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Nutrient uptake and economics of Indian mustard [*Brassica juncea* (L.) Czernj and Cosson] as influenced by tillage and irrigation frequency

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Abstract
A field experiment was conducted during the *rabi* season of 2014-15 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India) to study the effect of tillage and irrigation frequency on productivity of Indian mustard [*Brassica juncea* (L.) Czernj and Cosson]. The experiment was laid out in split-plot design with three replications. The main plot treatment consisted three tillage practices *viz.* Zero tillage, Reduced tillage (2 harrowing + 1 planking), Conventional tillage (1 deep ploughing with disc + 2 harrowing + 1 planking), whereas four levels of irrigations *i.e.*No irrigation, One irrigation (35 DAS), Two irrigations (35 DAS + 60 DAS), Three irrigations (35 DAS + 60 DAS + 90 DAS) were allocated to sub-plots. The tillage operations thus had positive effect on the nutrient uptake by the crop thereby recording a total of 142 kg NPK uptake under conventional tillage. Similarly increasing the frequency of irrigations recorded the highest nutrient uptake accounting for a total 135.4 kg NPK with application of three irrigations. As regards to the profitability, conventional tillage remained superior as compared to reduced tillage, recorded significantly higher Benefit: Cost ratio (3.14).Further, it can be also concluded Benefit: Cost ratio improved with increasing irrigation frequency up to three irrigations. However, application of two irrigations to the crop remained comparable with application of three irrigations.

Keywords: Mustard, tillage, irrigation frequency, nutrient uptake, return, economics, B-C ratio

Introduction
Oilseeds play a vital role in Indian economy, accounting for 5% of gross national product and 10% of the value of agricultural product. In India, oilseeds are the second largest agricultural commodity after cereals, which occupy about 13.5% of the gross cropped area in the country. India is the fourth largest oilseed economy in the world after the U.S., China and Brazil, and it is the second largest importer after china. The country accounts for 15 per cent of global oilseeds area, 7 per cent of vegetable oils production and 10 per cent of the total edible oils consumption (Jha *et al.*, 2012). Rapeseed-mustard is the third important oilseed crop in the world after soybean (*Glycine max*) and palm (*Elaeisguineensis* Jacq.). Among the seven edible oilseeds cultivated in India, rapeseed-mustard (*Brassica* spp.) contributes 28.6% to the total production of oilseeds. It ranks second in oilseeds production after groundnut, sharing 27.8% in the India's oilseed economy. Indian mustard accounts for about 75-80% of the 5.8 m ha of rapeseed and mustard with the productivity of 1142 kg ha^{-1} in the country. Mustard seed has 36% protein content with a high nutritive value. The oil content varies from 37 to 42%. It is a winter (*Rabi*) season crop that requires relatively cool temperature, a fair supply of soil moisture during the growing season and a dry harvest period. In the eastern Uttar Pradesh region the crop is primarily grown as a mixed crop mainly with wheat in rice wheat cropping system. As a pure crop it is grown on marginal lands under constraints of delayed sowing, nutrient, irrigation and plant protection. Therefore, to maintain the increasing production trend of Rapeseed and mustard in the country, it becomes imperative to boost the productivity of mustard in this region.

The productivity of Rapeseed-Mustard in Rice-Mustard system is low due to many related problems. The major contributory causes are delayed sowing. Cultivation of mustard after puddled transplanted rice requires relatively more tillage operations to bring the required tilth. Puddled soil generally becomes heavy due to breaking of water stable aggregates, increased

Bulk density and soil impedance. However, this loss can be minimized through manipulation of tillage operations enabling early sowing of mustard by adopting the concept of reduced tillage system.

Owing to its hardy nature and capacity to thrive well under poor condition of moisture, mustard is raised without adequate irrigation. This practice results in low yields (Rathore *et al.*, 1999) [14]. Water is costly and scarce input. Its judicious use is an important aspect to get maximum efficiency under resource conditions. Irrigation water has to be utilized in a manner that matcher the crops need. Optimum crop yield is not possible without application of timely and right amount of irrigation water. The yield of mustard in India is low as the crop is grown under rainfed condition. The crop is usually grown during November to January. Since rainfall during this period is inadequate and uncertain, mustard requires supplemental irrigation for its proper growth and development, otherwise the crop is likely to suffer from water stress and reduce ultimately the yield. In general, irrigation can be supplied to the crop based on the critical stages which are governed by the irrigation frequency or the number of irrigation given to a crop during its lifecycle. In general it can be stated that out of the four stages *viz.* the mid-season stage is most sensitive to water shortages (Brouwer *et al.* 1989). This is mainly because it is the period of highest crop water need. If water shortages occur during mid-season stages, the negative effect on the yield will be pronounced. The least sensitive to water shortages is the late season; this stage includes ripening and harvest. The growth stages of mustard are: vegetative stage, flowering stage, pod development stage, seed filling and ripening stage. Two irrigations one at pre-flowering and other at pod development stage are necessary for maximum seed yield of mustard (Ali, 1997).

Materials and Methods

The field experiment was conducted during the *Rabi* season of 2014-15 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh (India). The soil of experimental site was Gangetic alluvial having sandy clay loam texture with *p*H 7.4. Experimental soil was moderate in fertility with organic carbon of 0.35 per cent and available nitrogen content being 212.4 kg ha^{-1}, available phosphorus (25.7 kg ha^{-1}) and available potassium (187 kg ha^{-1}) in soil. "Ashirwad" variety of mustard was used for the experiment. The experiment was laid out in split-plot design with three replications. The main plot treatment consisted three tillage practices *viz.* Zero tillage, Reduced tillage (2 harrowing + 1 planking), Conventional tillage (1 deep ploughing with disc + 2 harrowing + 1 planking), whereas four levels of irrigations *i.e.*No irrigation, One irrigation (35 DAS), Two irrigations (35 DAS + 60 DAS), Three irrigations (35 DAS + 60 DAS + 90 DAS) were allocated to sub-plots. So the total numbers of treatment combinations were twelve. The treatments were replicated thrice to avoid any effect of heterogeneity.

Result and Discussion

Effect on nutrient uptake

A close examination of the data in Table 1 revealed marked effect of different tillage practices on N uptake by seed. All the tillage practices differed significantly in respect nitrogen uptake by seed. As regards the irrigation frequency, seed N uptake increased with increasing frequency of irrigation applications from one irrigation to three irrigations with respect to control. All the irrigation frequencies differed significantly in respect of nitrogen uptake by seed. A critical study of data on P uptake by seed Table 1 indicated improvement in P uptake by seed with each increment in intensity of tillage operations. All the tillage practices differed significantly in respect phosphorus uptake by seed. Similarly, P uptake by seed was also increased with increasing the frequency of irrigation application from one irrigation to three irrigations over control and the differences between any two levels remained significant. The K uptake by the seed of the test crop improved with increasing intensity of tillage operations from zero tillage to conventional tillage and the differences between any two levels remained significant. Increasing the irrigation frequency, from one irrigation to three irrigations increased the K uptake by seed over control. All the irrigation frequencies differed significantly in respect of potassium uptake by seed.

N uptake by stover, summarized in table 1 revealed, improvement in N uptake by stover increased with increase in intensity of tillage operations and the differences between any two levels remained significant. Further analysis of data revealed improvement in N uptake by stover with each increment of irrigation frequency to the highest level (three irrigations). All the irrigation frequencies differed significantly in respect of nitrogen uptake by stover. An inspection of the data revealed improvement in P uptake by stover with increasing intensity of tillage operations from zero tillage to conventional tillage and the differences between any two levels remained significant. Similarly, the different irrigation frequency influenced P uptake by stover to the level of significance. All the irrigation frequencies differed significantly in respect of phosphorus uptake by stover. Data pertaining to K uptake by stover furnished in table 1 revealed that increasing intensity of tillage operations from zero tillage to conventional tillage correspondingly enhanced K uptake by stover and the differences between any two levels remained significant. Similarly, increasing the frequency of irrigation application from one irrigation to three irrigation improved K uptake by stover over control. All the irrigation frequencies differed significantly in respect of potassium uptake by stover.

Nitrogen, phosphorus, potassium contents in seed and stover increased with increasing intensity of tillage operations up to conventional tillage (Table 1). A close examination of the data revealed marked effect of different tillage practices on N uptake by seed. All the tillage practices differed significantly in respect nitrogen uptake by seed. This could be attributed to the greater availability of nitrogen at higher tillage intensity due to better soil properties. In general, higher concentration of N, P and K were recorded in seed than straw suggesting efficient translocation of nutrients to the sink *i.e.* seed. Higher intensity of tillage operations assured the availability of nutrients in adequate amount. Hence, under conventional tillage, there was more healthy and vigorous plant growth as evident by taller plants, more number of leaf, branch, LAI and dry matter production. This accompanied with better nutrient contents which resulted in significantly higher nutrient uptake by seed and stover with increasing intensity of tillage up to conventional tillage (Table 1). These results are in close conformity with the findings of Arora *et al.* (2005) and Pal and Phogat (2006). Nitrogen, phosphorus and potassium uptake were positively influenced by tillage. The release of nutrient in soil solution depends upon intensity and capacity of soil to supply these nutrients. Tillage enhanced supply of nutrients and increased nitrogen, phosphorus and potassium content for their effective uptake.

As regards to irrigation application, seed N, P and K content increased with increasing frequency of irrigation applications from no irrigation to three irrigations. The differences were significant with respect to all the nutrients under study *viz.* nitrogen, phosphorus and potassium content of seed and stover (Table 1). This shows more efficient utilization irrigation in nutrient uptake by mustard. This supports the finding of Singh *et al.* (2015).

Table 1: Effect of tillage practice and irrigation frequency on nutrient uptake by seed and stover

Treatment	Nitrogen uptake (kg ha^1)		Phosphorus uptake (kg ha^1)		Potassium uptake (kg ha^1)	
	Seed	Stover	Seed	Stover	Seed	Stover
Tillage practices						
Zero tillage	42.11	27.85	5.72	1.70	7.17	34.91
Reduced tillage	45.23	30.92	6.36	1.90	7.80	38.07
Conventional tillage	49.26	34.21	6.81	2.09	8.42	41.27
SEm±	0.12	0.07	0.01	0.01	0.01	0.03
CD (P=0.05)	0.28	0.17	0.05	0.03	0.05	0.13
Irrigation Frequency						
Zero Irrigation	44.05	29.66	6.10	1.82	7.54	36.63
One Irrigations	45.09	30.36	6.24	1.86	7.71	37.51
Two Irrigations	46.00	31.50	6.35	1.93	7.88	38.68
Three Irrigations	46.98	32.45	6.48	1.98	8.05	39.50
SEm±	0.09	0.06	0.01	0.00	0.01	0.03
CD (P=0.05)	0.25	0.13	0.03	0.01	0.03	0.10

Effect on economics

There was marked difference in the cost of cultivation of mustard under different treatments. The cost of cultivation was markedly enhanced with increasing intensity of tillage practices from zero tillage to conventional tillage. Similarly, with each increment in irrigation frequency there was corresponding increase in cost of cultivation of mustard up to three irrigations. The data with respect to gross return or income as influenced by tillage practices and irrigation frequency are presented in table 2. An insight into the data clearly demonstrated that gross return enhanced significantly with each increment of intensity of tillage operations, recording maximum with conventional tillage. Lucid effect of increase in irrigation frequency was also observed on gross return. Application of irrigations significantly increased gross return over lower levels of irrigation application. Increasing tillage intensity from zero tillage to conventional tillage correspondingly improved net return. However, the differences were significant between any two tillage practices.Net return of mustard was increased with increasing frequency of irrigation application up to three irrigations. Application of three irrigations remained superior as compared to other irrigation treatments, recorded significantly higher net return over other irrigation treatments. Data pertaining to Benefit: Cost ratio as affected by various treatments is presented in Table 2. A close examination of data revealed improvement in B: C ratio due to increase in intensity of tillage operations from conventional tillage to zero tillage. Conventional tillage remained superior as compared to reduced tillage, recorded significantly higher Benefit: Cost ratio. Further, it was observed that Benefit: Cost ratio improved with increasing irrigation frequency up to three irrigations. However, the significant difference in B: C ratio was observed only between no irrigation and two irrigations application to the crop while two irrigation and three irrigations remained comparable.

In modern agriculture, crop production is taken as business. Therefore, based on the experimental results, the practices giving maximum net return under particular set of condition can only be recommended to the farmers. Under present investigation large variations were noticed for gross return and cost of cultivation under different tillage practices and irrigation frequency. The differences in gross return under various tillage practices and irrigation frequencies were mainly due to the differences in seed yield. Whereas the cost of cultivation was varied due to different tillage practices and irrigation frequency.

Increasing intensity of tillage practices significantly enhanced the gross return up to highest level (conventional tillage). However, the cost of cultivation was also increased by increasing the intensity of tillage operations. The net return also increased significantly with increasing the intensity of tillage operations. The benefit: cost ratio also followed the similar trend. This shows that conventional tillage was more remunerative over reduced and zero tillage. Gross return and net return were also increased with increasing frequency of irrigation application from no irrigation to three irrigations. The difference between any two treatments remained significant. This shows that though seed and stover yield differed significantly between two and three irrigations and due to better market price of produce, application of three irrigations was more remunerative than lower levels. However, the benefit: cost ratio increased with increasing the frequency of irrigations. Irrigation frequency of two irrigations and three irrigations being at par recorded significantly higher benefit: cost ratio than control. This shows that profit earned per unit of investment was more with the use of two irrigations and three irrigations. This is in conformity with the findings of Parihar *et al.* (2009).

Table 2: Effect of tillage practice and irrigation frequency on economics of cultivation

Treatment	Cost of cultivation	Gross return	Net return	B:C ratio
Tillage practice				
Zero	14,639	55,804	41,165	2.81
Reduced tillage	15,639	61,249	45,610	2.91
Conventional tillage	17,439	72,243	54,804	3.14
SEm±	-	642	542	0.048
CD (P=0.05)	NA	2057	1547	0.184
Irrigation frequency				
No irrigation	14,639	56,329	41,690	2.84
One irrigation	15,139	60,413	45,274	2.99
Two irrigation	15,439	66,390	50,951	3.30
Three irrigation	15,739	69,542	53,803	3.41
SEm±	-	351	221	0.036
CD (P=0.05)	NA	1152	657	0.125

Conclusion

Nitrogen, phosphorus, potassium contents in seed and stover increased with increasing intensity of tillage operations up to conventional tillage. The tillage operations thus had positive effect on the nutrient uptake by the crop thereby recording a total of 142 kg NPK uptake under conventional tillage. Similarly increasing the frequency of irrigations recorded the highest nutrient uptake accounting for a total 135.4 kg NPK with application of three irrigations. As regards to the profitability, conventional tillage remained superior as compared to reduced tillage, recorded significantly higher Benefit: Cost ratio (3.14). Further, it can be also concluded Benefit: Cost ratio improved with increasing irrigation frequency up to three irrigations. However, application of two irrigations to the crop remained comparable with application of three irrigations.

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