.

MATERIALS AND METHODS

A field experiment was conducted for two years during *Kharif* (rainy) and *Rabi* (winter) seasons of 2016-17 and 2017-18 in rice and wheat at ICAR - Directorate of Weed Research, Jabalpur (23°13’47.0"N 79°58’11.7"E). Soil properties of the study site had low organic carbon with clay loam texture and also had soil bulk density of ~1.3 g cm^{-2} with pH of 7.6. The study site was humid subtropical and had 1386 mm of annual rainfall and 1502 mm of evaporation.

The recommended LDHP molecules, *viz.* bispyribac-Na at 25 g/ha and clodinafop + metsulfuron at 60+4 g/ha was selected for rice and wheat, respectively as post-emergence (PoE) herbicides along with different nozzle types and spray volumes to standardize the spraying technique. Two nozzle types were studied, *viz.* even flat fan (FF) and floodjet (FJ) nozzles, which are recommended for the herbicide application (Anon 2015. Slocombe and Sharda 2015) along with two spray volumes of 250 and 500 l/ha. The experiment was conducted in split-split plot design and replicated thrice. The statistical analysis (ANOVA) of data was done using ICAR-IASRI, New Delhi online statistical portal (http://stat.iasri.res.in/SASLogon/index.jsp?_sasapp=Information+Delivery+Portal+4.3&). The main treatment includes the weed management practices, *viz.* PoE followed by (*fb)* one hand weeding (HW), PoE alone and weedy. The sub treatment includes nozzle type and sub-sub treatment includes the spray volume. A solar powered knapsack sprayer was used to maintain the uniform operating pressure during entire operation period. The detailed information of the selected nozzles for the study is given in **Table 1**.

The standardized spraying technique was compared with the conventional spraying method to obtain the operational difference. The different equations and parameters used for the comparison are given below and in **Table 2**.

Table 1. The characteristics of two nozzles studied in this experiment

Parameter	Nozzle type	
	Even flat fan	FloodJet
Cone angle, degrees	80^0	110^0
Discharge rate, liters per minute (lpm)	1.2	0.8
Spray releasing height, cm	50	50
Operating pressure, kPa	300	70
Droplet size, (v,0.5*) µm	236-340^{ad}	341-403^{ad}
Color code	Yellow^{bc}	Blue^{bc}
ASABE classification	Medium^{c}	Coarse^{c}
Body material	Brass	Brass

*Note: v,0.5: volume mean diameter (VMD)
(Source: Chethan *et al.* 2018b; BCPC; ASABE Standard S572.1; Department of Agriculture and Food, Govt. of Western Australia)

Table 2. Operational parameters of the spraying techniques

Parameter		Quantity
Sprayer used		Solar knapsack sprayer
Sprayer tank capacity, liters		16.0
Nozzle discharge rate, lpm	Flat fan	1.2
	FloodJet	0.8
Time required to spray 16 liters, minutes	Flat fan	13.3
	FloodJet	20
Time required from filling the tank to start the spray, minutes		7-10
Nozzle holding height above the ground level, meters		0.5

The spray operation was performed at morning hours (between 9-11 A.M.) to get the optimum spraying condition. The weather parameters *viz.* temperature, relative humidity (RH) and wind speed were not varied much during the respective seasons of both the years. A special care has taken to maintain the same operational parameters during respective seasons, as these parameters may affect the efficacy of herbicides, spray uniformity, drift potential, evaporation, degradation of the chemicals *etc.*

The effective field capacity (EFC) was calculated by using a following equation (Sarkar *et al.* 2016).

$$EFC = \frac{W \times S}{10} \times FE \qquad (1)$$

Where, W is the spray swath width in meter, S is the operator walking speed in kilometer per hour and FE is the field efficiency in percentage and it is considered 90% based on the previous studies for maximum output.

The weed control efficiency (WCE) was calculated by using the following equation (ISA 2009).

$$WCE = \frac{w_1 - w_2}{w_2} \times 100 \qquad (2)$$

Where, w_1 and w_2 are weed density in control and herbicide-treated plots, respectively.

The rice (cv. *Arize 6444 gold*) was dry-seeded at 25 kg/ha through Kamboj 11 tyne happy seeder under residue condition during last week of June and harvested in last week of October. In, wheat (cv. *GW-273*) was direct drilled at 100 kg/ha under residue condition during mid November and harvested during the first week of March. The recommended dose of fertilizers was maintained in both the crops and selected herbicides were applied as per the recommendations.

Bispyribac-Na in rice and clodinafop + metsulfuron in wheat were applied with proper precautions. The weed parameters such as weed density and weed dry biomass were recorded at 60 DAS by placing a quadrat having an area of 0.25 m^2 randomly at three different places within a plot. The year effect on the weed control was not significant, thus data's of different years were pooled.

RESULTS AND DISCUSSION

In rice, major weed flora observed were *Echinochloa crus-galli, Dinebra retroflexa, Alternanthera paronychioides*, *Physalis minima, Cyprus iria, Commelina benghalensis, Caesulia axillaris, Eclipta prostrata, Ludwigia prostrata* and others. However, it was observed a heavy infestation of *Echinochloa crus-galli* in both the years followed by *Alternanthera paronychioides* and others. In wheat, the major weed flora observed were *Medicago sativa, Chenopodium ficifolium, Avena fatua, Rumex dentatus, Chenopodium album, Sonchus Sp. Phalaris minor* and others. However, a heavy infestation of *Medicago sativa* mostly was observed in weedy plots. The recorded weed data in different years is given in the **Table 3** and **4**. The different weed management practices significantly affects the crop growth, weed control and grain yield. But the weed control efficiency was not significantly differed from nozzle types and spraying volumes (**Figure 1** and **2**). Treatments includes herbicide application *fb* one HW was more effective in controlling the weeds in both rice and wheat crops. Whereas in herbicide alone treatments, the scenario was totally different for both the crops. During *Kharif* season of 2016 and 2017 under rice the lowest weed density of 3.54 and 3.20 no./m^2, weed dry biomass of 3.83 and 3.73 g/m^2 and highest grain yield of 6.72 and 6.85 t/ha was recorded respectively in bispyribac-Na *fb* one HW (**Table 3**).

In *Rabi* (winter) season wheat, the lowest weed density of 2.36 no./m^2 and weed dry biomass of 2.11 g/m^2 was observed during 2016-17. The complete control of weeds was observed during 2017-18 with highest grain yield of 4.57 and 4.97 t/ha during 2016-17 and 2017-18 with clodinafop + metsulfuron *fb* one HW (**Table 4**). Similarly, the highest weed control efficiency was obtained in herbicide application followed by HW treatments for both the crops (**Figure 1** and **2**).

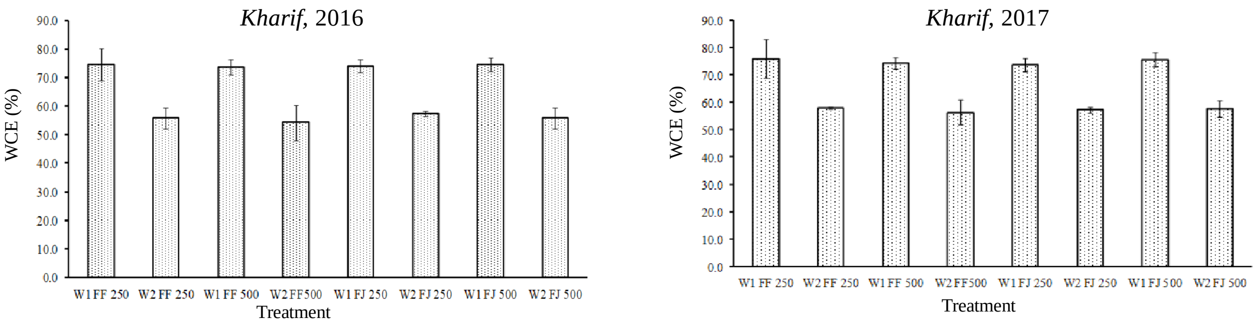
In *Kharif* (rainy) season weeds were suppressed initially after the application of herbicides [up to 15 days after application (DAA)]. However, during later period the regrowth of suppressed weeds started along with appearance of second flush of weeds due to seasonal favorability. Thus, the crop yield was slightly affected (**Table 3**) and weed control became problematic. Thus, the herbicide applied alone resulted in lesser crop yield and it can be managed by undertaking one hand weeding at 45-50 DAS. In *rabi* season the frequency and amount of weed appearance is very less, thus, an effective management of weeds and hundred percent weed control can be achieved by practicing herbicide application *fb* HW.

From the observed results it is evident that both the FF and FJ nozzle can be used at 250 and 500 l/ha of spraying volume per hectare to harness the full potential of bispyribac-Na and clodinafop +

Table 3. Weed density and biomass and grain yield of rice crop as influenced by different treatments during 2016 and 2017

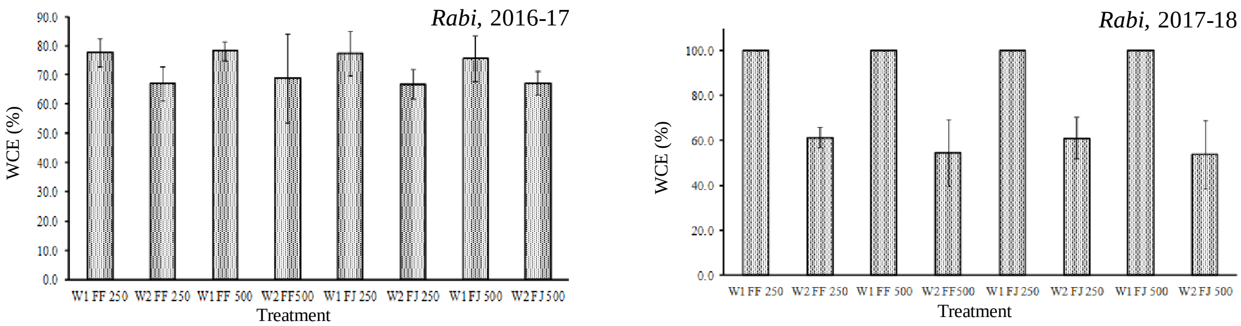
Treatment	Rice					
	Kharif, 2016			*Kharif*, 2017		
	Weed density (no./m^2)	Weed dry biomass (g/m^2)	Gain yield (t/ha)	Weed density (no./m^2)	Weed dry biomass (g/m^2)	Gain yield (t/ha)
Weed management						
Bispyribac (25 g/ha) + 1 HW	3.54^C	3.83^C	6.72^A	3.20^C	3.73^C	6.85^A
Bispyribac (25 g/ha)	5.73^B	6.58^B	6.06^B	5.58^B	6.38^B	6.08^B
Weedy check	7.63^A	14.98^C	4.81^C	7.74^A	15.00^A	4.85^C
LSD (p=0.05)	1.23	2.29	0.17	1.86	2.44	0.25
Nozzle type						
Flat fan	5.65	8.53	5.86	5.33	8.35	5.92
Floodjet	5.62	8.39	5.87	5.48	8.39	5.93
LSD (p=0.05)	NS	NS	NS	NS	NS	NS
Spraying volume (liter/ha)						
250	5.63	8.49	5.88	5.40	8.52	5.95
500	5.64	8.43	5.84	5.42	8.22	5.91
LSD (p=0.05)	NS	NS	NS	NS	NS	NS

*Weed data subjected to square root transformation



(W1 = Bispyribac (25 g/ha) + 1 HW; W2 = Bispyribac (25 g/ha); FF = Flat fan; FJ = Flood jet; 250 and 500 = Liters of water per ha)

Figure 1. Weed control efficiency (WCE) as influenced by different treatments in rice



(W1 = Clodinafop + metsulfuron (60+4 g/ha) + 1 HW; W2 = Clodinafop + metsulfuron (60+4 g/ha); FF = Flat fan; FJ = Flood jet; 250 and 500 = Liters of water per ha)

Figure 2. Weed control efficiency (WCE) as influenced by different treatments in wheat crop

Table 4. The weed density and biomass and grain yield of wheat crop as influenced by different treatments during 2016-17 and 2017-18

Treatment	Wheat					
	Rabi, 2016-17			*Rabi*, 2017-18		
	Weed density (no./m^2)	Weed dry biomass (g/m^2)	Gain yield (t/ha)	Weed density (no./m^2)	Weed dry biomass (g/m^2)	Gain yield (t/ha)
Weed management						
Clodinafop + metsulfuron (60+4 g/ha) + 1 HW	2.36^{B}	2.11^{B}	4.57^{A}	0^{C}	0^{C}	4.97^{A}
Clodinafop + metsulfuron (60+4 g/ha)	3.58^{B}	3.01^{B}	4.48^{A}	2.20^{B}	1.84^{B}	4.89^{A}
Weedy check	8.14^{A}	9.38^{A}	3.10^{B}	4.32^{A}	4.51^{A}	3.63^{B}
LSD (p=0.05)	1.98	1.57	0.67	0.22	1.43	0.23
Nozzle type						
Flat fan	4.59	4.83	4.14	2.18	2.08	4.56
Floodjet	4.80	4.83	3.96	2.17	2.15	4.42
LSD (p=0.05)	NS	NS	NS	NS	NS	NS
Spraying volume (liter/ha)						
250	4.77	4.74	3.98	2.21	2.10	4.48
500	4.62	4.93	4.12	2.14	2.13	4.50
LSD (p=0.05)	NS	NS	NS	NS	NS	NS

*Weed data subjected to square root transformation

metsulfuron (LDHP) molecules both in rice and wheat to manage weeds effectively. Even though, the rice and wheat yield with use of selected nozzle types and spraying volumes did not differ significantly results, but FF nozzle was slightly superior in terms of weed control and grain yield (**Table 3** and **4**). Further, the combination of either FF or FJ with spraying volume of 250 l/ha gave highest weed control efficiency of 76% in rice and 89% in wheat, which was either highest or equal to the results obtained in spraying volume of 500 l/ha during the year 2016 to 2018.

A comparison has been made with the existing spraying techniques with the standardized technique and given in Table 5. It has seen that, the existing spraying techniques obtained an actual field capacity of 0.07 to 0.09 ha/h with FF nozzle and 0.06 to 0.07 ha/h with FJ nozzle. The same results were also reported by Sharma and Mukesh (2013). Whereas, in standardized spraying techniques it has obtained an actual field capacity of 0.15 and 0.12 ha/h in FF and FJ nozzle respectively. This shows a decreased operational time and cost by 37.5 to 50% and an increased field capacity by 60 to 100%. Similarly, water required for spraying was also reduced from

Table 5. Comparison between conventional spraying and standardized spraying

Parameter	Flat fan nozzle		FloodJet nozzle	
	Conventional spraying	Standardized technique	Conventional spraying	Standardized technique
Spray volume used, l/ha	400 – 500	250	400–500	250
Number of tanks refill required per hectare, numbers	25–31.25 (approx. 32)	15.62 (approx. 16)	25–31.25 (approx. 32)	15.62 (approx. 16)
Time required for tank fill (approx. 10 minutes each time), minutes/ha	250 – 320	160	250–320	160
Time required to spay the solutions, minutes/ha	333.3–416.7	208.3	500.0–625.0	312.5
Total time includes filling spraying, minutes/ha	583.3–729.2 (9.7–12.2 hrs)	364.6 (6.1 hrs)	750.0–937.5 (12.5–15.6 hrs)	468.8 (7.8 hrs)
Field capacity, ha/hr	0.07–0.09	0.15	0.06–0.07	0.12
Operational cost per hectare based on the time required, `/ha	425–532	266	547–684	342
Percent increase in field capacity, %	-	60.0–100.0	-	60.0–100.0
Percent reduction in operational time and cost, %	-	37.5–50.0	-	37.5–50.0
Percent reduction in water required for spraying, %	-	37.5–50.0	-	37.5–50.0

37.5 to 50%. As the number of tank fills and operational time reduced in standardized spraying technique, which enhances the operator to work more efficiently by reducing the operational workload, human drudgery and physiological stress. The standardized spraying technique is also more useful and suitable to the places where water scarcity is a major problem and by adopting this technique an efficient weed control can be obtained. Therefore, presently using spraying volume of 500 l/ha can be shifted to standardized spraying technique *i.e.* 250 l/ha with either FF or FJ nozzle, for spraying LDHP herbicide molecules, without compromising in weed control, crop yield and quality (Chethan *et al.* 2018b).

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