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CHARACTERIZATION OF HERBICIDE USED AND FACTORS RESPONSIBLE FOR METSULFURON-METHYL RESISTANCE IN *RUMEX DENTATUS* IN WHEAT FIELD

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Abstract

Rumex dentatus, is commonly controlled using metsulfuron-methyl, a sulfonylurea herbicide, in wheat. However, lower efficacy of metsulfuron-methyl against *R. dentatus* was observed at some places in Haryana. Hence, a well-structured questionnaires-based survey was conducted in Haryana during rabi 2018-19 to understand the current-status and factors determining metsulfuron-methyl resistance against *R. dentatus*, among 120 farmers from three districts. The present study revealed a decrease in farmers' use of metsulfuron-methyl from 61.1 (2016-17) to 23.8% (2018-19), while metribuzin usage increased from 6.49 to 41.27%. The herbicide dose used by farmers increased from 0.99 to 1.16 times of X-dose from 2016-17 to 2018-19 to control *R. dentatus.* The highest percent-control of *R. dentatus* was recorded with 2,4-D (83-92%) and lowest for metsulfuron-methyl (69-72%). Over 90% farmers utilized 60-180 L water acre^{-1} while only 6.7% were used standard volume of water (200 L/acre) during spray. Only 19.2% farmers used standard flat-fan nozzle but the rest used flood jet/cut-nozzle. Most farmers (>80%) adopted delayed herbicide application while only 15.8% farmers applied herbicide at standard time (30-35 DAS). All these factors could be associated with reduced herbicide efficacy against *R. dentatus.* Over 50% of farmers used herbicides with similar modes of action, and 75% follow only rice-wheat crop rotation. Farmers' liking for herbicide was 2,4-D, metribuzin, clodinafop+metribuzin and last metsulfuron-methyl. The present-study revealed challenges in controlling *R. dentatus* in Haryana, particularly with metsulfuron-methyl. To avoid resistance development, it recommends reducing the usage of single-herbicides while advocating the rotational application of herbicides with proper spray techniques.

Introduction

Wheat *(Triticum aestivum* L.) is the world's most important cereal crop of several countries. In India, it is the second important staple food crop after rice (Anonymous 2023). Haryana is the major wheat growing state of India (Anonymous 2022). *Rumex dentatus* is one of the most dominating and problematic broadleaf weed of *rabi* season of irrigated wheat, mainly in the rice-wheat cropping system of north-western Indo Gangetic Plain regions of India. This weed placed in the shorter weed group having more leaf-area ratio, chlorophyll content, specific leaf-area, photosynthetic rate, leaf nitrogen mass and higher photosynthetic nitrogen use efficiency as compared to wheat crop (Singh *et al*. 2015). These characteristics of *R. dentatus* make it adapted for the shade condition under the crop like wheat crop canopy (Singh *et al*. 2015). It is more competitive in nature and has the potential to cause yield losses in wheat crop upto an extent of 55% (Singh 2016, Waheed *et al.* 2017).

Metsulfuron-methyl, a sulfonylurea herbicide has been recommended for its control for a longer period of time. However, wheat growers in Haryana have recently reported the poor efficacy of metsulfuron-methyl against *R. dentatus* (Chaudhary *et al.* 2021). Most of the studies conducted so far were focused on quantifying the dose required or manage this weed based on lab,

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pot, or field experiments. But identification of factors affecting the development of herbicide resistance was not covered systematically. Therefore, a questionnaires-based survey was conducted to know the current status of herbicide resistance in *R. dentatus* at farmers' field level. It was also conducted to evaluate the herbicides used along with the factors responsible for herbicide resistance in *R. dentatus* in wheat under rice-wheat cropping system.

Materials and Methods

A well-structured systematic survey study was conducted during January to April 2019 in Panipat, Karnal and Kurukshetra districts of Haryana. Two blocks were selected from each district and two villages from each block, and ten farmers from each village (Table 1). A total of 120 farmers from 12 villages were selected for this study. The total distance covered between villages was 138 km and the average distance between each other was 11.5 km.

Table 1. List of villages along with GPS location and key respondent covered under the survey.

Districts	Blocks	Villages	GPS Location	Key respondent
Panipat	Madlouda	Kalkha	29°20'02.7"N 76°50'24.9"E	Randhir Singh
		Adiyana	29°21'29.0"N 76°45'35.7"E	Ishwar Singh
	Israna	Ahar	29°18'01.8"N 76°44'45.6"E	Rajbir
		Jondhan Kalan	29°18'06.7"N 76°50'93.5"E	Rakesh
Karnal	Gharaunda	Gudha	29°29'91.1"N 76°56'87.5"E	Ratan Singh
		Bastara	29°34'00.1"N 76°59'13.9"E	Pawan Kumar
	Nilokheri	Dabarthala	29°50'59.8"N 76°50'78.8"E	Suresh Kumar
		Khawaja Ahmedpur	29°51'37.8"N 76°54'02.1"E	Pooran Singh
Kurukshetra	Ismailabad	Bhusthala	30°04'59.71"N 76°43'30.1"E	Satish
		Ajrana Kalan	30°05'96.76"N 76°47'08.5"E	Chanderbhaan
	Thaneser	Bhiwani Khera	29°59'50.7"N 76°49'25.0"E	Dharam Pal
		Udarsi Dhurwala	30°02'28.71"N 76°48'36.0"E	Pyara Singh

A questionnaire-based survey proforma was prepared. Along with the face-to-face interview of all the respondent farmers, field visits on the key respondent farmers' fields was also performed. The absolute amount of herbicide applied by the farmer in the wheat crop for one acre was asked and then converted into times of recommended dose of herbicide per hectare (X). Rating of herbicides by farmers was asked on a Likert scale 1-4 (Likert 1932). The statistical analysis was done through OPSTAT' software (http://14.139.232.166/ opstat/default.asp) of CCSHAU (Sheoran *et al*. 1998). For herbicide rating, Henery Garrett's rank technique was used (Garrett and Woodworth 1969). The order given by farmers was converted into per cent position as:

$$\text{Per cent position} = 100\ (Rij-0.5)/Nj$$

Where, Rij, Rank given for ith herbicide by the jth farmer; Nj, Number of herbicides ranked by the jth farmer.

The per cent position derived for each rank was converted into a score by referring to the table given by Garrett and Woodworth (1969). Then for each herbicide, the score of each individual

farmer was added and then total value and mean value of score was calculated. A higher mean value denotes the prime preference of a particular herbicide among the farmers.

Results and Discussion

Besides the general information of farmers cultural factors *viz*., sowing method, time of first irrigation (DAS), crop rotation, herbicide rotation and continuity of rice-wheat cropping system significantly affect the chances for the development of herbicide resistance in *R. dentatus* (Table 2).

Table 2. General information of respondent and related agronomic practices.

Farmer's general information				
Age	<20 years	20-45 years	45-60 years	>60 years
	0 (0.0%)	63 (52.5%)	45 (37.5%)	12 (10%)
Education level	Up to 12th standard	Graduation	Post-graduation	PhD
	89 (74.2%)	28(23.3%)	3(2.5%)	0(0.0%)
Source of infor.	Government agency	Pesticide dealers	Others (Fellow farmer)	
	31(25.8%)	117(97.5%)	112(93.3%)	
Is zero-till wheat helpful to control *R. dentatus*?			No, 11.4% (unable to identify)	
Ever heard about resistance (Yes)			119(99.9%)	
In which weed ever heard about resistance?			*P. minor*	*R. dentatus*	Others
			119(99.9%)	117(97.5%)	51(42.5%)
Agronomic practices adopted				
Sowing method	CT-drill	Zero tillage	Happy seeder	CT-rotavator
	8(6.7%)	11 (9.2%)	1 (0.8%)	115(95.8%)
1st irrigation	15-20 DAS	21-25 DAS	26-30 DAS	>30 DAS
	0 (0.0%)	52 (43.3%)	60 (50.0%)	10(8.3%)
Follow herbicides rotation (yes)			58(48.3%)	
After how many year rotate herbicides			2.04 year	
Follow diverse crop rotation (yes)			40(25.0%)	
Follow only rice-wheat rotation			80(75.0%)	

Majority of respondents were up to 12th standard (74.2%) followed by graduate (23.3%) and post graduate (2.5%). Around 52.5% of the respondent farmers were between 20-45 years age group, and 37.5% between 45-60 years and around 10% above 60 years. It was found that only 25.8% farmers gathered farming related information from different government agencies. But ultimately most of the farmers' (97.5%) final decision related to farm management were mainly influenced by the information provided by pesticide dealers. This is one of the key reasons that farmers do not follow standard agricultural practices which are recommended by the state agriculture department, govt. agencies or by the state agricultural university.

Wheat sowing by conventional tillage with rotavator (CT-rotavator) shared highest (95.8%) percentage and was more popular among farmers as the field was well prepared by rotavator in one run and crop was sown by broadcasting in place of line sowing. Only one farmer used happy seeder for wheat sowing, while drill sowing by conventional tillage (CT-drill) and zero tillage

(ZT-drill) shared 6.7 and 9.2%, respectively. Similarly, Tripathi *et al.* (2013) also reported that in spite of several economic and environmental advantages, there was less adoption of ZT technology because of limited availability of zero-till seed drill machine during sowing period. Around 11.4% of respondent farmers stated that zero-till wheat is not helpful to control *R. dentatus* but they were unable to identify the increase in *R. dentatus* was either due to resistance or due to ZT. Chhokar *et al.* (2017) also reported that there is was more buildup of *R. dentatus* in wheat under ZT situation.

Only 43.3% farmers applied first irrigation at around crown root initiation stage (21-25 DAS), 50% farmers applying it between 26-30 DAS and rest 8.3% farmers go for first irrigation at more than 30 DAS. The time of application of first irrigation, influences the farmers' decision to apply herbicides and if there was delay in first irrigation then it will ultimately interrupt the timely application of herbicides. With time span/advance stage, *R. dentatus* plants become sturdy and get harder enough to resist any herbicides. Application of first irrigation within first 24 DAS reduces the chances of development of herbicide resistance by 72% (Singh *et al.* 2021).

The results also revealed that almost all of the respondent farmers (99.9%) knew about herbicide resistance; despite that, only few farmers (48.3%) follow herbicide rotation, while others tend to use the same herbicide until up to the time it gave some favorable results. Some farmers rotate only the brand formulation or company, not the herbicides. Continuously using the herbicides with same group/brand/mode of action enhances the process of resistance development by imposing selection pressure (Qasem 2003, Beckie 2006). If farmers follow crop rotation, then there will be a lesser (90%) chance for the development of herbicide resistance (Singh *et al.* 2021) and it is considered as a critical factor for delaying or management of herbicide resistance (Gill and Holmes 1997). However, in this study only 25% farmers followed diverse crop rotation while 75% were continuously growing rice-wheat.

Now days, farmers are mainly using power sprayer to reduce the drudgery for herbicides application. It was found that 43.3% farmers used knapsack sprayer and 56.7% used power sprayer in surveyed districts (Table 3). Regarding the spray nozzle, only 19.2% of the respondent farmers used flat-fan nozzle while the rest used flood jet nozzle. Flat fan nozzle is generally recommended as most appropriate nozzle for herbicide spray as it generates a flat spray swath and thoroughly covers the entire weed in the swath limit (Qasem 2011). Despite that it was less adopted by farmers because it takes more time to spray than other nozzles. Beside this farmer's ignorance and their casual approach were also the contributing factors for its less adoption which is one of the main reason for the development of resistance in *R. dentatus*.

In case of water volume used for herbicides spray, around 88% farmers used water volume from 90-150 L $acre^{-1}$ while, only 6.7% used the standard recommended amount of water 200 L ac^{-1} (Table 3). Most of the farmers (93%) did not use standard water volume because of cost and time factors. Weeds exposed to under/overdose of herbicides, leads to the rapid development of herbicide resistance (Norsworthy *et al.* 2012). Further, some farmers also had false conception that concentrated spray provides better results while higher water volume dilutes the herbicides, resulting in lower efficacy. This might also be the reason for the accelerated development of herbicide resistance problem.

Maximum number of farmers (63.3%) go for herbicide application between 35-45 DAS while about 35.8% applied at 3-4 leaf stage (40-45 DAS) and only 15.8% farmers apply herbicides at recommended time of 30-35 DAS (Table 3). One of the prime reasons for delay in herbicide application was that most of the farmers (93.3%) go for first irrigation between 21-30 DAS of wheat crop (Table 2) and field takes time to attain the field capacity (vattar) condition. Even 2.5% of respondent farmers have applied herbicide at >50 DAS (>5 leaf stage) as these farmers had

done first spray of herbicide after first irrigation and failed to get satisfactory control of *R. dentatus*, so they were compelled to go for second spray. It was observed in present study that most of the farmers did not adopt the standard spray tools and techniques. As in the earlier study also it was observed that faulty spray tools and techniques were used by the farmers (Punia *et al*. 2013), which were responsible for poor herbicide efficacy and inappropriate coverage at farmers' fields (Qasem 2011) that ultimately leads to lower yield and productivity (Lathwal and Ahalawat 2011).

Table 3. **Information about spray tools, techniques along with time of spray of post emergence herbicides and *R. dentatus* growth stage.**

Spray tools	No. of farmers (%)	Water volume used for spray (liters/acre)	No. of farmers (%)	Time of spray (DAS)	*R. dentatus* growth stage	No. of farmers (%)
Sprayer		60	1(0.8)	20-25	~ 25-30% germination	0(0.0)
Knapsack	52 (43.3)	90	9 (7.5)	25-30	>50% germination (1-2 leaf stage)	14(11.7)
Power	68 (56.7)	120	41(34.2)	30-35	2-3 leaf stage	19(15.8)
Nozzle		150	55(45.8)	35-40	2-4 leaf stage	33(27.5)
Flood jet/ cut	97 (80.8)	180	6 (5.0)	40-45	3-4 leaf stage	43(35.8)
Hollow cone	0.0 (0.0)	200	8 (6.7)	45-50	4-5 leaf stage	11(9.2)
Flat fan	23 (19.2)	>200	0(0.0)	>50	>5 leaf stage	3*(2.5)

*Repeat spray cases.

Information about the herbicides used pattern at X-dose or more applied by the farmers against *R. dentatus* was recorded as reported by farmers during last 3 years *i.e* 2018-19, 2017-18 and 2016-17 (Table 4). In 2018-19, overall farmers applied 1.16 times of X-dose of total herbicides to control *R. dentatus* which was the highest in case of Kurukshetra district (1.24X) and the lowest in Karnal (1.10X). Further, farmers applied 1.17, 0.93, 1.43 and 1.00 times of X- dose in Panipat, 1.11, 0.97, 1.30 and 1.00 times of X- dose in Karnal and 1.11, 1.13, 1.46 and 1.25 times of X- dose in Kurukshetra district of metsulfuron-methyl, 2,4-D, metribuzin and clodinafop+ metribuzin, respectively. During 2017-18, on an average farmers applied 1.00 times of X-dose of total herbicides to control *R. dentatus* which was the highest in case of Panipat district (1.02X) and lowest in Karnal (0.97X). Further, farmers applied 1.10, 0.99, 1.00 and 1.00 times of X- dose in Panipat, 1.04, 0.92, 0.90 and 1.00 times of X- dose in Karnal and 1.00, 0.90, 1.13 and 1.00 times of X- dose in Kurukshetra district of metsulfuron-methyl, 2,4-D, metribuzin and clodinafop+ metribuzin, respectively. In 2016-17, overall farmers applied 0.99 times of X-dose of total herbicides to control *R. dentatus* which was the highest in case of Kurukshetra district (1.13 X) and the lowest in Karnal (0.84 X) (Table 4). During 2016-17, farmers applied 1.02, 0.98, 0.00 and 0.00 times of X- dose in Panipat, 1.00, 0.86, 0.50 and 1.00 times of X- dose in Karnal and 1.00, 0.89, 1.63 and 1.00 times of X- dose in Kurukshetra district of metsulfuron-methyl, 2,4-D, metribuzin and clodinafop+metribuzin, respectively. The dose of herbicides used by farmers increased from 0.99X to 1.16 times of X-dose from 2016-17 to 2018-19 to control *R. dentatus*. In Karnal it increased from 0.84 to 1.10 of X-dose, in Panipat from 1.00 to 1.13 of X-dose and in Kurukshetra from 1.13 to 1.24 of X-dose from 2016-17 to 2018-19.

From 2016-17 to 2018-19 the highest % control of *R. dentatus* was recorded under 2,4-D (83-92%) and lowest under metsulfuron-methyl (69-72%). Further, It was observed that the efficacy of metsulfuron-methyl in terms of per cent control was decreasing successively from 2016-17 (71.58%) to 2018-19 (68.69%) while the efficacy of clodinafop+metribuzin was improved from 2016-17 (67.5%) to 2018-19 (83.3%). Consequently, the per cent of farmers using metsulfuron-methyl was going down year by year (61.1% in 2016-17 to 23.8% in 2018-19) while the per cent of farmers using metribuzin was raised from 2016-17 (6.49%) to 2018-19 (41.27%).

Table 4. **Herbicide used against *Rumex dentatus* during 2016-17 to 2018-19.**

		Metsulfuron-methyl		2,4-D		Metribuzin		Clodinafop + Metribuzin		Mean of times of (X-dose)
Year	Districts	Times of X-dose	Control (%)	Times of X-dose	Control (%)	Times of X-dose	Control (%)	Times of X-dose	Control (%)	
2018-19	Panipat (58)	1.17	63.33	0.93	97.94	1.43	64.03	1.00	100	1.13
	Karnal (60)	1.11	74.84	0.97	84.00	1.30	75.71	1.00	80.00	1.10
	Kurukshetra (72)	1.11	67.89	1.13	67.96	1.46	67.40	1.25	70.00	1.24
Average		1.13	68.69	1.01	83.30	1.40	69.05	1.08	83.30	1.16
2017-18	Panipat (58)	1.10	58.25	0.99	94.05	1.00	70.00	1.00	90.00	1.02
	Karnal (60)	1.04	71.34	0.92	91.25	0.90	69.00	1.00	80.00	0.97
	Kurukshetra (72)	1.00	66.67	0.90	86.90	1.13	85.75	1.00	50.00	1.01
Average		1.05	65.42	0.94	90.73	1.01	74.91	1.00	73.30	1.00
2016-17	Panipat (58)	1.02	65.00	0.98	88.93	-	-	-	-	1.00
	Karnal (60)	1.00	75.16	0.86	96.25	0.50	90.00	1.00	85.00	0.84
	Kurukshetra (72)	1.00	74.60	0.89	91.11	1.63	80.00	1.00	50.00	1.13
Average		1.00	71. 58	0.91	92.09	1.07	85.00	1.00	67.50	0.99

Yadav *et al.* (2017) also observed in their bioassay studies that *R. dentatus* population from Panipat was not controlled effectively (30%) by metsulfuron-methyl even upto 4X dose of 16 g/ha, however, the efficacy of 2, 4-D and carfentrazone-ethyl was good even at X- doses. In the present study also, it was recorded that metsulfuron-methyl was not providing satisfactory control of *R. dentatus*, so it contributed only 23.8% of the total herbicide used during 2018-19. The poor efficacy of metsulfuron-methyl and effectiveness of 2,4-D against *R. dentatus* was also reported by Chhokar (2014), Singh (2016), Chhokar *et al.* (2017), Yadav *et al.* (2017) and Chhokar *et al.* (2018).

Farmers also observed that *R. dentatus* defying the action of metsulfuron-methyl since last 3 to 4 years. This may be the reason that percentage of farmers using metribuzin in Panipat district was suddenly increased from 2.3% in 2017-18 and 56.14% in 2018-19. Previous field survey (Lathwal and Ahlawat 2011, Punia *et al.* 2013) also indicated that over the years, *P. minor* had developed resistance against alternate herbicide and then by each year farmers were compelled to rise herbicide X-dose and number of spray for getting satisfactory control. Similar was in case of *R. dentatus* that even with increasing the dose and no. of spray of metsulfuron-methyl, farmers were not getting desirable control of *R. dentatus* so they shifted towards alternate herbicide like metribuzin or 2,4-D.

Farmers' preference for herbicide was 2,4-D, metribuzin, clodinafop+metribuzin and last metsulfuron-methyl with ratings 1.36, 1.45, 2.07 and 2.96, respectively.

It may be concluded that farmers are facing problem with the management of *R. dentatus* particularly by use of metsulfuron-methyl in Haryana. Cultural practices adopted by farmers made *R. dentatus* ecologically fit. Initially when *R. dentatus* exposed with faulty spray techniques exaggerated the chances of herbicide resistance development by imposing selection pressure. Moreover, random use of herbicides with similar mode of action by IGP farmers without knowing the importance of herbicide rotation further accelerated the problem. Therefore, continuous use of single herbicide may be discouraged while, the rotational use of herbicides may be advocated in order to avoid and delay the development of resistance in *R. dentatus* in India. Further, proper spray techniques, crop rotation including pulses, oil seed crops and cereals other than rice-wheat, timely sowing and irrigation, adopting proper crop residue management techniques should also be adopted. Large scale trainings and demonstrations on improved herbicide spraying tools and techniques is also required for farmers, service providers and pesticide dealers.

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