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Effect of various herbicide molecules on weed management in Indian mustard (*Brassica juncea* L. Czern & Coss)

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Abstract
A field experiment was conducted with ten treatments pendimethalin 1000 g ha^{-1}, oxadiargyl 90 g ha^{-1}, trifluralin 750 g ha^{-1}, oxyfluorfen 150 g ha^{-1}, quizalofop 60 g ha^{-1}, clodinafop 60 g ha^{-1}, isoproturon 1000 g ha^{-1} (PE), isoproturon 1000 g ha^{-1} (PoE), Weedy and Weed free Check at Faizabad (Uttar Pradesh.) during *rabi* season of the year 2011-12.The crop was infested with divergent type of weed flora e.g. *Phalaris minor* (21.35%) and *Cynodon dactylon* (7.78%) of grassy, *Chenopodium album* (17.58%), *Anagallis arvensis* (27.43%), *Melilotus alba*, *Vicia hirsuta*, *Lathyrus asphaca* and Rumex sp. (19.22%) of broad leaved and *Cyperus rotundus* (10.61%) of sedges group.Weed density of the different weed species and total weeds affected significantly due to different weed control treatments, oxadiargyl, pendimethalin, trifluralin and oxyfluorfen were found more effective in reducing the population of *Chenopodium album* and *Anagallis arvensis*. Similarly integration of quizalofop and clodinafop effectively taken care of *Phalaris minor*. Oxadiargyl, pendimethalin and trifluralin recorded significantly lower values of nitrogen uptake. Oxadiargyl, pendimethalin and trifluralin resulted in higher yield attributes (siliquae $plant^{-1}$, length of silique and seeds $siliqua^{-1}$) and seed yield of mustard.

Keywords: Herbicide, Mustard, Weed management, Yield.

Introduction
India is the fourth largest oilseed economy in the world. Among the seven edible oilseeds cultivated in India, rapeseed-mustard (*Brassica juncea L.*) ranks second after soybean and contributed 23.94 % and 24.65 % in total oilseed acreage and production, respectively, in India during 2014-15. For an estimated Indian population of about 1.32 billion, 21.12 million tonnes (mt) of edible oil will be require by the end of 12th five year plan in 2017 at an estimated per capita consumption of 16 Kg edible oil per person/day. This demand has to met by producing about 63.4 mt of total oilseeds, of which, about 20 per cent has to met by rapeseed-mustard equivalent to 12.7 mt. An all-out of effort is to be made to achieve this target for rapeseed-mustard production from the present level of 7.3 mt (DRMR, 2011) [6]. This target could be achieved through area expansion and or increase in productivity of rapeseed-mustard. Scope for area expansion is limited so production would be increased only though increase in productivity per unit land. The per hectare productivity of the crop is quite low in the country (1262 kg ha^{-1}) against the world average of about 1970 kg ha^{-1} in world (DRMR, 2015) [7]. The low productivity of mustard in the country might be the resultant of a number of factors *viz.*
Agronomic, edaphic, genetic and others. Among the agronomic factors, proper weed management may be a very serious issue (Singh 1992) [14]. Yield losses due to crop-weed competition in rapeseed-mustard have estimated to the tune of 10-58% (Bhan 1992, Banga and Yadav, 2001 [3, 2] and singh *et al*. 2001) [13] or even ranging from 20-70 % depending upon the type of weed flora, magnitude and duration of weed infestation (Tiwari and Kurchania 1993, Yadav *et al*., 1997 [18], and Chopra and Saini, 2007) [16, 5]. Competition by weeds at initial stages is a major limiting factor to its productivity. There are a number of methods available by which weeds can be controlled effectively in mustard. Among them mechanical and manual have been very common but are highly laborious, expensive and rush always and many time labour are not available during the peak period when the crop is affected due to weeds to a great extent. As an alternative method, herbicide weed control. The most common herbicidal weed control measure recommended in rapeseed-mustard is the pre-emergence application of pendimethalin. Farmers and extension functionaries require information on post-emergence herbicidal weed control when pre-emergence application of herbicide was not made. Post-emergence herbicides may have an added economic advantage over super imposition of hand

weeding. In spite of recoding the highest weed control efficiency and providing higher sugar cane yield, hand weeding could not found economical because of higher expenditure incurred on engaging labourers (Kumar *et al*., 2014) [9]. Therefore it is imperative weed management strategy for achieving season long weed control in rapeseed-mustard.

Materials and Methods

The experiment was conducted during *Rabi* season 2011-12 at Agronomy Research Farm of Narendra Dev University of Agriculture and Technology, Kumarganj, Faizabad, Uttar Pradesh (26^0 47'Nlatitude, 82^0 12' E longitude and 113 metres altitude).The soil of experimental field was slightly alkaline in reaction (7.8 pH), low in organic carbon (0.47%) and low in available nitrogen (185 kg ha^{-1}), phosphorus (11 kg ha^{-1}) and medium in potassium (215kg ha^{-1}).Ten treatments *Viz.* pendimethalin 1000 g ha^{-1}(pre-emergence), oxadiargyl 90 g ha^{-1} (pre-emergence), trifluralin 750 g ha^{-1}(pre-plant incorporation), oxyfluorfen 150 g ha^{-1} (pre-emergence), quizalofop 60 g ha-^{1}, (post-emergence) clodinafop 60 g ha^{-1}, (post-emergence) isoproturon 1000 g ha^{-1} (pre-emergence), isoproturon 1000 g ha^{-1} (post-emergence)), weedy check and weed free check in a randomized block design (RBD) with three replications. The seeds of mustard variety 'VARUNA' were sown in rows 45 cm. apart on October 30, 2012 using 5 kg ha^{-1}. Urea, DAP, muriate of potash and sulphur were used to supply 120 kg N, 60 kg P_2O_5 40 kg k_2O and 40 kg S ha^{-1}, respectively. Half dose of nitrogen and full dose of phosphorus potassium and sulphur were applied as basal dressing in the field at the time of sowing in furrows. Remaining half dose of nitrogen through urea was top dressed after first irrigation. The recommended cultural practices and plant protection measures were followed to rise the healthy crop. Weeding was done manually in weed free check plots with help of hand tool 'Khurpi' as when required. Species-wise number of weeds were recorded from three places selected at random in each plot by using quadrate of 50 cm x 50 cm size after that the samples were dried in hot air oven at 70 $\pm$ 1^0C for 48 hours or till a constant weight attained and then weed dry weight was recorded in gm^{-2}. The herbicides were sprayed with the help of handoperated Knapsack sprayer fitted with flat fan nozzle using 600 litres of water ha^{-1}. Weedcontrol efficiency (WCE) was determined by the following formula.

$$\text{W.C.E.}(\%) = \frac{W_0 - W_1}{W_0} \text{ x } 100$$

Where, W_0 – Weed dry weight in weedy check.
W_1 – Weed dry weight in treated plot.

Results and Discussion

Effect on weeds

The pre-dominant weeds were noted in the experimental field Phalaris minor (21.35%) and Cynodon dactylon (7.78%),Chenopodium album (17.58%), Anagallis arvensis (27.43%), Melilotus alba, Vicia hirsuta, Lathyrus asphaca and Rumex sp.(19.22%)of broad leaved and Cyperus rotundus (10.61%) of sedges group.The Similar type of weed flora in mustard crop was reported by Yadav, (2004) [17] and Bisen and Singh, (2008) [4]. All weed control treatments significantly influenced weed density over the weedy check. Pre-emergence application of Oxadiargyl 90 g ha^{-1} resulted more effective in reducing the density of broad-leaved weed as well as grasses weeds compare to other herbicides however, it was very much close to pendimethalin 1000 g ha^{-1} and trifluralin 750 g ha^{-1}(Table-1).These findings are in close conformity with those of Kumar *et al*. (2012). Oxyfluorfen 150 g ha^{-1} was effective against Chenopodium album, Anagallis arvensis and other broad leaved weeds however, quizalofop 60 g ha^{-1}, and clodinafop 60 g ha^{-1} being statistically was more effective in reducing the population of Phalaris minor. The density of Cynodon dactylon was not influenced due to any herbicide treatments however weed free check recorded lowest dencity. Similar trend was observed in case of Cyperus rotundus. Due to species-wise suppression of weeds, all weed control treatments appreciably reduced weed dry matter accumulation as compared to weedy check (Table.1). Oxadiargyl 90 g ha^{-1} reduced the dry matter accumulation appreciably as compared to other weed control treatments, however, other treatment e.g. pendimethalin 1000 g ha^{-1} also reduced the weed dry matter and was at par with trifluralin 750 g ha^{-1}. Quizalofop 60 g and clodinafop 60 g ha^{-1} each applied as post-emergence could not control the full spectrum of weeds as both of these have been reported to control the P. minor more effectively as compared to BLWs (Table-2). These results were also in conformity with the work of Singh, (2009) [15] and Mitra, (2011) [12]. Since uptake is a function dry matter and content of the nutrients, it follows the trend of dry matter. Thus nitrogen uptake by weeds was significantly affected under weed control treatments. Oxadiargyl 90 g ha^{-1} recorded significantly lower nitrogen uptake by weed over rest of the treatments. After that treatment minimum nitrogen uptake was recorded with pendimethalin 1000 g ha^{-1} fb trifluralin 750 g ha^{-1} and oxyfluorfen 150 g ha^{-1}. Treatment oxadiargyl 90 g ha-1 showed lowest uptake of nitrogen due to weeds (Table-2). It might be because of the fact that lowest quantity of dry weight of weeds was accumulated. The similartype of results have been reported by Meena and Shah (2011) [11]. As far as the weed control efficiency (W.C.E. %) was concerned, it was also affected due to various weed control treatments. The higher W.C.E. was recorded in oxadiargyl 90 g ha^{-1} fb pendimethalin 1000 g ha-1, trifluralin 750 g ha-1and oxyfluorfen 150 g ha^{-1} and lowest with quizalofop 60 g ha^{-1} and clodinafop 60 g ha-1respectively. Quizalofop and clodinafop both of these herbicides used to control onlynarrow leaved weeds and in the experimental field density of narrow leaf weeds was comparatively less as compared to broad leaved weeds, so this was a main reason to showed showed the minimum W.C.E. over rest of the herbicide treatments (Table-2).

Effect on Crop

All weed control treatments showed significant differences on plant height. Significantly taller plants were recorded under oxadiargyl 90 g ha^{-1} fb pendimethlin 1000 g ha^{-1},trifluralin 750 g ha^{-1} and oxyfluorfen 150 g ha^{-1} due to effective control of weeds and favourable growth of the crop in these treatments and minimum plant height was recorded with quizalofop 60 g ha^{-1} and clodinafop 60 g ha^{-1} might be due to their lethal effect on narrow leaved weeds specially on P. minor but BLWs escaped absolutely and cause the competition with crop and ultimately reduced the plant height at all the stages at a greater extents (Table-3). These results are in conformity with the work done at 24, Co-ordinating Centres of AICRP on Mustard across five zones of the country (Anonymous, 2012) [1]. Better growth and development of the crop under competition free environment with effective control of weeds due to different weed control

treatments showed influence on the formation of higher yield attributing characters. The yield attributing characters viz. silique plant^{-1}

Table 1: Effect of weed control treatments on weed density (No. m^{-2}) of different weed species at 90 DAS of mustard

Treatments	BLWs		Grassy weeds		Sedge		
	C. album	*A. arvensis*	*Phalaris minor*	*Cynodon dactylon*	*Cyperus rotundus*	Others	Total
Pendimethalin 1000 g ha^{-1} (PE)	3.53 (11.98)	3.61 (12.53)	3.07 (9.15)	4.16 (16.80)	4.35 (18.40)	2.69 (6.75)	8.71 (75.41)
Oxadiargyl 90 g ha^{1} (PE)	3.28 (10.32)	3.20 (9.80)	2.80 (7.39)	4.24 (17.58)	4.40 (18.90)	2.43 (5.45)	8.36 (69.44)
Trifluralin 750 g ha^{-1} (PPI)	3.84 (14.15)	3.63 (12.70)	3.69 (13.14)	4.05 (15.95)	4.69 (21.50)	2.73 (6.98)	9.21 (84.52)
Oxyfluorfen 150 g ha^{-1} (PE)	3.97 (15.30)	4.01 (15.58)	4.03 (15.80)	4.31 (18.10)	4.36 (18.53)	3.23 (9.93)	9.68 (93.24)
Quizalofop 60 g ha^{-1} (POE)	6.14 (37.30)	7.88 (61.70)	3.78 (13.80)	4.18 (16.98)	4.52 (19.95)	5.85 (33.80)	13.56 (183.53)
Clodinafop 60 g ha^{-1} (POE)	5.89 (34.21)	7.69 (58.69)	3.58 (12.30)	4.12 (16.50)	4.45 (19.33)	5.68 (31.74)	13.16 (172.77)
Isoproturon 1000 g ha^{-1} (PE)	5.49 (29.65)	7.00 (48.58)	4.45 (19.37)	4.37 (18.66)	4.64 (21.10)	5.36 (28.30)	12.88 (165.66)
Isoproturon 1000 g ha^{-1} (POE)	5.09 (25.54)	6.56 (42.63)	3.97 (15.32)	4.21 (17.26)	4.77 (22.30)	4.71 (21.75)	12.03 (144.80)
Weedy	6.50 (39.80)	8.11 (65.20)	7.15 (50.74)	4.41 (18.95)	5.07 (25.23)	6.80 (43.70)	15.43 (237.67)
Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
C.D. at 5%	0.38	0.45	0.30	0.36	0.39	0.33	0.92

Figures in the parenthesis are the original value, transformed by $\sqrt{x+0.5}$). PE- Pre-emergence, PPI- pre-plant incorporation, PoE- post-emergence DAS- days after sowing BLW- broad leaved weeds.

Table 2: Effect of weed control treatments on dry matter of total weeds, nitrogen uptake by weeds and weed control efficiency in mustard

Treatments	Dry matter(g m^{-2})		Nitrogen uptake by weeds (kg ha^{-1})	W.C.E. (%)
	At 90 DAS	At harvest		
Pendimethalin 1000 g ha^{-1} (PE)	6.83(46.19)	6.24(38.47)	3.60	78.03
Oxadiargyl 90 g ha^{-1} (PE)	6.37(40.37)	5.76(32.88)	2.98	81.82
Trifluralin 750 g ha^{-1} (PPI)	7.37(53.96)	6.69(44.32)	3.85	74.69
Oxyfluorfen 150 g ha^{-1} (PE)	8.09(64.97)	7.48(55.47)	4.58	68.33
Quizalofop 60 g ha^{-1} (POE)	10.70(114.09)	10.43(108.36)	7.64	38.13
Clodinafop 60 g ha^{-1} (POE)	10.40(107.75)	10.08(101.16)	7.20	42.24
Isoproturon 1000 g ha^{-1} (PE)	10.24(104.52)	9.91 (97.91)	6.13	44.09
Isoproturon 1000 g ha^{-1} (POE)	9.55(91.11)	9.25(85.38)	5.78	51.25
Weedy	13.68(186.68)	13.25(175.15)	19.78	-
Weed free	0.71(0.00)	0.71(0.00)	0.00	100
C.D. at 5%	0.73	0.69	0.87	-

Figures in the parenthesis are original value, transformed by $\sqrt{x+0.5}$).

Table 3: Effect of different treatments on plant height and yield attributes of mustard

Treatments	Plant height (cm)	Siliquae plant^{-1}	Length of silique (cm)	Seed siliqua^{-1}	Test weight
Pendimethalin 1000 g ha^{-1} (PE)	155.35	230.56	6.02	11.21	4.78
Oxadiargyl 90 g ha^{-1} (PE)	164.50	240.53	6.14	11.43	4.85
Trifluralin 750 g ha^{-1} (PPI)	157.40	224.18	5.80	10.95	4.74
Oxyfluorfen 150 g ha^{-1} (PE)	147.62	207.65	5.73	10.75	4.70
Quizalofop 60 g ha^{-1} (POE)	126.72	165.50	4.78	9.40	4.55
Clodinafop 60 g ha^{-1} (POE)	129.43	170.80	4.87	9.50	4.57
Isoproturon 1000 g ha^{-1} (PE)	132.62	176.65	4.99	9.59	4.67
Isoproturon 1000 g ha^{-1} (POE)	140.39	189.60	5.30	9.95	4.60
Weedy	106.73	115.44	3.95	7.61	4.28
Weed free	168.72	247.72	6.23	11.81	4.95
C.D. at 5%	24.06	33.88	1.05	1.54	NS

Length of siliquae, seeds silique^{-1} and test weight increased with weed control treatments. Oxadiargyl 90 g ha^{-1} fb pendimethalin 1000 g ha^{-1}, trifluralin 750 g ha^{-1} and oxyfluorfen 150 g ha-1 recorded significantly higher yield attributes.As far as the 1000- seed weight or test weight was concerned, it was not affected significantly due to different weed control treatments (Table-3), as it is directly related with the genetic character of the crop or variety. However weed free check was superior treatment in the order. The seed yield is contributed by the different yield attributes. The treatments in which these attributes got better response ultimately would give more seed as well as stover yield. As the different weed control treatments influenced the growth attributes and yield attributes significantly. Consequently, influenced the seed

yield in the same manner Oxadiargyl 90 g ha^{-1}, pendimethalin 1000 g ha^{-1}, trifluralin 750 g ha^{-1} and oxyfluorfen 150 gha^{-1} being at par recorded significantly higher seed yield over rest of the treatments (Table-3). Improvement in yield contributing characters and thereby seed yield under weed control treatments may be attributed to low weed pressure. Weedy check had lowest seed yield due to higher weed density and dry matter accumulation. Weed in untreated check reduced seed yield of mustard by 49.24 per cent. Kumar *et al.* (2012) [10] and Kumar and Kaur (2015) [8] had also obtained more plant height, seed yield and yield attributing characters with weed control treatments over untreated control.

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