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Productivity 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. All the yield attributing characters were positively influenced by increasing the intensity of tillage operations and the frequency of irrigation. In the present investigation, yield attributing characters *viz.* siliqua on main shoot, siliquaeplant^{-1}, length of siliqua, seeds siliqua^{-1}, 1000-seed weight and seed yield were are markedly higher with conventional tillage and three irrigations at 35 DAS, 60 DAS and 90 DAS.Conventional tillage produced 30.6% and reduced tillage recorded 10.2% higher seed yield than and zero tillage. Application of one irrigation, two irrigations and three irrigations recorded 7.8, 18.6% and 24.2% higher yield as compared to the control.

Keywords: Mustard, tillage, irrigation frequency, yield attributes, yield

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 (Anonymous 2014). 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), and 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 of tillage practices on yield attributes and yield of mustard

In the present investigation, yield attributing characters *viz.* siliqua on main shoot, siliquaeplant^{-1}, length of siliqua, seeds siliqua^{-1} and 1000-seed weight were are markedly higher at higher intensity of tillage operations. Siliqua on main shoot as influenced by various treatments are summarized in Table 1. A close examination of the data revealed marked reduction in number of siliqua on main shoot with decreasing intensity of tillage from conventional tillage to zero tillage and the differences were significant between any two tillage practices. There was a significant effect of different tillage practices on number of siliqua plant^{-1}. Increasing the intensity of tillage from zero tillage to reduced tillage and conventional tillage progressively increased number of siliquae plant^{-1} up to the level of significance. Siliqua length was found to increase with increasing intensity of tillage from zero tillage to conservation and conventional tillage. Significant difference was noticed between zero tillage, reduced tillage and conventional tillage with respect to length of siliqua. Pronounced effect of tillage practices was found on seeds siliqua^{-1}. Decreasing tillage intensity from conventional to conservation and thereafter zero tillage significantly reduced the number of seeds siliqua^{-1}.The different tillage practices differed markedly in respect of test weight of 1000 seeds. Test weight increased with increasing the intensity of tillage operations from zero tillage to conventional tillage. Among the different tillage practices conventional tillage recorded highest test weight of (5.04 g), followed by reduced tillage (4.63 g) and zero tillage (4.19 g) which were statistically significant. The seed yield increased with increasing intensity of tillage operations. Conventional tillage produced 30.6% and reduced tillage recorded 10.2% higher seed yield than and zero tillage. It is evident from the data that increasing the intensity of tillage operations markedly increased the harvest index and was found to be significant between any two treatments. In the present investigation, yield attributing characters *viz*. siliqua on main shoot, siliquae plant^{-1}, length of siliqua, seeds siliqua^{-1} and 1000-seed weight were are markedly higher at higher intensity of tillage operations. However, for all the yield attributing characters, the differences were significant. The higher number of siliqua on main shoot at conventional tillage is attributed to taller plant and thereby longer central axis at higher intensity of tillage operations due to better growth condition. The increase in siliquae plant^{-1} may be explained due increase in number of branches under higher tillage levels. With the conventional tillage due to better vegetative growth and initial establishment, the tissue differentiations from the somatic to reproductive, meristematic activity and the development of floral primordia might have been enhanced causing greater production of flowers which latter developed to siliqua. Higher tillage intensity giving better growth is likely to induce greater translocation of photosynthates from leaves *via* stem to sink site *i.e.* siliqua and seeds. This resulted in bigger siliqua and more numbers of seed which on maturity becomes bold with highest test weight. These results are in accordance with the findings of Mondal *et al.* (2008) [7].Increased intensity of tillage operations levels enhanced the seed and stover yields significantly in conventional tillage. The highest seed yield increase was recorded under conventional tillage followed by reduced tillage and zero tillage. Higher yield was associated with higher intensity of tillage operations were consistently observed because of enhanced growth and yield attributes. The positive response of mustard to increased tillage operations in conventional tillage was also reported by Mandal *et al.* (1994) and Saha *et al.* (2010) [15, 16]. Harvest index of mustard was found to increase with increasing tillage operations from zero tillage to conventional tillage (Table 2). And the differences differed significantly. These facts were also supported by Mondal *et al.* (2008) [7].

Effect of irrigation frequency on yield attributes and yield of mustard

Yield attributing characters *viz.* siliquae on main shoot, siliqua plant^{-1}, seeds siliqua^{-1}, siliqua length, 1000 seed weight and seed yield plant^{-1} are presented in Table 1. All the yield attributing characters were positively influenced by increasing frequency of irrigation. Increase in irrigation frequency of one, two and three irrigations produced marked increase with respect to number of siliqua on main shoot over the control. It was noted that increase in frequency of irrigation from no irrigation to three irrigations correspondingly enhanced the number of siliqua per plant and the one, two and three irrigations produced significantly higher siliquae plant^{-1} then control. Similarly, three irrigations also proved its distinct superiority over two irrigations and one irrigation respectively. Increasing the frequency of irrigation application, though increased siliqua length of mustard but the differences were not significant between two irrigation and three irrigations. Marked effect of irrigation frequency was also noticed on the production of seeds siliqua^{-1}. Increasing frequency of irrigation from no irrigation to one, two and three irrigation correspondingly increased the number of seeds siliqua^{-1}. As regards the irrigation frequency, test weight of mustard improved markedly with increasing irrigation frequency from no irrigation to three irrigations. The difference between no irrigation and one irrigation and two irrigation and three irrigations were significant. It is also clear from the data that with increasing the frequency of irrigation, the seed yield (kg ha^{-1}) of mustard improved markedly and significant increase in yield with increase in irrigation levels to three irrigations over the control. Application of one irrigation, two irrigations and three irrigations recorded 7.8, 18.6% and 24.2% higher yield as compared to the control. The data presented in table 2 further revealed that harvest index of test crop increased with increase in irrigation frequency and the harvest index was found to be significant between any two treatments. As irrigation increases the plant water status, thus boosting metabolism and the availability of different nutrients in the soil, its application has been found to enhance the process of tissue differentiation, cell multiplication, cell enlargement i.e. from somatic to reproductive phase, meristematic activity and development of floral primodia leading thereby to increased flowering and ultimately the fruit setting. As a result of this, higher siliqua plant^{-1} was obtained with increasing frequency of irrigation application up to highest level (3 irrigations). Moreover, the taller shoot produced under the influence of increasing frequency of irrigation, enabled the plants to bear higher number of siliqua on main shoot which is considered to be the major determinate of mustard seed yield. As water is the chief metabolic reactant in all biochemical reactions of the plants and major medium for translocation in the plant, there would have been greater translocation of photosynthates from source to sink leading thereby to production of bigger siliqua with more number of seeds. The favourable effect of irrigation on yield attributing character *viz.* siliquae on main shoot, siliqua plant^{-1}, seed siliqua^{-1}, siliqua length and 1000 seed weight was reflected on seed yield plant^{-1} and seed yield ha^{-1}. Consequently, the seed yield was increased significantly with increasing the frequency of irrigation up to the highest level (3 irrigations). The results are in agreement with the findings of Piri and Sharma (2007) [12], Verma *et al.* (2009) and Rajput and Karauria (2010) [13]. Higher irrigation frequency produced taller plants and increased no of functional leaves plant^{-1}, primary and secondary branches plant^{-1} and accumulation of dry matter plant^{-1} which ultimately resulted into higher stover yield. This observation confirms the findings of Kantwa and Meena (2002) [5] and Singh and Singh (2014).The harvest index was improved with the application of irrigation. The harvest index improved with increasing the irrigation frequency and the difference was significant. This shows that at higher frequency of irrigation application, the translocation of photosynthates to the sink was efficient that favoured more to the stover production.

Conclusion

All the yield attributing characters were positively influenced by increasing the intensity of tillage operations and the frequency of irrigation. In the present investigation, yield attributing characters *viz*. siliqua on main shoot, siliquaeplant^{-1}, length of siliqua, seeds siliqua^{-1}, 1000-seed weight and seed yield were are markedly higher with conventional tillage and three irrigations at35 DAS, 60 DAS and 90 DAS.Conventional tillage produced 30.6% and reduced tillage recorded 10.2% higher seed yield than and zero tillage. Application of one irrigation, two irrigations and three irrigations recorded 7.8, 18.6% and 24.2% higher yield as compared to the control.

Table 1: Effect of tillage practice and irrigation frequency on yield attributes of mustard

Treatment	Siliquae on main shoot	Siliquae plant^{-1}	Siliqua length (cm)	Seeds siliqua^{-1}	1000-seed weight (g)
Tillage practice					
Zero tillage	38.93	271.45	4.15	14.58	4.19
Reduced tillage	46.13	277.05	4.50	14.94	4.63
Conventional tillage	46.88	282.25	4.83	15.27	5.04
SEm±	0.42	1.74	0.12	0.18	0.17
CD (P=0.05)	1.49	5.20	0.42	0.43	0.53
Irrigation frequency					
No irrigation	40.21	268.31	3.96	14.38	3.95
One irrigation	42.54	274.81	4.36	14.79	4.45
Two irrigation	43.75	279.83	4.68	15.12	4.85
Three irrigation	45.65	284.73	4.98	15.43	5.23
SEm±	0.25	2.12	0.07	0.08	0.10
CD (P=0.05)	0.78	4.74	0.18	0.19	0.23

Table 2: Effect of tillage practice and irrigation frequency on yield of mustard

Treatment	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index
Tillage practice			
Zero tillage	1465	4529	24.44
Reduced tillage	1615	4724	25.48
Conventional tillage	1914	5253	26.71
SEm±	72	91	0.26
CD (P=0.05)	215	357	0.75
Irrigation frequency			
No irrigation	1477	4634	24.17
One irrigation	1591	4728	25.18
Two irrigation	1753	5135	25.45
Three irrigation	1837	5247	25.93
SEm±	25	205	0.12
CD (P=0.05)	71	602	0.25

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