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Study of chemical properties and growth parameters of Indian mustard [*Brassica juncea* (L.) Czern and Coss.] influenced by application of herbicides and fertilizers

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Abstract
The field experiment was conducted at research farm, RARI, Durgapura for two 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 herbicides (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 factorial randomized block design with three replications. Results showed that, after weed free, the lowest total weed density was recorded under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha DAS which was found at par with Pendimethalin 30 EC pre-emergence @ 750 g a.i./ at 90 DAS. Plant height and number of branches per plant at 90 DAS increases with increase in fertility levels. So, the maximum pooled plant height and number of branches per plant were recorded in 125% (RDF + K + Zn) treatment. Plant height of all the treatments were significantly superior over pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha treatment at 90 DAS. There was no significant variation in plant height was recorded in between other herbicidal treatments at 90 DAS. It was found that, due to herbicides, no significant variation in potassium content in mustard seed and stover was recorded, but fertility levels in mustard significantly increased potassium content in mustard seed and stover. It was recorded that application of 125% (RDF + K + Zn) significantly increased the potassium content in mustard seed and stover.

Keywords: Pendimethalin; oxydiargyl; propaquizafop; fluazifop-p-butyl

Introduction
India is the third largest rapeseed-mustard producer in the world after Canada and China. This crop accounts for nearly one-third of the oil produced in India, making it the country's key edible oilseed crop. During 2014-15, rapeseed-mustard contributed 22.83% to the total oilseeds production of India (Anonymous, 2014-15) [1]. Rajasthan is one of the major mustard producing states in the country, contributing 46.2% of total production of India. National and state yield of mustard in 2014-15 are 1010 kg/ha and 1183 kg/ha, respectively (Anonymous, 2014-15) [1]. Rapeseed-mustard is the major source of income especially to the marginal and small farmers in rainfed areas. Since these crops are cultivated mainly in the rainfed and resource scarce regions of the country, their contribution to livelihood security of the small and marginal farmers in these regions is also very important. By increasing the domestic production, substantial import substitution can be achieved.

Among the various constraints attributing to low productivity of mustard in arid and semi-arid region, 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. Among various components of production technology, weed control in Indian mustard needs due attention. As this crop is grown in poor soils with poor management practices, weed infestation is one of the major causes of low 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. Farmers and extension functionaries require information

on post-emergence herbicidal weed control due to one or other reason, if pre-emergence application of herbicide was not made. 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. Therefore, it is imperative to find out an alternative weed management strategy for achieving season long weed control in Indian mustard. Development of effective method of weeds control in mustard, and knowing effective herbicide in controlling specific type of weed flora present in the region is the need of the hour.

Nutrient management is the key technology in maintaining and sustaining the production potential of rapeseed-mustard. The present emphasis is 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. Among several micronutrients zinc deficiency is fairly wide spread. Mustard is reported to respond to zinc application @ 10-20 kg/ha as basal or 0.5% as foliar spray. The nutrient supply, the flows and the nutrient added should be managed properly in order to achieve as high yield as possible under the climatic circumstances while minimizing environmental pollution. Nitrogen being the structural part of plant body, helps in synthesis of protein and important for photosynthetic activities in the plants. The response to phosphorus is determined by soil phosphorus status, moisture availability and yield level attained. P initially important for root development and afterwards fruiting and synthesis of oil in oilseed crops help to increase yield of crops. 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, phosphorus, potassium, sulphur and zinc can therefore, go a long way in boosting average yield of mustard in this region.

Material and Methods

The treatment consisted of three fertility levels and eight levels of weed management practices. The experiment was laid out in Factorial Randomized Block Design (RBD). The treatments were randomly allotted to different plots using random number table of Fisher and Yates (1963) [6].

Weed density

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. Weed density is also known as absolute density of a species. In order to draw valid conclusion, the weed count data were subjected to square root transformation as suggested by Blackman and Roberts (1950) [2]. Before subjecting to statistical analysis.

$$\left(\sqrt{(x+0.5)}\right)$$

Potassium content in mustard seed and stover (%)

The representative samples of seed and stover drawn at the time of threshing and winnowing were ground and analysed for potassium content. Potassium content in samples was determined in tri-acid digested material by using Flame photometer. When atoms of potassium are excited in flame emit a flame specific wavelength, the intensity of emission is proportional to the concentration of K which is determined in flame photometer using K filter (Jackson, 1973) [7].

Plant height

Five plants were selected randomly from each plot and tagged permanently. Height of individual plant was measured at 30 DAS. The height was measured from base of the plant to the top of the main shoot by metre scale and averaged to express in cm.

Number of branches per plant

The total number of branches was counted on five randomly selected and tagged plants in each plot at 30 DAS and then mean was recorded as total number branches $plant^{-1}$.

Result and Discussion

Total weed density

It was found that after weed free, the lowest total weed density was recorded under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha DAS which was found at par with Pendimethalin 30 EC pre-emergence @ 750 g a.i./ha during both the years of study and in pooled analysis at 90 DAS. On the basis of pooled mean, pendimethalin 38.7 CS reduced the total weed density by 14.4, 17.0 and 68.0 per cent at 90 DAS in comparison to pendimethalin 30 EC, oxydiargyl 6 EC and weedy check treatments, respectively. These results corroborate the findings of Marwat *et al.* (2003) [9]. in rapeseed. Further it was revealed that due to fertility levels there was no significant variation in the total weed density at 90 DAS, during both the years of study and in pooled analysis (Table 1).

Table 1: Effect of treatments on total weed density at 90 DAS

Treatments	Total Weed Density		
	2014-15	2015-16	Pooled
Fertility levels			
100% RDF*	5.89	5.61	5.75
	[40.12]	[36.75]	[38.43]
100% RDF + K + Zn	5.97	5.69	5.83
	[40.9]	[37.47]	[39.18]
125% RDF + K + Zn	6.03	5.76	5.90
	[41.68]	[38.36]	[40.02]
SEm±	0.059	0.065	0.061
CD (P = 0.05)	N.S.	N.S.	N.S.
Herbicides			
Weedy check	9.44	9.21	9.33
	[88.09]	[83.91]	[86]
Weed free	1.00	1.00	1.00
	[0.00]	[0.00]	[0.00]
Pendimethalin 30 EC pre-emergence @ 750 g a.i./ha	4.87	4.50	4.69

	[22.84]	[19.47]	[21.15]
Pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha	4.76	4.39	4.58
	[21.73]	[18.36]	[20.04]
Pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha.	9.22	8.99	9.11
	[84.09]	[79.82]	[81.95]
Oxydiargyl 6 EC pre-emergence @ 90 g a.i./ha.	5.72	5.39	5.56
	[31.73]	[28.20]	[29.96]
Propaquizafop 10% EC @ 100 g a.i./ha at 20-25 DAS	6.49	6.16	6.33
	[41.24]	[37.16]	[39.2]
Fluazifop-p-butyl 13.4% EC @ 134 g a.i./ha at 20-25 DAS	6.19	5.85	6.02
	[37.47]	[33.29]	[35.38]
SEm±	0.096	0.107	0.099
CD (P = 0.05)	0.270	0.303	0.283

Data in parentheses indicate the original weed density per m^2.
Square root transformation $\sqrt{(x + 0.5)}$ was applied

Plant height

Result indicated that all the treatments are significantly superior over pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha treatment at 90 DAS during both the years of study and in pooled analysis. There was no significant variation in plant height of mustard was recorded in other treatments during both the years of experimentation and in pooled analysis. On the basis of pooled mean, pyrazosulfuron-ethyl 10 WP reduced the plant height by 51.6 per cent at 90 DAS in comparison to weedy check (Table 2).

Data further revealed that different fertility levels bought significant variation in plant height. It was found that, application of 125% (RDF + K + Zn) significantly increased the plant height at 90 DAS, during both the years of experimentation and in pooled analysis. Also 100% RDF + K + Zn significantly increased the plant height in comparison to 100% RDF at 90 DAS during both the years of experimentation and in pooled analysis. On the basis of pooled mean, application of 125% (RDF + K + Zn) increased the plant height by 9.5 per cent at 90 DAS in comparison to 100% RDF treatment (Table 2).

In regard to plant height, all the treatments were significantly superior over pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha treatment at 90 DAS. Due to the phytotoxic effect of pyrazosulfuron-ethyl 10 WP on mustard, many of the crop plants died after 10-15 days of their emergence. And that is why there was significant variation in plant height in comparison to pyrazosulfuron-ethyl 10 WP. Although, pendimethalin 30 EC and pendimethalin 38.7 CS recorded maximum plant height at 90 DAS, but they were not significantly superior over any other treatments, except pyrazosulfuron-ethyl 10 WP. The result of maximum plant height in pendimethalin is strongly in support of the findings of Kumar *et al.* (2012) [8]. In mustard.

Number of branches per plant

Result indicated that there was no significant variation in number of branches per plant due to herbicides methods, during both the years of experimentation and in pooled analysis at 90 DAS (Table 2).

Data further revealed that at 90 DAS, application of 125% (RDF + K + Zn) significantly increased the number of branches per plant during 2015-16 and in pooled analysis. At 90 DAS, highest number of branches per plant was recorded in 125% (RDF + K + Zn) treatment, which remained at par with 100% RDF + K + Zn treatment. On the basis of pooled mean, application of 125% (RDF + K + Zn) increased the number of branches per plant by 10.2 per cent at 90 DAS in comparison to 100% RDF treatment (Table 2).

Potassium content in mustard seed

Analysis showed that herbicides could not bought significant variation in potassium content in mustard seed during both the years of experimentation and in pooled analysis, but fertility levels in mustard significantly increased potassium content in mustard seed. It was recorded that application of 125% (RDF + K + Zn) significantly increased the potassium content in mustard seed during both the years of experimentation and in pooled analysis. On the basis of pooled mean, application of 125% (RDF + K + Zn) increased potassium content in mustard seed by 2.7 and 6.5 per cent in comparison to 100% RDF + K + Zn and 100% RDF treatments, respectively (Table 2).

Potassium content in mustard stover

It was revealed that herbicides could not bought significant variation in potassium content in mustard stover during both the years of experimentation and in pooled analysis, but fertility levels in mustard significantly increased potassium content in mustard stover. It was recorded that application of 125% (RDF + K + Zn) significantly increased the potassium content in mustard stover during both the years of experimentation and in pooled analysis. On the basis of pooled mean, application of 125% (RDF + K + Zn) increased potassium content in mustard stover by 5.9 and 12.4 per cent in comparison to 100% RDF + K + Zn and 100% RDF treatments, respectively (Table 2).

The significant increase in potassium content in mustard seed and stover with increase in fertility levels is due to the greater availability of potassium in soil, applied through addition of fertilizers. These results in mustard are in the line with the findings of Deo and Khandelwal (2009) [4].

Table 2: Effect of treatments on plant height & number of branches at 90 DAS and potassium content in seed and stover of mustard

Treatments	Plant height (cm)			No. of branches			K in mustard seed (%)			K in mustard stover (%)		
	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled	2014-15	2015-16	Pooled
Fertility levels												
100% RDF*	143.87	142.58	143.23	11.23	11.03	11.13	1.08	1.06	1.07	1.62	1.59	1.61
100% RDF + K + Zn	150.80	149.56	150.18	11.85	11.68	11.77	1.12	1.10	1.11	1.72	1.69	1.71
125% RDF + K + Zn	157.03	155.91	156.47	12.37	12.16	12.27	1.15	1.13	1.14	1.82	1.79	1.81
SEm±	1.600	1.605	1.605	0.190	0.185	0.187	0.004	0.005	0.004	0.004	0.004	0.004

CD (P=0.05)	4.570	4.569	4.569	0.310	0.527	0.532	0.012	0.013	0.012	0.012	0.012	0.012
Herbicides												
Weedy check	158.25	156.86	157.56	12.20	12.07	12.14	1.12	1.09	1.11	1.72	1.69	1.71
Weed free	161.68	160.42	161.05	12.13	11.91	12.02	1.12	1.09	1.10	1.72	1.68	1.70
Pendimethalin 30 EC pre-emergence @ 750 g a.i./ha	159.56	158.32	158.94	11.75	11.61	11.68	1.12	1.09	1.10	1.72	1.68	1.70
Pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha	162.80	161.49	162.15	12.01	11.81	11.91	1.12	1.09	1.11	1.72	1.69	1.71
Pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha.	76.66	75.80	76.23	9.95	9.69	9.82	1.12	1.10	1.11	1.73	1.69	1.71
Oxydiargyl 6 EC pre-emergence @ 90 g a.i./ha.	161.46	160.07	160.77	12.16	11.94	12.05	1.13	1.10	1.11	1.73	1.69	1.71
Propaquizafop 10% EC @ 100 g a.i./ha at 20-25 DAS	162.06	160.98	161.52	12.22	12.08	12.15	1.12	1.09	1.10	1.72	1.69	1.70
Fluazifop-p-butyl 13.4% EC @ 134 g a.i./ha at 20-25 DAS	162.06	160.87	161.47	12.12	11.88	12.00	1.12	1.10	1.11	1.73	1.69	1.71
SEm±	2.620	2.621	2.620	0.310	0.302	0.305	0.007	0.008	0.007	0.007	0.007	0.007
CD (P=0.05)	7.460	7.462	7.461	N.S.	0.861	0.869	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Conclusion

After weed free, total weed density was recorded lowest under pendimethalin 38.7 CS pre-emergence @ 750 g a.i./ha treatment, at 90 DAS, however, fertility levels did not bought significant variation in the total weed density at 90 DAS. Plant height and number of branches of all the treatments were significantly superior over pyrazosulfuron-ethyl 10 WP pre-emergence @ 150 g a.i./ha treatment, however, there was no significant variation in these observations was found in between other treatments. These growth parameters increase with increase in fertility levels. So, the maximum plant height and number of branches at 90 DAS were recorded in 125% (RDF + K + Zn).

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