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Integrated use of Herbicides and different Fertility Levels in Suppressing the Weed Species in Indian Mustard (*Brassica juncea*)

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ABSTRACT: A field experiment was conducted at research farm, Rajasthan Agricultural Research Institute, Durgapura, Jaipur for 2 consecutive years during *rabi* seasons 2014-15 and 2015-16 on loamy sand soil. The twenty-four treatment combinations consisting of 3 fertility levels {100% RDF; 100% RDF + K + Zn and 125% (RDF + K + Zn)} and 8 herbicidal treatments (Weedy check, weed free, pendimethalin 30 EC, pendimethalin 38.7 CS, pyrazosulfuron-ethyl 10 WP, oxydiargyl 6 EC, propaquizafop 10% EC and fluazifop-p-butyl 13.4% EC) were tested in mustard in factorial randomized block design with 3 replications. *Chenopodium album, Argemone maxicana*, *Portulaca oleraceae*, *Tithonia diversifolia,* and *Heliotropium ovalifolium* among the broadleaved weeds, *Cyperus rotundus* among the sedges and *Cynodon dactylon* among the grasses were predominant throughout the cropping period of mustard. Results showed that weed density of most of the broad-leaved weeds and total dry weight was most effectively controlled by pendimethalin 38.7 CS @ 750g a.i./ha, followed by pendimethalin 30 EC @ 750 g a.i./ha and oxydiargyl 6 EC pre-emergence @ 90 g a.i./ha whereas propaquizafop 10% EC @ 100 g a.i./ha (POE) and fluazifop-p-butyl 13.4 % EC @ 134 g a.i./ha (POE) significantly decreased the density of grassy weeds. Pyrazosulfuron-ethyl 10 WP as pre-emergence showed phytotoxic effect on the germination of mustard. Maximum siliqua length, siliquae per plant, seed and stover yield were obtained under weed free, which was found at par with pendimethalin 38.7 CS @ 750 g a.i./ha. The siliqua length, siliquae per plant, seed and stover yield were significantly higher in fertility level 125% (RDF + K + Zn) in mustard. Pendimethalin 38.7 CS combined with 125% (RDF + K + Zn) or 100% RDF + K + Zn and weed free along with 125% (RDF + K + Zn) were found at par with each other and most superior treatment combinations for obtaining higher seed yield in mustard. Thus, integrated use of 100% RDF + K + Zn with pendimethalin 38.7 CS @ 750g a.i./ha appeared to be the most promising approach for effective weed management and obtaining higher productivity of Indian mustard.

Keywords: Pendimethalin, oxydiargyl, propaquizafop, fluazifop-p-butyl, fertility levels, herbicides, siliqua, stover.

INTRODUCTION

Mustard is the third most important edible oilseed crop in India after soybean and groundnut. Mustard is one of the major sources of oil in the meal in India. Rajasthan is the major mustard producing states in the country, contributing 46.2 % of total production of India. This is a potential crop in winter (Rabi) season due to its wider adaptability and suitability to exploit residual moisture (Mukherjee, 2010). Among the various constraints attributing to low productivity of mustard, the erratic nature of climate, inefficient irrigation water, weed infestation, fertilizer management and poor soil physical conditions are the most important factors which lead to the low crop yield. It has been estimated that yield depression in rapeseed mustard due to weed infestation varied from 20-70% depending on the composition and density of weed flora and time of their occurrence (O-Donovan *et al.,* 2007). Competition by weeds at initial stages is a major limiting factor to its productivity. Manual weeding at 3-4 weeks after sowing is the most common practice to control weeds in Indian mustard. But increasing wages and scarcity of labor compel to search for other alternatives. The most common herbicidal weed control measure recommended in Indian mustard is the pre-emergence application of herbicide. Under situations when weeds are not taken care completely by pre-emergence application of herbicides, post-emergence herbicides may have an added economic advantage over super imposition of hand weeding. Application of adequate fertilizer to plant crop increases their leaf growth, which facilitates earlier shading of the soil surface and thus reduces weed seed germination (Wicks *et al.,* 2012). Nutrient management is the key technology in maintaining and sustaining the production potential of rapeseed-mustard. Balanced fertilization is more essential even at low levels of fertilizer usage for maintaining long term fertility. The present emphasis on the production and promotion of fertilizers containing N, P, K and S has to be modified to include the fifth major plant nutrient Zn.

In Western Rajasthan, mustard cultivation is expanding in area due to the availability of irrigation water from the Indira Gandhi Canal System. Working out balance fertilizer schedule involving both nitrogen and phosphorus can therefore, go a long way in boosting average yield of mustard in this region. In the past, little attention has been given to improve mustard productivity through weed and fertilizer management. Therefore, the proposed study was carried out with the objective to develop suitable fertilizer level and weed control technology for mustard production under arid and semi-arid region of Rajasthan.

MATERIAL AND METHODS

The experiment was conducted at Rajasthan Agricultural Research Institute, Durgapura, Jaipur (Raj.) during 2014-15 and 2015-16. Geographically this place is situated at 75° 47' East longitude, at 26°51' North latitude and at altitude of 390 m above mean sea level in Jaipur district of Rajasthan. This region falls under Agro-climatic zone IIIa (Semi-arid eastern plain zone) of Rajasthan. The soil of experimental field was loamy sand in texture, slightly alkaline in reaction, poor in organic carbon, low in available nitrogen and medium in available phosphorus and potassium status.

The treatment consisted of three fertility levels {100% RDF; 100% RDF + K + Zn and 125% (RDF + K + Zn)} and eight levels of weed management practices (weedy check, weed free, Pendimethalin 30 EC pre-emergence @ 750 g a.i./ha, Pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha, Pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha., Oxydiargyl 6 EC pre-emergence @ 90 g a.i./ha., Propaquizafop 10% EC @ 100 g a.i./ha at 20-25 DAS and Fluazifop-p-butyl 13.4 % EC @ 134 g a.i./ha at 20-25 DAS), were replicated thrice in Factorial Randomized Block Design. Recommended dose of fertilizer was 60 kg N + 30 kg P_2O_5 + 40 kg S per hectare for mustard, which were applied in the form of Urea, Single Super Phosphate and Gypsum. K_2O and $ZnSO_4$ was applied in the form of muriate of potash and zinc sulphate @ 30 and 20 kg per hectare, respectively in the second treatment of fertility level. Half dose of nitrogen and full dose of phosphorus, sulphur, potassium and zinc sulphate were applied as basal and half dose of nitrogen was applied at first irrigation.

Pendimethalin 30 EC, pendimethalin 38.7 CS, pyrazosulfuron-ethyl 10 WP, oxydiargyl 6 EC was sprayed at 1 DAS with a knapsack sprayer with flatfan nozzle. Weed density of each weed species was taken at 30, 60 and 90 DAS from five random spots in each plot by counting the number of weeds per quadrate of 0.25 m^2 and the average was computed. The gross plot size was of 18 m^2 and the seed and stover yield of each net plot of 12 m^2 size was recorded in kg $plot^{-1}$ after cleaning the threshed produce and was converted as q ha^{-1}.

The experimental data were analyzed statistically by applying the technique of analysis of variance (ANOVA) prescribed for the design to test the significance of overall difference among treatments by the F test and conclusions were drawn at 5% probability level. Weed density and dry weight data were subjected to square root transformation ($\sqrt{(x+0.5)}$) before statistical analysis. The effect of treatments was evaluated on pooled analysis basis.

RESULTS AND DISCUSSION

Weed flora. Regular weed survey during the course of experimentation showed that mustard crop was heavily invaded by broad leaf and some grassy weeds immediately with the crop emergence. The prominent broad-leaved weed species found to infest the experimental crop were *Chenopodium album, Argemone maxicana*, *Portulaca oleraceae*, *Tithonia diversifolia,* and *Heliotropium ovalifolium. Cyperus rotundus* and *Cynodon dactylon* were the major sedges and grassy weed species, respectively, noted to invade the crop.

Effect of fertility levels on weed. Fertility levels did not bought significant variation in the density of *Argemone maxicana, Chenopodium album, Heliotropium ovalifolium, Portulaca procumbense, Tithonia diversifolia, Cynodon dactylon*, *Cyperus rotundus* and total dry weight of weeds at all the stages, during both the years of study and in pooled analysis (Table 1 and 2).

Effect of herbicides on weed. The results indicated that all the herbicide treatments, except pyrazosulfuron-ethyl 10 WP caused significant reduction in pooled weed density of all weed species and total weed dry weight at all the stages of crop in comparison to weedy check treatment (Table 1 and 2). These findings are in conformity with those reported by Chauhan *et al.* (2005) in mustard, Sarkar *et al.* (2005) in mustard, Mukherjee (2014) in mustard, and Duary (2015) in mustard. Application of different herbicides *viz*., pendimethalin 30 EC, pendimethalin 38.7 CS, oxydiargyl 6 EC, fluazifop-p-butyl 13.4 % EC and propaquizafop 10% EC reduces the density of different weed species and total dry weight of weeds at different crop stages in comparison to weedy check. However, these herbicides varied in their performance among themselves on different weeds too.

(i) ***Cynodon dactylon*****.** Data presented in Table 1 indicated that after weed free, the density of *Cynodon dactylon* at all the stages of observation was recorded lowest under propaquizafop 10% EC @ 100 g a.i./ha at 20-25 DAS treatment, remained at par with fluazifop-p-butyl 13.4 % EC @ 134 g a.i./ha at 20-25 at all the stages of observation during both the years of study and in pooled analysis. On the basis of pooled mean, it reduced the density of *Cynodon dactylon* by 15.1 and 92.0 per cent at 30 DAS, 17.6 and 90.5 per cent at 60 DAS and 13.7 and 88.9 per cent at 90 DAS, in comparison fluazifop-p-butyl 13.4 % EC @ 134 g a.i./ha and weedy check treatments, respectively.

(ii) ***Cyperus rotundus*****.** A perusal of data presented in Table 1 indicated that after weed free, the density of *Cyperus rotundus* was recorded lowest under fluazifop-p-butyl 13.4 % EC @ 134 g a.i./ha at 20-25, which was at par with propaquizafop 10% EC @ 100 g a.i./ha at 20-25 DAS at 30 and 60 DAS but at 90 DAS the density of *Cyperus rotundus* was recorded lowest under propaquizafop 10% EC @ 100 g a.i./ha at 20-25 DAS treatment, remained at par with fluazifop-p-butyl 13.4 % EC @ 134 g a.i./ha during both the years of study and in pooled analysis. On the basis of pooled mean, fluazifop-p-butyl 13.4 % EC @ reduced the density of *Cyperus rotundus* by 26.8 and 90.1 per cent at 30 DAS, 11.8 and 90.0 per cent at 60 DAS in comparison to propaquizafop 10% EC @ 100 g a.i./ha and weedy check treatments, respectively. At 90 DAS, in pooled mean, propaquizafop 10% EC reduced the density of *Cyperus rotundus* by 3.4 and 85.5 per cent in comparison to fluazifop-p-butyl 13.4 % EC @ 134 g a.i./ha and weedy check treatments, respectively.

(iii) ***Argemone maxicana*****.** A perusal of data presented in Table 2 indicated that after weed free, the density of *Argemone maxicana* at 30 DAS was recorded lowest under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha, remained at par with pendimethalin 30 EC @ 750 g a.i./ha and oxydiargyl 6 EC @ 90 g a.i./ha during both the years of study and in pooled analysis. On the basis of pooled mean, application of pendimethalin 38.7 CS reduced the density of *Argemone maxicana* by 15.2, 5.6 and 84.3 per cent at 30 DAS in comparison to pendimethalin 30 EC @ 750 g a.i./ha, oxydiargyl 6 EC @ 90 g a.i./ha. and weedy check treatments, respectively. At 60 and 90 DAS, after weed free, the density of *Argemone maxicana* was recorded lower under pendimethalin 30 EC pre-emergence @ 750 g a.i./ha treatment, remained at par with pendimethalin 38.7 CS @ 750 g a.i./ha and oxydiargyl 6 EC @ 90 g a.i./ha during both the years of study and in pooled analysis. Application of pendimethalin 30 EC pre-emergence @ 750 g a.i./ha decreased the pooled density of *Argemone maxicana* by 10.6, 23.0 and 87.6 percent at 60 DAS and 12.1, 8.4 and 84.3 percent at 90 DAS as compared to pendimethalin 38.7 CS @ 750 g a.i./ha, oxydiargyl 6 EC @ 90 g a.i./ha. and weedy check treatments, respectively.

(iv) ***Chenopodium album*****.** Results presented in Table 2 indicated that after weed free, the density of *Chenopodium album* at 30 DAS was recorded significantly lower under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha treatment during both the years of study and in pooled analysis. On the basis of pooled mean, pendimethalin 38.7 CS reduced the density of *Chenopodium album* by 69.0, 84.6 and 98.5 per cent at 30 DAS in comparison to pendimethalin 30 EC @ 750 g a.i./ha, oxydiargyl 6 EC @ 90 g a.i./ha. and weedy check treatments, respectively. At 60 DAS, after weed free, the density of *Chenopodium album* was recorded lowest under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha, remained at par with pendimethalin 30 EC @ 750 g a.i./ha and at 90 DAS the density of *Chenopodium album* was recorded lowest under both pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha and pendimethalin 30 EC @ 750 g a.i./ha treatments, remained at par with oxydiargyl 6 EC @ 90 g a.i./ha. during both the years of study and in pooled analysis. Application of pendimethalin 38.7 CS and pendimethalin 30 EC pre-emergence @ 750 g a.i./ha decreased the pooled density of *Chenopodium album* by 17.7 and 88.2 percent at 90 DAS as compared to oxydiargyl 6 EC @ 90 g a.i./ha. and weedy check treatments, respectively.

(v) ***Heliotropium ovalifolium*****.** Results presented in Table 2 indicated that after weed free, the density of *Heliotropium ovalifolium* at 30 DAS was recorded lowest under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha treatment remained at par with pendimethalin 30 EC @ 750 g a.i./ha but at 60 and 90 DAS lowest density of *Heliotropium ovalifolium* was recorded under pendimethalin 30 EC @ 750 g a.i./ha treatment which was at par with pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha during both the years of study and in pooled analysis. On the basis of pooled mean, pendimethalin 38.7 CS reduced the density of *Heliotropium ovalifolium* by 6.3, 61.6 and 80.8 per cent at 30 DAS in comparison pendimethalin 30 EC @ 750 g a.i./ha, oxydiargyl 6 EC @ 90 g a.i./ha and weedy check treatments, respectively. Application of pendimethalin 30 EC pre-emergence @ 750 g a.i./ha decreased the pooled density of *Heliotropium ovalifolium* by 24.7, 67.1 and 85.7 per cent at 60 DAS, 4.1, 53.9 and 80.8 at 90 DAS in comparison pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha, oxydiargyl 6 EC @ 90 g a.i./ha and weedy check treatments, respectively.

(vi) ***Portulaca oleraceae*****.** A perusal of data presented in Table 2 indicated that *Portulaca oleraceae* was not observed at 30 DAS under pendimethalin 38.7 CS @ 750 g a.i./ha, pendimethalin 30 EC @ 750 g a.i./ha and oxydiargyl 6 EC @ 90 g a.i./ha. treatments. They reduced the density of *Portulaca oleraceae* by 100 per cent at 30 DAS in comparison to all the other treatments. At 60 and 90 DAS lowest density of *Portulaca oleraceae,* after weed free was recorded under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha treatment which was at par with oxydiargyl 6 EC pre-emergence @ 90 g a.i./ha during both the years of study and in pooled analysis. On the basis of pooled mean, pendimethalin 38.7 CS reduced the density of *Portulaca oleraceae* by 57.1, 35.0 and 94.2 per cent at 60 DAS, 69.8, 41.0 and 94.6 per cent at 90 DAS in comparison to pendimethalin 30 EC @ 750 g a.i./ha, oxydiargyl 6 EC @ 90 g a.i./ha and weedy check treatments, respectively.

(vii) *Tithonia diversifolia.* Data presented in Table 2 indicated that after weed free, the density of *Tithonia diversifolia* was recorded lowest under oxydiargyl 6 EC pre-emergence @ 90 g a.i./ha treatment at all the stages of observations, remained at par with pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha and pendimethalin 30 EC @ 750 g a.i./ha at 30 DAS and with pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha at 60 and 90 DAS during both the years of study and in pooled analysis. On the basis of pooled mean, oxydiargyl 6 EC reduced the density of *Tithonia diversifolia* by 17.4, 9.5 and 77.8 per cent at 30 DAS, 10.7, 42.0 and 67.4 per cent at 60 DAS, 13.7, 38.3 and 64.1 per cent at 90 DAS in comparison to pendimethalin 38.7 CS, pendimethalin 30 EC and weedy check treatments, respectively.

Total dry weight of weeds. Data presented in Fig.1 indicated that after weed free, the total dry weight of weeds at 30 and 90 DAS was recorded significantly lowest under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha, but at 60 DAS it was recorded lowest under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha remained at par with pendimethalin 30 EC @ 750 g a.i./ha during both the years of study and in pooled analysis. On the basis of pooled mean, pendimethalin 38.7 CS reduced the pooled total dry weight of weeds by 9.3, 32.6 and 65 per cent at 30 DAS, 12.4, 19.1 and 67.6 per cent at 60 DAS, 14.8, 16.2 and 65.9 per cent at 90 DAS in comparison to pendimethalin 30 EC, oxydiargyl 6 EC and weedy check treatments, respectively. These findings are in conformity with those reported by Roshdy *et al.* (2008) in canola, Chaudhry *et al.* (2011) in canola, Kumar *et al*. (2012) in mustard.

Table 1: Effect of treatments on density of sedges and grassy weed species at different stages.

Treatments	*Cynodon dactylon*			*Cyperus rotundus*		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
Fertility levels						
100 % RDF*	2.61	2.92	3.04	2.31	2.52	2.73
	[7.17]	[9.13]	[9.80]	[5.36]	[6.58]	[7.55]
100 % RDF + K + Zn	2.77	2.96	3.05	2.24	2.51	2.72
	[7.97]	[9.40]	[9.97]	[4.56]	[6.4[	[7.46]
125 % RDF + K + Zn	2.78	3.06	3.02	2.24	2.58	2.72
	[8.18]	[9.80]	[9.75]	[4.73]	[6.73]	[7.53]
SEm±	0.042	0.052	0.058	0.058	0.054	0.048
CD (P = 0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Herbicides						
Weedy check	4.13	4.34	4.31	3.61	4.18	4.32
	[16.09]	[17.87]	[17.60]	[12.09]	[16.44]	[17.69]
Weed free	1.00	1.00	1.00	1.00	1.00	1.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Pendimethalin 30 EC pre-emergence @ 750 g a.i./ha	2.99	3.58	3.59	2.30	2.47	2.98
	[7.91]	[11.83]	[11.86]	[4.35]	[5.15]	[7.91]
Pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha	2.93	3.65	3.73	2.31	2.58	2.68
	[7.60]	[12.36]	[12.94]	[4.44]	[5.69]	[6.22]
Pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha.	4.04	4.08	4.24	3.23	3.87	3.96
	[15.29]	[15.65]	[16.98]	[9.6]	[13.95]	[14.66]
Oxydiargyl 6 EC pre-emergence @ 90 g a.i./ha.	3.67	3.89	3.99	2.60	2.97	3.07
	[12.45]	[14.14]	[14.94]	[5.77]	[7.82]	[8.4]
Propaquizafop 10% EC @ 100 g a.i./ha at 20-25 DAS	1.46	1.60	1.67	1.59	1.64	1.86
	[1.29]	[1.69]	[1.96]	[1.64]	[1.86]	[2.57]
Fluazifop-p-buty 13.4 % EC @ 134 g a.i./ha at 20-25 DAS	1.56	1.69	1.76	1.44	1.57	1.90
	[1.52]	[2.05]	[2.27]	[1.2]	[1.64]	[2.66]
SEm±	0.068	0.086	0.095	0.095	0.088	0.079
CD (P = 0.05)	0.195	0.243	0.271	0.270	0.252	0.225
Data in parentheses indicate the original weed density per m^2.						
Square root transformation $\sqrt{(x + 0.5)}$ was applied						

The extent of weed control achieved with these herbicides seems to be due to their phytotoxic action on weeds. Being a dinitroaniline, pendimethalin exerts it herbicidal effect by inhibiting root and shoot growth of weed species when absorbed by them. It generally inhibits microtubule assembly during cell division. The inhibition of root growth is a direct and the most spectacular observable symptom following its root absorption. Propaquizafop and Fluazifop-p-butyl are systemic selective post-emergence herbicides, which are quickly absorbed by the leaves and translocated from the foliage to the growing points of the leaves and roots of the sprayed weeds, where they are absorbed rapidly through leaf surfaces and quickly hydrolyzes to acid. The acid is transported primarily in the phloem and accumulated in the meristems where it disrupts the synthesis of lipids in susceptible species (Erlingson 1988). They inhibit acetyl CoA carboxylase (ACCase), an enzyme that catalyzes an early step in fatty acid synthesis.

Table 2: Effect of treatments on density of broad leaf weeds at different stages.

Treatment	*Tithonia diversifolia*			*Portulaca oleraceae*			*Heliotropium ovalifolium*			*Chenopodium album*			*Argemone maxicana*		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Fertility levels															
100 % RDF*	2.48	2.96	3.10	2.02	2.22	2.32	2.00	2.26	2.39	2.15	2.48	2.55	2.13	2.26	2.39
	[6.09]	[8.67]	[9.57]	[4.04]	[5.02]	[5.40]	[3.36]	[4.66]	[5.28]	[4.82]	[6.40]	[6.72]	[4.17]	[5.13]	[5.52]
100 % RDF + K + Zn	2.63	3.01	3.06	2.00	2.29	2.33	2.01	2.21	2.31	2.09	2.46	2.58	2.17	2.29	2.36
	[7.01]	[9.13]	[9.37]	[4.07]	[5.20]	[5.49]	[3.4]	[4.46]	[4.93]	[4.42]	[6.34]	[6.90]	[4.37]	[5.04]	[5.47]
125 % RDF + K + Zn	2.67	3.09	3.08	2.02	2.35	2.34	2.04	2.27	2.33	2.17	2.56	2.55	2.13	2.33	2.37
	[7.04]	[9.50]	[9.38]	[4.14]	[5.63]	[5.58]	[3.46]	[4.78]	[5.05]	[4.64]	[6.80]	[6.74]	[4.24]	[5.25]	[5.45]
SEm±	0.062	0.048	0.040	0.026	0.044	0.045	0.032	0.048	0.048	0.047	0.047	0.058	0.050	0.051	0.051
CD (P = 0.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
Herbicides															
Weedy check	3.77	4.10	4.07	3.35	3.54	3.53	2.82	3.28	3.48	3.60	4.23	4.28	3.25	3.63	3.67
	[13.25]	[15.83]	[15.60]	[10.23]	[11.56]	[11.47]	[6.93]	[9.77]	[11.11]	[12.00]	[16.89]	[17.34]	[9.60]	[12.18]	[12.45]
Weed free	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Pendimethalin 30 EC pre-emergence @ 750 g a.i./ha	2.01	3.14	3.17	1.04	1.56	1.73	1.54	1.50	1.74	1.74	1.56	1.70	1.63	1.55	1.68
	[3.25]	[8.89]	[9.07]	[0.09]	[1.56]	[2.05]	[1.42]	[1.4]	[2.13]	[0.58]	[1.51]	[2.05]	[1.78]	[1.51]	[1.96]
Pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha	2.12	2.59	2.73	1.08	1.27	1.25	1.51	1.66	1.77	1.08	1.54	1.72	1.55	1.61	1.77
	[3.56]	[5.78]	[6.49]	[0.18]	[0.67]	[0.62]	[1.33]	[1.86]	[2.22]	[0.18]	[1.43]	[2.05]	[1.51]	[1.69]	[2.23]
Pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha.	3.94	4.30	3.81	3.13	3.49	3.57	2.59	2.92	2.97	3.41	3.79	3.80	3.25	3.29	3.43
	[14.54]	[17.51]	[18.10]	[8.80]	[11.2]	[11.74]	[5.69]	[7.51]	[7.84]	[10.67]	[13.34]	[13.43]	[9.60]	[9.87]	[10.76]
Oxydiargyl 6 EC pre-emergence @ 90 g a.i./ha.	1.94	2.47	2.56	1.00	1.39	1.41	2.11	2.28	2.36	1.42	1.82	1.84	1.58	1.69	1.73
	[2.94]	[5.16]	[5.60]	[0.00]	[1.03]	[1.05]	[3.46]	[4.26]	[4.62]	[1.17]	[2.40]	[2.49]	[1.60]	[1.96]	[2.14]
Propaquizafop 10% EC @ 100 g a.i./ha at 20-25 DAS	2.90	3.24	3.36	3.00	3.13	3.16	2.43	2.66	2.80	2.73	3.30	3.31	2.51	2.84	2.95
	[7.47]	[9.49]	[10.31]	[8.00]	[8.78]	[8.96]	[4.89]	[6.13]	[6.8]	[6.49]	[9.87]	[9.96]	[5.34]	[7.07]	[7.74]
Fluazifop-p-buty 13.4 % EC @ 134 g a.i./ha at 20-25 DAS	3.07	3.33	3.44	2.52	2.91	3.00	2.13	2.67	2.63	2.61	2.76	2.83	2.37	2.72	2.75
	[8.45]	[10.14]	[10.85]	[5.34]	[7.47]	[8.00]	[3.55]	[6.13]	[5.95]	[5.91]	[6.67]	[7.03]	[4.63]	[6.40]	[6.58]
SEm±	0.101	0.079	0.065	0.042	0.072	0.073	0.051	0.078	0.078	0.077	0.076	0.095	0.082	0.084	0.083
CD (P = 0.05)	0.287	0.225	0.185	0.121	0.205	0.207	0.147	0.223	0.222	0.220	0.217	0.269	0.233	0.239	0.236
Data in parentheses indicate the original weed density per m^2															
Square root transformation $\sqrt{(x + 0.5)}$ was applied															

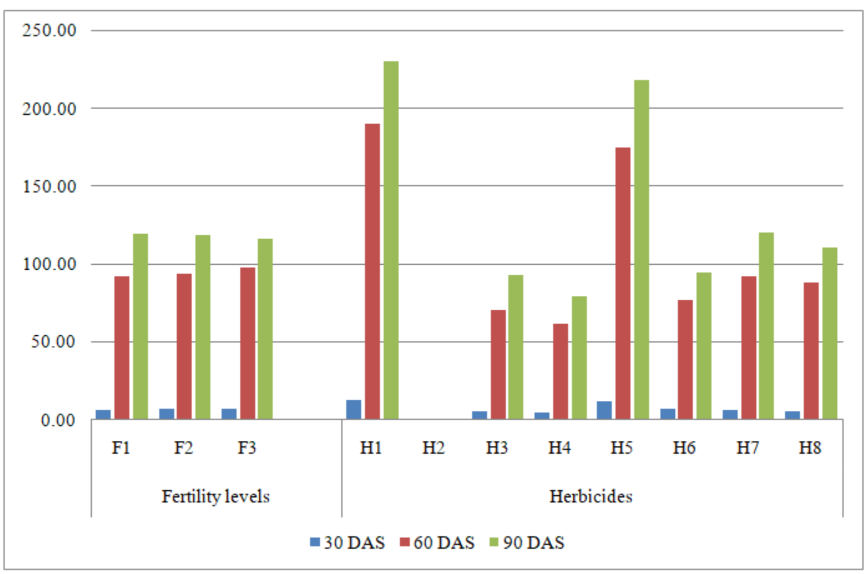

Fig. 1. Effect of treatments on total dry weight of weeds at 30, 60 and 90 DAS.

They kill annual and perennial grasses but do little or no harm to broad leaved plants, reported by Sukhadia *et al*. (1998). Oxadiargyl is an oxadiazole compound used as selective herbicide. Like any other oxadiazoles, oxadiargyl inhibits protoposphyrinogen IX oxidase, the enzyme that converts from Protox to Proto, which finally helps in the weed's necrotic action. Seedlings emerged from treated soil and then wilt and die. These findings are in conformity with those reported by Marwat *et al.* (2003) in rapeseed, Kumar *et al.* (2012) in mustard and Suganyadevi *et al.* (2012).

Effects on crop. It is evident from the results that all the herbicides treatments evaluated in present investigation differed in their effect on yield attributing characters like siliqua length, number of siliquae per plant, seed yield and stover yield. Except pyrazosulfuron-ethyl 10 WP, all the herbicide treatments were found significantly superior in comparison to weedy check treatment (Table 3). All the above-mentioned yield attributes and yield characters were found highest in weed free. After weed free, pre-emergence application of pendimethalin 38.7 CS recorded the highest number of siliquae per plant as 199.89, the highest siliqua length as 5.13 cm, the maximum seed yield as 19.37 q/ha, and the maximum stover yield as 43.99 q/ha, where siliqua length, seed yield and stover yield remained at par with pendimethalin 30 EC, siliquae per plant was at par with fluazifop-p-butyl 13.4 % EC. Hillel Chishi *et al.* (2021) reported that weed management treatment including pendimethalin 750 g/ha PE recorded highest seed/siliqua, siliqua/plant, length of siliqua, seed weight, seed, stover and biological yield of Indian mustard. The lowest yield attributes and yield were obtained under pyrazosulfuron-ethyl 10 WP pre-emergence treatment which was mainly due to the death of most of the mustard crop due to its phytotoxic effect on the crop. After pyrazosulfuron-ethyl 10 WP, the lowest yield attributes and yield was recorded under weedy check. The lowest value of yield attributes and yield may be due to severe competition by weeds for resources, which made the crop plant incompetent to take up more moisture and nutrients, consequently growth was adversely affected. Poor growth and less uptake of nutrients in weedy check might have produced less photosynthates and partitioned less assimilates to numerous metabolic sink and ultimately poor development of yield components. Significantly the lowest seed and stover yield were recorded under weedy check. Deprived growth and development of the crop under weedy check might have been responsible for poor yield. The higher seed yield obtained with either of these treatments could be better explained by their effectiveness in weed control in comparison to weedy check. These superior treatments kept the crop almost weed free of weeds upto 30-35 DAS which in turn resulted to significant reduction in competition for nutrients and other growth resources by weeds as a consequence of which reduction in weed dry matter and nutrient depletion by weeds was obtained. Reduced crop-weed competition under these treatments thus saved a substantial amount of nutrients for crop that led to profuse growth enabling the crop to utilize more soil moisture and nutrients from deeper soil layers. The higher values of yield attributes coupled with the higher crop dry matter recorded under these treatments might be the most probable reason of higher pod yield. Further, it might have enhance photosynthetic activity and partitioning of assimilates, resulting in improved yield attributes and yield. The results of the present study are in close conformity with the finding of Marwat *et al.* (2003) in rapeseed, Chauhan *et al.* (2005) in mustard, Chaudhary *et al.* (2011) in canola, Kumar *et al.* (2012) in mustard, Mukherjee (2014) in mustard, Tomar (2015) in mustard.

Table 3: Effect of treatments on yield attributes and yield.

Treatments	Siliqua length (cm)	Siliquae per plant	Seed Yield (q/ha)	Stover Yield (q/ha)
Fertility levels				
100 % RDF*	4.58	163.78	14.26	34.20
100 % RDF + K + Zn	4.73	169.99	15.48	35.58
125 % RDF + K + Zn	4.77	182.27	17.28	38.50
SEm±	0.05	2.38	0.20	0.37
CD (P=0.05)	0.14	6.77	0.57	1.06
Herbicides				
Weedy check	4.56	170.61	14.03	34.24
Weed free	5.41	210.70	19.92	45.13
Pendimethalin 30 EC pre-emergence @ 750 g a.i./ha	5.08	189.61	18.67	42.55
Pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha	5.13	199.89	19.37	43.99
Pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha.	3.08	63.11	3.98	9.47
Oxydiargyl 6 EC pre-emergence @ 90 g a.i./ha.	4.68	173.95	14.83	34.49
Propaquizafop 10% EC @ 100 g a.i./ha at 20-25 DAS	4.77	178.40	16.81	38.19
Fluazifop-p-butyl 13.4 % EC @ 134 g a.i./ha at 20-25 DAS	4.82	189.89	17.78	40.69
SEm±	0.08	3.88	0.33	0.61
CD (P=0.05)	0.23	11.06	0.93	1.72
Interaction (FX H)	N.S.	N.S.	Sig.	Sig.

CONCLUSIONS

On the basis of pooled data, it can be concluded that pre-emergence application of pendimethalin 38.7 CS @ 750g a.i./ha reduces the weed density and total dry weight of broadleaf weeds whereas propaquizafop 10% EC @ (POE) and fluazifop-p-butyl 13.4 % EC @ 134 g a.i./ha (POE) significantly decreased the density and total dry weight of grassy weeds in comparison to other herbicidal treatments. Weed free produced the maximum pooled seed yield and stover yield, followed by pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha treatment. Highest yield of mustard was obtained in weed free plots when fertilizer was given at the rate of 125% RDF + K + Zn, which was closely followed by the pendimethalin CS at the same dose of fertilizer. Combined application of Pendimethalin 38.7 CS + 100% RDF + K + Zn was found at par with the highest yield observed under weed free + 125% RDF + K + Zn and hence it is recommended in case of scarce labor condition.

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Conflict of Interest. None.

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