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RESPONSE OF MUSTARD (*Brassica juncea* L.) TO MOISTURE REGIMES AND LEVELS OF NITROGEN, PHOSPHORUS, POTASH AND ZINC

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ABSTRACT

An experiment was conducted during winter season of 2007-08 and 2008-09 at Agricultural Research Station, Morena (MP) on a sandy loam soil to assess the response of mustard (*Brassica juncea* L.) to varying moisture regime and levels of nitrogen, phosphorus, potash and zinc. Two irrigations applied at flower initiation and siliqua formation stages gave significantly higher growth and yield attributes, water utilization efficiency (WUE), production efficiency, nutrient uptake and oil yield, and resulted in 11.2 and 33.3% higher seed yield over one irrigation applied either at flower initiation- or siliqua-formation-stages, respectively. Among the fertility levels tested, 125% RDF (100, 22, 20.7 and 6.25 kg ha^{-1} of N, P, K and Zn, respectively) gave significantly higher values of growth and yield contributory characters, WUE, production efficiency, nutrient uptake and quality components over 100% RDF (80.0, 17.6, 16.6 and 5.0 kg ha^{-1} of N,P, K and Zn, respectively). Application of 125% RDF gave 19.94, 11.86 and 3.97% higher mustard seed yield over 50, 75 and 100% RDF, respectively. The highest oil content was found in 125% RDF treatment which was significantly superior to 50% RDF. The interaction effect among irrigation and fertility levels was non-significant. Maximum net monitory returns of ₹ 40441 and 36916 ha^{-1} and benefit cost ratio of 4.37 and 3.82 were realized under two irrigations and 125% RDF treatments, respectively.

Key words: Moisture usage, monetary returns, mustard, nutrient uptake, quality, seed yield

INTRODUCTION

Oilseeds play vital role in Indian economy, accounting for 5% gross national product and 10% of the value of agricultural product. Rapeseed-mustard [*Brassica juncea* (L.) Czernj and Coss] is an important oilseed crop in the world. Worldwide, India ranks 2nd in acreage and 3rd in production contributing 21.7 and 10.7% to the estimated global area (30.74 million ha) and production (59.93

million tonnes mustard), respectively, during 2009-2010 (Anonymous, 2010). The process of productivity of oilseed is now slowing down coupled with decline in soil fertility. Low and imbalanced use of fertilizers is one of the major reasons for low productivity. It has been recognized that N, P and K fertilizers alone are not always sufficient to provide balanced nutrition for optimal yield and quality of mustard (Jain and Sharma, 2000). Thus the application of secondary and micronutrient element has to be made. Zinc is a micro-nutrient and a few years back nobody thought of its significance in crop production. Reports reveal that growth and productivity of mustard increased with increased use of Zn in field (Baudh and Prasad, 2012).

Coarse textured soils with low organic matter content of Indo-Gangetic alluvium plains are inherently low in available zinc status (Katyal and Rattan, 1993). In this context balanced nutrition is necessary, which means application of all the deficient plant nutrients in sufficient amount, in appropriate forms and ratios is necessary to derive maximum benefit from the applied nutrients (Roul *et al.*, 2006). The adequate soil moisture is required for normal development of mustard at all the critical stages of crop growth, which can be created by timely scheduling of irrigation (Panda *et al.*, 2000; Chauhan *et al.*, 2002). During last 30 years 50-55% improvement in crop productivity has been attributed to irrigation and fertilizers but their efficiency has remained low (Wamjari *et al.*, 2004). The present study was undertaken to assess the effect of various moisture regimes and NPK and Zn levels on growth, yield, quality, nutrient uptake and economics of mustard in Indo-Gangatic plains of India.

MATERIALS AND METHODS

Field experiments were conducted during winter seasons of 2007-08 and 2008-09 at Zonal Agricultural Research Station, Morena, Madhya Pradesh (India). The soil of experimental field was sandy loam, low in available nitrogen (134.5 kg ha^{-1}) and zinc (0.43 mg kg^{-1}), medium in available phosphorus (14.2 kg ha^{-1}) and potassium (223 kg ha^{-1}) with pH 7.7. The available moisture at field capacity was 23.5%, bulk density 1.4 g cc^{-1}, permanent wilting point 7.2% and infiltration rate 14.5 mm hr^{-1} with electrical conductivity 0.32 dSm^{-1}. No rainfall was received during crop growth period.

The experiment was laid out in the same field in split-plot design with each treatment replicated four times. Twelve treatment combinations, comprising of three irrigation schedules *viz.*, one irrigation at flower initiation stage, one irrigation at siliquae formation stage and two irrigations at flower initiation and siliquae formation stages in main plots and four levels of NPK fertilizers + zinc in sub-plots. The N, P, K and Zn were applied @ 50, 75, 100 and 125% of the recommended doses of fertilizers (RDF) and the recommended N,P, K and Zn applied was 80.0: 17.6: 16.6: 5.0 kg ha^{-1}. Half of the nitrogen and full dose of phosphorus, potash and zinc were applied through urea, diammonium phosphate, muriate of potash and zinc sulphate before seed sowing. The remaining nitrogen was top dressed after 1st irrigation applied as per treatments. Mustard variety “JM-4” was sown in the 3rd week of October and harvested in the 3rd week of February during both the years. The seed were sown @ 5 kg ha^{-1} maintaining plant spacing of 30 cm x 10 cm. Other operations were followed as per the recommended package of practices of the crop. The irrigation was applied at a depth of 7 cm as per treatment in addition to 8 cm as pre-sowing irrigation.

Growth parameters like plant height, leaves $plant^{-1}$, branches $plant^{-1}$, siliquae $plant^{-1}$ and yield parameters such as seeds $siliqua^{-1}$, seed weight and 1000-seed weight were recorded at harvest from five randomly sampled plants from each treatment. The water use efficiency (WUE) in kg ha^{-1}-cm^{-1} was calculated by dividing the seed yield with total water applied to the crop. The production efficiency was computed by dividing the seed yield with total days of crop period. The nutrient use in seed was calculated by dividing the seed yield with the quantity of NPKZn applied to the crop as per treatment. Nitrogen content was determined by micro-Kjeldahl method (Chopra and Kanwar, 1980), phosphorus content colorimetrically by vanadomolybdate procedure (Champan and Pratt, 1961), potassium by flame photometric method (Jackson, 1973) and zinc by atomic absorption spectrophotometer (Model Perkin Elemer AA 100). The oil content was determined by extracting 2 g seed material by petroleum ether (B.P. 60-80^{o}C) in a Soxhlet oil extractor glass apparatus for 8 h at 60^{o}C as per AOAC procedure (AOAC, 1960). The economics of various treatments was calculated based on input and output at market price, which was Rs. 2400 and Rs.50 q^{-1} for mustard grain and straw, respectively. The data on various biometric characters were statistically analyzed as per the method of Panse and Sukhatme (1999).

RESULTS AND DISCUSSION

Growth and yield

Growth and yield attributing characters of mustard were significantly influenced by different irrigation regimes in both the years as well as in pooled analysis (Table 1). Among irrigation schedules, two irrigation applied at flower initiation and siliquae formation stage gave significantly higher plant height, leaves plant^{-1}, branches plant^{-1}, siliquae plant^{-1}, seed plant^{-1}, seed weight plant^{-1} and 1000-seed weight over one irrigation applied either at flower initiation or siliquae formation stage. The increase in growth and yield components may be attributed to more soil moisture supplied with two irrigations providing congenial growth environment which improved the cell turgidity and stomatal opening to the sink (Chauhan *et al*., 2002). Single irrigation applied at flower initiation stage also maintained significantly higher values of all the yield contributing characters over single irrigation at siliquae formation. All these characters progressively declined due to the delay in irrigation at siliquae formation stage which resulted in water stress at grand growth stage and adversely affected nutrient translocation, photosynthesis and metabolic activity in the plant system.

The progressive and significant increase in growth and yield components of mustard were noticed with successive increase in fertilizer levels from 50 to 125% NPKZn (Table 1). Maximum values for growth and yield attributes were achieved in treatment wherein 125% NPKZn was applied, which showed significant improvement over other fertilizer doses. The addition of fertilizer

Table 1: Influence of irrigation and N, P, K and Zn levels on growth and yield attributes of mustard [2 years (2007-08 and 2008-09) pooled data]

Treatments	Plant height (cm)	Leaves plant^{-1} (No.)	Branches plant^{-1} (No)	Siliquae plant^{-1} (No)	Seed siliquae^{-1} (No.)	Seed weight plant^{-1} (g)	1000-seed weight (g)
Irrigation schedules							
One at flower initiation stage	176.4	17.28	8.44	281	10.77	11.56	4.64
One at siliquae formation stage	172.5	16.28	7.62	245	10.16	10.81	4.20
Two – 1st at flower initiation & 2nd at siliquae formation stage	181.3	19.40	8.89	290	12.15	12.32	4.81
SEm±	0.42	0.25	0.06	1.66	0.27	0.08	0.07
$CD_{0.05}$	1.25	0.74	0.16	5.03	0.78	0.25	0.21
NPKZn levels (kg ha^{-1})							
40:8.8:8.3:2.50	173.5	17.17	7.69	252	10.34	10.79	4.41
60:13.2:12.4:3.75	176.9	17.76	8.12	266	10.96	11.25	4.48
80:17.6:16.6:5.0	178.8	18.68	8.78	288	11.61	12.14	4.73
100:22:20.7:6.25	180.2	18.75	8.88	295	11.94	12.29	4.83
SEm±	0.30	0.17	0.07	1.45	0.20	0.08	0.06
$CD_{0.05}$	0.92	0.50	0.18	4.38	0.62	0.24	0.18

improved nutrient uptake which might have favoured the plant growth and helped in improving yield attributing characters under125% NPKZn. On the other hand the lowest values of this parameter were registered with 50% NPKZn. These findings are in close conformity with Jain and Sharma (2000) and Reager *et al.* (2006) who reported that increasing nitrogen from 0 to 80 and 40 to 100 kg ha^{-1} significantly enhanced siliquae $plant^{-1}$, seed $siliquae^{-1}$, siliqua length and test weight of mustard. The interaction effect between irrigation and fertility levels were non-significant. Significant increase in yield attributing components of mustard with increasing levels of NPK and Zn were also reported by Yadav *et al*. (2010) and Baudh and Prasad (2012).

Seed yield and quality

The seed and biological yield of mustard improved significantly due to irrigation schedules in both the years and pooled over two years (Table 2). Two irrigations applied at flower initiation and siliquae formation stages showed best performance with respect to seed yield (2.08 t ha^{-1}) and straw yield (4.80 t ha^{-1}) improvement which was 11.2 and 33.3% higher in seed yield and 7.4 and 27.3% in straw production over single irrigation applied either at flower initiation or at siliquae formation stage, respectively. Increase in seed and straw yield may be due to vigorous growth and higher order of growth and yield components due to adequate supplies of moisture to the crop at grand growth and reproductive phase under two irrigations as compared to single irrigation treatment at flower initiation stage or at siliquae formation stage.

The fertilizer application significantly increased seed yield and stover production of mustard with subsequent increase in fertilizer doses from 50 to 125% NPKZn (Table 2). The mean response gain due to 125% NPKZn was 17.1, 12.2 and 4.2% in seed yield and 19.9, 11.8 and 4.0% in stover yield over 50, 75 and 100% NPKZn, respectively. Fertilizer application provided better conducive condition for better nutrient uptake which, in turn, helped the plants to boost their growth, leading to the development of yield attributes through supply of more photosynthates towards reproductive sink with the successive increase in nutrient doses. The results are in conformity with Sarangthem *et al*. (2008) who reported that the application of 60 kg N ha^{-1} gave highest rape-seed (1.18 t ha^{-1}) and straw (1.69 t ha^{-1}). Yadav *et al*. (2010) also reported that the application of increasing levels of NPK from 50 to 125% ha^{-1} significantly enhanced the seed yield of mustard.

Table 2: Influence of irrigation and N, P, K and Zn levels on yield, quality and economics of mustard [2 years (2007-08 and 2008-09) pooled data]

Treatments	Seed yield (t ha^{-1})			Stover production (t ha^{-1})	Harvest index (%)	Net returns (₹ ha^{-1})	B:C ratio	Oil content (%)	Oil production (kg ha^{-1})
	2007-08	2008-09	Pooled						
Irrigation schedules									
One at flower initiation stage	1.69	2.05	1.87	4.47	29.5	35808	4.11	40.95	765
One at siliquae formation stage	1.42	1.70	1.56	3.77	29.3	27997	3.43	41.10	641
Two – 1st at flower initiation & 2nd at siliquae formation stage	1.98	2.18	2.08	4.80	30.2	40441	4.37	40.65	845
SEm±	0.02	0.02	0.01	0.11	--	--	--	0.07	18
$CD_{0.05}$	0.08	0.05	0.05	0.30	--	--	--	0.23	51
Levels of NPKZn (kg ha^{-1})									
40:8.8:8.3:2.50	1.56	1.82	1.69	3.71	29.6	31085	3.68	40.53	686
60:13.2:12.4:3.75	1.65	1.92	1.78	3.98	29.6	32986	3.74	40.86	727
80:17.6:16.6:5.0	1.75	2.05	1.90	4.28	29.8	35477	3.82	41.05	782
100:22:20.7:6.25	1.84	2.13	1.98	4.45	29.9	36916	3.82	41.19	818
SEm±	0.03	0.01	0.01	0.05	--	--	--	0.16	9.0
$CD_{0.05}$	0.09	0.03	0.04	0.15	--	--	--	0.45	24.0

Economics of crop have been work out on the basis of different cost of material and labour cost of cultivation per hectare

The irrigation and fertility levels caused significant variations in the quality of mustard (Table 2). One irrigation at siliquae formation stage recorded significantly higher oil content (41.1%) over other moisture regimes. The probable reason for low oil content under two irrigation applied at flower initiation + siliquae formation stages may be adequate supply of moisture that help in the greater uptake of nitrogen which, in turn, lowers the oil content in seed. However, maximum oil production (845 kg ha^{-1}) was achieved under two irrigations, which might be owing to higher seed yield. The oil content and oil production gradually increased with increase in fertility levels and maximum oil content and oil production was obtained under 125% NPKZn (41.2% and 818 kg ha^{-1}). The highest oil content with increasing fertility levels appears due to more nutrient availability to the plants. Improvement in seed yield helped in increasing the oil production. Sarangthem *et al*., (2008) also reported that addition of nitrogen (60 kg ha^{-1}) significantly increased oil content in mustard seed.

Moisture and nutrient use

Water use efficiency (WUE) and production efficiency improved significantly due to the variation in moisture regimes (Table 3). Maximum production efficiency was achieved under two irrigation (17.38 kg ha^{-1}day^{-1}) treatment, followed by single irrigation applied at flower initiation stage (15.65 kg ha^{-1}day^{-1}). This might be attributed to the higher seed yield under these treatments. Significantly high WUE (125.3 kg ha^{-1}-cm^{-1}) was realized with single irrigation at flower initiation stage than single irrigation at siliquae stage. However, two irrigations showed marked improvement in WUE over siliquae formation stage of irrigation. WUE in terms of seed yield was highest with single irrigation at flower initiation stage as under such conditions plants would use available moisture most economically and thereby increase WUE as compared to two irrigations. The consumptive use of water was markedly higher under two irrigations than that of single irrigation. This might be due to the fact that under two irrigations, evaporation was at potential rate due to availability of more soil moisture than the crop irrigated only once (Panda *et al*., 2000; Chauhan *et al*., 2002). Irrigation regimes exerted marked influence on moisture extraction patterns of the crop. Maximum soil moisture depletion from 0-20 cm soil layers was registered under two irrigations which might have

Table 3: Influence of irrigation and N, P, K and Zn levels on production efficiency, consumptive use of water, water use efficiency and moisture extraction pattern of mustard [2 years (2007-08 and 2008-09) pooled data]

Treatments	Production efficiency (kg ha^{-1}day^{-1})	Water applied (mm)	Consumptive use of water (mm)	Water use efficiency (kg ha^{-1}-cm^{-1})	Moisture extraction (%) pattern from different soil depths (cm)		
					0-20	20-40	40-60
Irrigation schedules							
One at flower initiation stage	15.65	150	210.8	125.3	47.5	31.5	18.4
One at siliquae formation stage	13.06	150	180.0	104.5	39.6	24.2	21.3
Two – 1st at flower initiation & 2nd at siliquae formation stage	17.38	220	265.6	115.8	54.9	36.3	15.1
SEm±	0.15	--	--	0.34	--	--	--
$CD_{0.05}$	0.42	--	--	1.01	--	--	--
Levels of NPKZn (kg ha^{-1})							
40:8.8:8.3:2.50	14.11	173	175.2	105.9	41.3	25.6	15.7
60:13.2:12.4:3.75	14.89	173	195.4	111.6	45.5	29.5	17.0
80:17.6:16.6:5.0	15.90	173	245.6	119.1	49.3	32.4	19.4
100:22:20.7:6.25	16.64	173	259.3	124.1	53.1	35.2	20.9
SEm±	0.16	--	--	0.35	--	--	--
$CD_{0.05}$	0.45	--	--	1.06	--	--	--

Table 4: **Influence of irrigation and N,P,K and Zn levels on nutrient use efficiency, nutrient uptake and nutrient status of mustard [2 years (2007-08 and 2008-09) pooled data]**

Treatments	Nutrient use efficiency (kg seed kg nutrient^{-1})				Total nutrient uptake (kg ha^{-1})				Available nutrient status (kg ha^{-1})			
	N	P	K	Zn	N	P	K	Zn	N	P	K	Zn*
Irrigation schedules												
One irrigation at flower initiation stage	29.4	58.8	117.7	471	97.3	15.5	77.6	0.531	129	13	221	0.40
One irrigation at siliquae formation stage	24.8	49.6	99.3	394	81.1	12.9	64.8	0.443	130	14	222	0.42
Two irrigations 1st at flower initiation and 2nd at siliquae formation stage	32.6	65.2	130.5	522	108.0	17.2	86.2	0.732	128	13	220	0.38
SEm±	1.30	2.25	3.4	22.0	4.2	0.70	2.3	0.04	0.8	0.5	1.0	0.11
$CD_{0.05}$	3.80	6.8	9.9	64.3	12.5	2.15	7.2	0.12	NS	NS	NS	NS
Levels of NPKZn (kg ha^{-1})												
40:8.8:8.3:2.50	42.3	84.6	169.4	677	87.7	14.0	70.0	0.480	128	13	220	0.37
60:13.2:12.4:3.75	29.7	59.5	119.1	474	92.5	14.8	73.9	0.505	129	13	220	0.39
80:17.6:16.6:5.0	23.8	47.6	95.4	380	98.8	15.8	78.9	0.539	129	14	222	0.41
100:22:20.7:6.25	19.8	39.7	79.5	316	102.9	16.4	82.1	0.512	130	14	223	0.43
SEm±	1.83	2.72	5.0	30.4	1.61	0.26	1.23	0.009	0.3	0.2	0.6	0.003
$CD_{0.05}$	5.53	8.30	15.1	90.3	5.0	0.80	3.71	0.025	0.9	0.6	1.0	0.015

*****mg kg^{-1}

helped in better root development in upper profiles due to adequate availability of soil moisture. The lowest extraction was noticed under siliquae formation stage of irrigation. However, reverse was true for 40-60 cm soil profile wherein maximum amount of moisture was depleted under siliquae formation stage of irrigation. Under this treatment, the crop suffered from water scarcity in upper layers, compelling the roots to go deeper in search of moisture. WUE, consumptive use of water, soil moisture depletion and production efficiency increased appreciably due to increasing fertility levels (Table 3). The highest values for these four parameters, on an average, were associated with 125% NPKZn, perhaps due to improved vegetative growth and extensive root system which enabled the plants to utilize more nutrients with increased levels of fertilizer.

The application of irrigation showed significant positive responsive on nutrient use efficiency (NUE) and total NPKZn uptake (Table 4). Maximum NUE and total NPKZn uptake was observed under two irrigations at flower initiation and siliquae formation stages. Single irrigation at flower initiation also registered significantly higher NUE and total nutrient uptake than single irrigation at siliquae formation stage. Higher soil moisture availability under two irrigations appeared to have improved the physiological and metabolic functions inside the plant and led to higher seed yield and biomass production. The available nutrient status at crop harvest remained unaffected due to moisture regimes. The significant reduction in nutrient use was observed with increasing levels of nutrients. However, total NPKZn uptake and available nutrient status of soil improved significantly due to successive increase in fertility levels (Table 4). The highest NUE, total NPKZn uptake and available nutrient status were observed with 125% NPKZn. This might be owing to the increased supply of nutrient sources to the crop. Similar findings were also reported by Yadav *et al*. (2010).

Economics

Irrigation and fertility levels brought about considerable variation in harvest index, net returns and B:C ratio (Table 2). However, two irrigations applied at flower initiation and siliquae formation stages fetched highest harvest index (30.2%), net monitory returns (₹ 40441 ha^{-1}) and highest B:C ratio (4.37). Maximum harvest index (29.97), net returns (₹ 36916 ha^{-1}) and B:C ratio (3.82) were realized with 125% NPKZn. This might be due to higher seed yield in these treatments.

Conclusion: From the present study it may be concluded that two irrigation (at flowering + siliquae formation stages) schedule was beneficial for the growth components, yield, nutrient uptake and net return of mustard. However, maximum oil content was found with single irrigation at siliquae formation stage. The results revealed that 125% NPKZn significantly improved yield attributing characters, yields, oil content, net returns, production efficiency, WUE and nutrient uptake in mustard. The nutrient use efficiency significantly decreased with increasing levels of nutrient.

REFERENCES

Anonymous. 2010. *17th Annual All India Rapeseed-Mustard Research Workers Group Meeting.* Sep. 1-3, 2010. RVSKVV, Gwalior Madhya Pradesh, India.

AOAC. 1960. *Official Methods of Analysis of the Association of Official Agricultural Chemist* (9th edn.). AOAC, Washington, USA.

Baudh A.K. and Prasad, G. 2012. Interaction effect of different dose of sulphur and zinc with nitrogen, phosphorus and organic manure on growth and productivity of mustard (*Brassica compestris*). *Indian Journal Science Research,* **3**: 141-144.

Chapman, H.D. and Pratt, P.F. 1961. *Method of Analysis for Soil, Plants and Waters.* Division of Agricultural Sciences, University of California, California, USA.

Chauhan, D.R., Ram, M. and Singh, I. 2002. Response of Indian mustard to irrigation and fertilization with various and levels of sulphur. *Indian Journal of Agronomy,* **47**: 422-426.

Chopra, S.L. and Kanwar, J.S. 1980. *Analytical Agricultural Chemistry*. Kalyani Publishers, Ludhiana, Punjab, India.

Jackson, M.L. 1973. *Soil Chemical Analysis*. Prentice Hall of India, New Delhi, India.

Jain, N.K. and Sharma, P.P. 2000. Integrated nutrient management in mustard. *Indian Journal of Agronomy,* **17**: 127-129.

Katyal, J.C. and Rattan, R.K. 1993. Micronutrient use in the 90s. pp. 109-135. **In**: *Soil Fertility and Fertilizer Use,* Vol. 4 (ed. V. Kumar). IFFCO, New Delhi, India.

Panda, P.K., Sounda, S. and Tripathi, S.K. 2000. Effect of irrigation and sulphur on yield, nutrient uptake and quality of mustard. *Journal of Oilseeds Research,* **17**: 122-126.

Panse, V.G. and Sukhatme, P.V. 1999. Statistical methods for agricultural workers. ICAR, New Delhi, India.

Reager, M.L., Sharma, S.K. and Yadav, R.S. 2006. Yield attributes, yield and nutrient uptake of Indian mustard (*Brassica juncea*) as influence by nitrogen levels and its split application in arid Western Rajasthan. *Indian Journal of Agronomy,* **51**: 213-216.

Roul, P.K., Sarawgl, S.K., Shrivastava, G.K. and Deepak, K. 2006. Effect of integrated nutrient management techniques on productivity, nitrogen uptake, N-use efficiency, economics and energetic of rice (*Oryza sativa*) – Indian mustard (*Brassica juncea*) sequence. *Indian Journal of Agronomy,* **51**: 170-173.

Sarangthem, I., Singh, L., Somendra, G.S. and Sarkar, A.K. 2008. Response of rapeseed to nitrogen and sulphur. *Journal of Indian Society of Soil Science,* **56**: 222-224.

Wamjari, R.H., Singh, M.V. and Ghosh, P.K. 2004. Sustainable yield index, an approach to evaluate the sustainability of long term intensive cropping system in India. *Journal of Sustainable Agriculture,* **25**: 29-56.

Yadav, R.P., Tripathi, M.L. and Trivedi, S.K. 2010. Yield and quality of Indian mustard (*Brassica juncea*) as influenced by irrigation and nutrient levels. *Indian Journal of Agronomy,* **55**: 56-59.