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Water Use Efficiency and Economics of Indian Mustard (*Brassica juncea* L.) Influenced by Drip Irrigation and Micronutrient Application Methods

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Abstract: A field experiment was conducted in split plot design with drip irrigation levels (0.4, 0.6 and 0.8 IW/CPE ratios) in main plot and micronutrient application methods (control, soil, foliar and fertigation) in sub plot during *Rabi* season 2018 at S.K.N. College of Agriculture, Jobner (Rajasthan). The scheduling of drip irrigation at 0.8 IW/CPE ratio recorded significantly higher plant height, dry matter accumulation, siliquae per plant, seeds per siliqua, test weight and seed yield over 0.4 IW/CPE ratio, however remaining statistically at par with 0.6 IW/CPE ratio. Drip irrigation at 0.8 IW/CPE ratio recorded higher net return. Among micronutrient application methods, fertigation significantly increased plant height at 80 days after sowing and at harvest, dry matter accumulation at all growth stages, siliquae per plant, seeds per siliqua and seed yield over all other application methods. Significantly higher net return and B: C ratio was also recorded under fertigation method of micronutrient application.

Keywords: Mustard, IW/CPE, Micronutrient, Drip irrigation and fertigation

India is a key player in the global oilseeds scenario with 12-15 per cent of oilseeds area, 6-7 per cent of vegetable oils production, 9-11 per cent of the total edible oils consumption and 14 per cent of vegetable oil imports. Despite of being the largest cultivator of oilseeds at the global level, India was an exporter of oil till fifties and now become a major importer of edible oil. Nutrient and irrigation management are the most important agronomic factors that affect the yield of Indian mustard (*Brassica juncea* L.). Drip irrigation is one of the most efficient methods of irrigation and it is viewed as a promising technology for its ability to support farmers in raising incomes (IWMI). A number of benefits have been ascribed to the use of drip irrigation. In addition to saving of water these include increased yield and productivity of crops, labour cost savings, electricity savings, lesser pumping hours and hence easier irrigation, better crop growth and also better soil health. In IW/CPE approach, known amount of irrigation water is applied when cumulative pan evaporation reaches predetermined level. For practical purpose irrigation should be started when allowable depletion of available moisture in the root zone reaches. The available water is soil moisture which lies between field capacity and permanent wilting point. Thus irrigation scheduling provides information to the managers to develop irrigation strategies for each plot of field on the farm.

Multiple micronutrient deficiencies are emerging at a faster rate in intensively cultivated high production areas due to greater removal of soil micronutrients through annual biomass harvest of 15-20 tonnes ha^{-1}. The deficiency range of micronutrients especially Zn and B in oilseed growing soils emphasizes the need to focus immediate attention on balanced nutrient management practices. The production of mustard in the region, state and in country often suffers from a higher degree of variation in the annual production owing to their predominant cultivation under low and uncertain rainfall situations and further handicapped by input starved conditions with poor crop management. There is limited scope for expansion of area under mustard and also the irrigation. Increasing the vertical growth in productivity is the feasible option. Fertigation is a modern agro technique, combining water and fertilizer application through irrigation provides an excellent opportunity to both maximize yield and minimize environmental pollution. It localizes the water supply and this triggers the development of a restricted root system that requires frequent replenishment of the nutrients. Applying nutrients in the irrigation water may satisfy this requirement. In a fertigation system, the timing, amounts, concentrations and ratios of the nutrients are easily controlled. Due to this improved control, crop yields are greater than those produced by a simple fertilizer application and irrigation system. Therefore, as a result of the shift from surface irrigation to drip method of irrigation, fertigation becomes the most common fertilisation in the irrigated agriculture. The use of soluble and compatible fertilisers, good quality irrigation water and application of actual crop water need are the prerequisite of the successful fertigation system.

MATERIAL AND METHODS

The experiment was conducted at S.K.N. college of agriculture, Jobner, Rajasthan(Lat 26.971873^0 long 75.377156^0). The region fall under semi-arid eastern plains agroclimatic zone of Rajasthan. The experimental soil was loamy sand in texture, alkaline in reaction (8.1), poor in organic matter (0.18), low in available nitrogen (129.50 kg/ha), medium in phosphorus (17.10 kg/ha) and potassium content (181.20 kg/ha). Field capacity and PWP of soil was 10.85 and 4.32 per cent, respectively. The experiment consisting of 12 treatment combinations with three levels of drip irrigation in main plot (drip at 0.4, 0.6 and 0.8 IW/CPE ratio) and four levels of micronutrient application method in sub plots (control, soil application, foliar application and fertigation) was conducted in split plot design and replicated four times. The seeds of mustard variety Laxmi @ 5 kg/ha was used for sowing in the experiment. Mustard seeds were sown at a spacing of 30 x 10 cm^2 apart. Two hoeing-cum-weedings were done manually at 30 and 40 days after sowing. To maintain uniform plant stand at 10 cm for mustard, extra plants were thinned out. The experimental mustard crop was fertilized uniformly with 60:40 kg/ha of N and P respectively. Half of the nitrogen along with full amount of phosphorous was applied at the time of sowing as basal. Five plants for each treatment were taken for recording the various data. Data on yield attributes and yield were recorded as per standard process at harvest. Various indices were used to assess the effectiveness of water management practices *viz.,* consumptive use of water by Dastane (1972) and Water-use-efficiency by Viets (1961). The economics of treatments was computed on the basis of prevailing market price of input and outputs for each treatment. Net returns and B: C ratio was calculated by following formulas.

$$\text{B: C ratio} = \frac{\text{Net return (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

All data were subjected to statistical analysis using the F–test, as per the procedure given by Gomez and Gomez (1984).

RESULT AND DISCUSSION

Effects of Drip Irrigation

Growth parameters: Scheduling of drip irrigation at 0.8 IW/CPE ratio, recorded significantly higher plant height (150.49 and 196.00 cm) as compared to 0.4 IW/CPE ratio at 80 days after sowing and at harvest, while it remained statistically at par with 0.6 IW/CPE ratio (143.59 and 193.70 cm, respectively) (Table 1). The drip irrigation level at 0.8 IW/CPE ratio, recorded significantly maximum dry matter accumulation (40.65, 114.99 and 196.00 g) as compared to 0.4 IW/CPE ratio at 40, 80 days after sowing and at harvest, while it remained statistically at par with 0.6 IW/CPE ratio (34.54, 100.95 and 155.16 g, respectively). The crop plants are able to maintain higher water potential with increasing IW/CPE ratio under drip irrigation which improves physiological and biochemical activities. This leads to improved growth of plant. Beside it, reduced water supply causes closure of stomata which raises the plant temperatures consequently increases respiration leading to higher break down of assimilates and ultimately poor growth and reduced dry matter accumulation. Similar results have

Table 1. Effect of drip irrigation level and micronutrient application method on plant height and dry matter accumulation of mustard

Treatment	Plant height (cm)			Dry matter accumulation per meter row length		
	40 DAS	80 DAS	At harvest	40 DAS	80 DAS	At harvest
Drip irrigation levels						
0.4 IW/CPE	70.90	129.29	177.30	34.54	100.95	155.16
0.6 IW/CPE	71.99	143.59	193.70	38.98	110.60	175.39
0.8 IW/CPE	72.49	150.49	196.00	40.65	114.99	185.13
CD (P=0.05)	NS	10.99	14.72	2.95	8.44	13.37
Micronutrient application methods						
Control	66.30	123.55	173.30	32.20	97.39	154.70
Soil application	70.80	137.15	185.90	37.08	105.96	168.45
Foliar application	74.60	147.55	197.30	40.90	113.76	178.95
Fertigation	75.48	156.25	199.50	42.05	118.27	185.46
CD (P=0.05)	3.91	7.91	10.52	2.14	6.07	9.67

NS=non-significant

also been reported by Bhunia et al (2004) and Choudhary et al (2005).

Yield attributes and yield: The different drip irrigation level affected the yield attributing characters of mustard significantly (Table 2). Among the different drip irrigation levels, the drip irrigation at 0.8 IW/CPE ratio recorded significantly higher no. of siliquae/plant (288.80), no. of seed/siliqua (15.64), test weight (3.86g), seed (18.06 q/ha), straw (69.66 q/ha) and biological yield (88.26 q/ha) over 0.4 IW/CPE ratio remain at par on 0.6 IW/CPE ratio (281.90, 14.95, 3.66, 18.06, 66.31 and 88.26, respectively) at all the growth stages. This increase in seed yield might be due to maintenance of sufficient moisture in root zone during critical stages of the crop growth, resulting in higher yields. The, higher seed yield with increasing IW/CPE ratio could be the resultant of cumulative beneficial effects of irrigation schedules first on vegetative growth and later on better partitioning of photosynthates towards the sink. These findings are in close conformity with those of Solanki et al (2014) and Kunapara et al (2017).

Economics: The higher net returns and B: C ratio of (Rs. 42639/ha and 1.87, respectively) at 0.8 IW/CPE ratio were significantly higher over 0.4 IW/CPE ratio (30413/ha and 1.65, respectively) and it remained statistical at par with 0.6 IW/CPE ratio (Table 3). The significantly higher net returns obtained under 0.8 IW/CPE ratio was due to higher seed and straw yields along with higher price of mustard. The total cost of production increased slightly with an increase in IW/CPE ratio for scheduling irrigation, because the irrigation charges were insignificant as compared with other expenses. The cost involved under this treatment was comparatively lower than its additional income, which led to more returns under

Table 2. Effect of drip irrigation level and micronutrient application method on yield attributes and yield of mustard

Treatment	No. of siliquae/ plant	No. of seed/ siliqua	Test weight (g)	Seed yield (q/ha)	Straw yield (q/ha)	Biological yield (q/ha)
Drip irrigation level						
0.4 IW/CPE	257.90	13.32	3.20	15.78	57.63	73.41
0.6 IW/CPE	281.90	14.95	3.66	18.06	66.31	84.37
0.8 IW/CPE	288.80	15.64	3.86	18.60	69.66	88.26
CD (P=0.05)	21.56	1.14	0.28	1.38	4.17	5.30
Micronutrient application method						
Control	240.50	12.27	3.13	14.17	56.39	70.56
Soil application	267.90	14.45	3.46	17.37	62.90	80.27
Foliar application	289.80	15.5	3.74	18.65	68.18	86.83
Fertigation	306.60	16.34	3.97	19.73	70.66	90.39
CD (P=0.05)	15.42	0.83	0.20	1.00	3.65	4.65

Table 3. Effect of drip irrigation level and micronutrient application method on net returns, B: C ratio, consumptive use of water and water use efficiency in mustard

Treatment	Net return (Rs/ha)	B:C ratio	Consumptive use of water (mm)	Water use efficiency (kg/ha-mm)
Drip irrigation level				
0.4 IW/CPE	30413	1.65	191.1	8.26
0.6 IW/CPE	40784	1.85	264.3	6.83
0.8 IW/CPE	42639	1.87	334.6	5.56
CD (P=0.05)	2555	0.12	20.06	0.53
Micronutrient application method				
Control	30382	1.77	263.33	5.58
Soil application	34271	1.67	263.33	6.84
Foliar application	41215	1.82	263.33	7.34
Fertigation	45914	1.9	263.33	7.77
CD (P=0.05)	2250	0.10	15.57	0.35

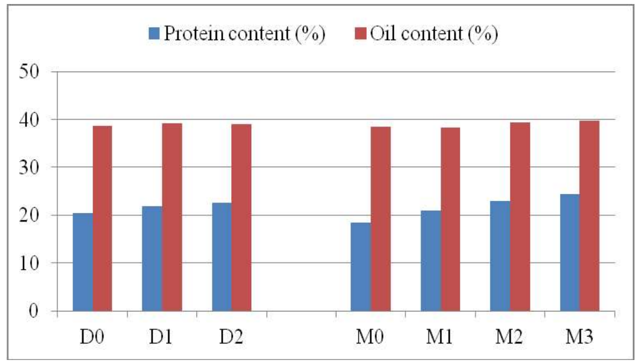
this treatment. These findings are in accordance with the results reported by, Mahalakshmi et al (2011) and Rajiv (2012).

Effects of Micronutrient Application Method

Growth parameters: Among micronutrients application method, fertigation recorded significantly higher plant height at 40, 80 days after sowing and at harvest (75.48, 156.25 and 199.50 cm, respectively) however, it remained at par with foliar application method, over control and soil application. The fertigation recorded maximum dry matter accumulation at 40, 80 days after sowing and harvest (42.05, 118.27 and 185.46 g, respectively) however, it remained at par with foliar application method, compared to control and soil application. Among the methods of nutrient application, foliar application is recognized as an important method of fertilization, since foliar spray usually penetrate the leaf cuticle or stomata and enters the cells facilitating easy and rapid utilization of nutrients. This leads to efficient utilization of micronutrients. The observed improvement in overall vegetative growth of the crop with the application method of micronutrient in the present investigation is in conformity with those of *Sintupachee* et al *(2010)* and Moosavi and Ronaghi (2011).

Yield attributes and yield: Micronutrient application method of fertigation recorded significant improvement in yield attributes and yield of mustard (Table 2). The fertigation recorded highest number of siliquae/plant, number of seed/siliqua and test weight (g) (306.60, 16.34 and 3.97, respectively) followed by foliar application (289.80, 15.50 and 3.74, respectively) over control at all the growth stages. Same trend was also observed in yield i.e. fertigation recorded highest seed, straw and biological yield (q/ha) (19.73, 70.66 and 90.39, respectively) followed by foliar application (18.65, 68.18 and 86.83, respectively) over control at all the growth stages. The combined application of micronutrients provided fertigation greater availability of nutrients for the development of reproductive structures and increase in the number of grains and grain weight. Since boron and combination of all micronutrients were responsible for the translocation of food materials in plants therefore it played a vital role in grain setting as well as higher number of grain. These results are in close conformity with the findings of Singh and choudhari (2001).

Oil and protein content (%): The micronutrient application by all methods significantly increased the oil and protein content in mustard seed. Further data showed that fertigation (39.83 and 22.88 %), being at par with foliar application (39.30 and 22.88 %), recorded significantly highest protein content in mustard seed over control and soil application (Fig. 1). The oil content and protein in seed of mustard was recorded significantly highest in fertigation of micronutrient.



D0-0.4 IW/CPE, D1-0.6 IW/CPE, D2-0.8 IW/CPE, M0- Control, M1- Soil application, M2- Foliar application and M3- Fertigation

Fig. 1. Effect of drip irrigation level and micronutrient application method on protein and oil content (%)

Higher nitrogen in seed is directly responsible for higher protein because it is a primary component of amino acids which constitute the basis of protein. These results are in close conformity with the findings of Mona et al (2015).

Economics: Significantly highest net returns (Rs. 45914/ha) and B:C ratio (1.90) were recorded under fertigation over control, soil and foliar application (Table 3). The highest income obtained in fertigation due to more yield. Similar findings were also observed by Jabran et al (2011) and Shankar et al (2017).

Water use Parameters

Consumptive use of water: The higher consumptive use of water obtained in 0.8 IW/CPE ratio as compared to 0.4 IW/CPE ratios. The 0.6 IW/CPE ratio statistically at par with 0.8 IW/CPE ratio. Water application with 0.8 IW/CPE provide higher water to crop, which leads to more available water and consumptive use by crop.

Water use efficiency (kg/ha-mm): The higher water use efficiency (kg/ha-mm) recorded in 0.4 IW/CPE ratio (8.26) followed by 0.6 IW/CPE ratio (6.83). Among different micronutrient application method, fertigation recorded higher water use efficiency (kg/ha-mm) (7.77) statically at par on foliar application (7.34).

CONCLUSION

The application of irrigation water through drip irrigation in mustard at 0.6 IW/CPE ratio provided higher plant growth parameter, yield attributes, yield, net return and quality. Similarly application of micronutrients through fertigation gave significantly higher growth, yield, net return, quality and water use efficiency.

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