



## Comparative effect of irrigation systems and nitrogen fertigation on growth, productivity and water use efficiency of Indian mustard (*Brassica juncea*) under semi-arid conditions of Rajasthan

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### ABSTRACT

An experiment on standardization of micro-irrigation and fertigation methods for Indian mustard [*Brassica juncea* (L.) cernj. & Cosson] crop under semi-arid conditions of Rajasthan was undertaken during the winter (*rabi*) seasons of 2009–10 and 2010–11. The treatments consisted of 5 irrigation systems in main plot, viz. micro-sprinkler system (MS), micro sprinkler followed by check basin (MS+CB), drip irrigation system, drip system followed by check basin (DS+CB) and check basin (CB) alone. In sub-plots, 4 treatments of N doses, viz. control (0 kg/ha N), 40, 80 and 120 kg N/ha, were taken. Pressurized irrigation through micro-sprinkler, drip system and their combination with check basin method resulted in significantly higher growth attributes like plant height, above-ground dry matter and chlorophyll concentration than check basin alone. Similar trend was observed for biological, seed and oil yields. Other parameters like water-use efficiency and production efficiency were the highest under pressurized irrigation systems. Among the sub-plots, growth parameters and yield attributes improved with increasing dose of nitrogen up to 120 kg/ha. The enhanced yield under 120 kg N/ha also resulted in higher production efficiency and water-use efficiency.

**Key words** : Crop management, drip, Indian mustard, Micro-irrigation, Water-use efficiency

In India, the demand for water resources is exceeding the supply and the competition for this scarce water among the various sectors like domestic, industrial and agricultural use is becoming intense. The projected increase in demand of water from other sectors will correspondingly reduce its availability for agricultural purposes. The scenario of water availability for agriculture will be critical in India, as India supports 18% of human and 30% of the livestock population on just 4% of the water resources. Presently, 60% of cultivated land is rainfed and vulnerable to frequent moisture stress, droughts, floods and soil erosion. Under changing socio-economic and climatic scenario, the vulnerability of Indian agriculture will be severe if the present trend of water use is not changed with efficient practices. The poor efficiency of flood irrigation reduces potential irrigated area in the country by 50% and causes soil erosion, land degradation and 40% annual yield reduction (Langdale *et al.*, 1979). This scenario can only be reversed if inefficient flood irrigation practices are being replaced with efficient micro-irrigation systems

(Buttar *et al.*, 2006).

Rapeseed-mustard is one of the most important group of crops of India which is grown on an area of about 5.53 million ha with 6.41 million tonnes production and the productivity of 1,159 kg/ha (DAC, GoI, 2010). Almost 75.5% area under rapeseed–mustard is irrigated and requires at least 1.2–2.0 million litres of water for recommended practice of two flood irrigations 35 and 70 days after sowing. Up to 50% irrigation water can be saved through micro-irrigation and the remaining quantity of water could be utilized for further intensification of cropping system. The task force on micro-irrigation stated that potential area of 4.9 million ha under oilseeds might be brought under micro-irrigation. The micro-irrigation system not only helps in enhancing water-use efficiency but also improves other nutrient-use efficiencies due to its precise application through fertigation. But the detailed information regarding the overall impact of micro-irrigation on growth, yield attributes, seed yield, economics, crop responses to the enhanced fertilizer supply through fertigation by input-responsive cultivars of Indian mustard under semi-arid conditions is lacking. Hence present field experiment was conducted to study the comparative effect

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of various irrigation systems and N fertigation on growth, productivity and water-use efficiency of Indian mustard under semi-arid conditions of Rajasthan.

### MATERIALS AND METHODS

An experiment was conducted at the Directorate of Rapeseed-Mustard Research, Bharatpur, Rajasthan during the winter (*rabi*) seasons of 2009–10 and 2010–11, to standardize micro-irrigation and fertigation methods for Indian mustard crop under semi-arid conditions. It was laid out in split plot design (SPD) with 3 replications. Micro-sprinkler system (MS), micro sprinkler followed by check basin (MS+CB), drip irrigation system (DS), drip followed by check basin (DS+CB) and check basin (CB) irrigation system alone made 5 irrigation methods in the main plots. In sub-plots, four N doses, viz. control (0 N), 40 kg/ha, 80 kg/ha and 120 kg/ha of N doses were taken. The micro-sprinkler head operated at 2.5 kg/cm<sup>2</sup> pressure and single micro-sprinkler head covered 9 m diameter. They were installed in the field to work in overlapping manner. The uniformity coefficient of the entire micro-irrigation system was above 85%. The drip laterals were used in 3:1 ratio (one lateral after 3 Indian mustard rows) and 20.0 mm water was applied during each irrigation.

The clay loam soil (25% sand, 41% silt and 34% clay) of the field was saline-sodic (pH and electrical conductivity (EC) varied from 8.5 to 9.5 and 2.5 to 3.5 dS/m). The soils were poor in organic carbon (2.1 g/kg), KMnO<sub>4</sub> oxidizable N (125 kg/ha), medium in 0.5 N NaHCO<sub>3</sub>-extractable P<sub>2</sub>O<sub>5</sub> (20 kg/ha)/ha and 1.0 N NH<sub>4</sub>OAc-exchangeable K<sub>2</sub>O (245 kg/ha). The bulk density and infiltration rate of the soil were 1.50 Mg/m<sup>3</sup> and 5.9 mm/hr respectively. The pH and EC of the water was 8.5 and 2.3 ds/m. The total dissolved solids (TDS) and salt TDS was 1120 and 790 ppm respectively.

'Rohini' cultivar of the crop was sown in the first fortnight of October during both years. The seeds were sown @ of 5 kg/ha at 30 cm × 10 cm spacing at a depth of 5 cm with a seed drill. The plant-to-plant distance was maintained at 10–15 cm by thinning at 15–20 days after sowing (DAS). Phosphorus (40 kg/ha) as diammonium phosphate (DAP) and potassium (40 kg/ha) as murate of potash were applied basal at the time of land preparation. Variable doses of nitrogen were given according to the sub-plot treatments. Half dose of N and full dose of P and K were applied basal, whereas the remaining N in the form of urea was applied through fertigation in micro-irrigation systems. Fertigation of N was done through urea fertilizers with the help of ventuary attached with the micro-irrigation system in the main line. The required pressure for fertigation through ventuary was 1.5 kg/cm<sup>2</sup>.

Conventionally 2 irrigations were applied to Indian

mustard crop through check basin method. One lateral of the drip system was laid between 3 rows of Indian mustard. The diameter of the main line, sub-main line and laterals was 75, 63 and 16 mm respectively. The discharge of the emitter was 4 liters/hr. The irrigation through micro-sprinkler and drip method was scheduled as per the water requirement of the crop. The volume of water to be given was calculated as per FAO Irrigation Water Management Training Manual No. 3 (Brouwer and Heibloem, 1986). Irrigation water-use efficiency was calculated based on yield of Indian mustard obtained per unit of irrigation water applies, i.e.  $WUE_i = Ye/We$ , where,  $WUE_i$  is the irrigation water-use efficiency;  $Ye$  is the economic yield, and  $We$  is the irrigation water applied. Gross water-use efficiency was calculated based on yield of mustard obtained per unit of total available water, i.e. both irrigation water and rainfall and can be expressed as:  $WUE_g = Ye/Wi+r$ , where  $WUE_g$  is the gross water-use efficiency,  $Ye$  is the economic yield and  $Wi+r$  is the total water available through irrigation and rainfall. The production efficiency is the increase in seed yield on a daily basis. Production efficiency (kg/day) was calculated as  $PE = Ys/n$ , where  $Ys$  is the economic yield in a particular treatment and  $n$  is the duration of the crop. The economics was estimated in terms of cost of cultivation as per the guidelines of Commission of Cost and Prices and net returns and benefit: cost ratio was calculated on the basis of minimum support price. The government is promoting micro-irrigation systems by providing subsidy provisions for the benefit of stakeholders. The economics of micro-irrigation systems was assessed on the basis of 100% subsidy.

Soil-plant analysis and development (SPAD) meter has been devolved by soil-plant analysis and development unit of Minolta Company (SPAD 502) which reflects the chlorophyll content. Observations on SPAD chlorophyll meter were taken 50 and 75 DAS. The youngest fully expanded leaf of 3 plants in 60 plots was used for SPAD measurement. Three readings were taken on one side of the midrib of each leaf blade at the midway between the leaf base and the tip.

### Climate

Monthly average of weather parameters, viz. temperature (minimum and maximum), relative humidity, wind velocity, sunshine hours, evaporation and total rainfall was recorded during the crop seasons from 2009 to 2011 (Table 1). The grand growth phase of the Indian mustard coincided with minimum diurnal difference in the temperature. The higher day temperature by the end of the February month induced the physiological maturity in Indian mustard.

The standard analysis of variance (ANOVA) test was

**Table 1.** Monthly average of weather data observed during 2009–11 at Bharatpur, Rajasthan.

Month	Temp (°C)		Mean RH (%)	Rainfall (mm)	Sun Shine Hrs
	Max.	Min.			
September	33.8	24.25	75.35	194.6	5.9
October	34.3	18.95	55.25	3.05	7.25
November	27.4	14.1	67.75	30.9	5.25
December	22.7	7.2	71.25	2.4	6.2
January	18.8	4.95	80.8	5.0	5.1
February	25.3	8.95	70	15.2	7.7
March	33.8	14.1	57.8	0	7.95
April	39.5	21.6	29.35	8.65	7.95

performed using SPSS 17.0 statistical software to compare the treatment means for each year separately and was pooled. Treatment means were compared at the 5% level of significance ( $P < 0.05$ ) using least significant difference (LSD). The variance over the years was estimated by performing Bartlett  $\chi^2$  test and hence results of pooled analysis are presented here to draw logical inferences.

## RESULTS AND DISCUSSION

### Growth parameters

Different micro-irrigation systems and fertigation of nitrogen significantly influenced plant height, above-ground dry matter, days to 50% flowering and chlorophyll concentration in terms of SPAD value in the crop. Significantly higher plant height was recorded under drip irrigation system, whereas the minimum plant height under micro-sprinkler irrigation system, which was at par with check basin (Table 2). The above-ground dry-matter accumulation/plant was found to be the highest under combination of micro-sprinkler and check basin method being at par with the micro-sprinkler alone. Different irrigation systems resulted in significant variation in commencement

of flowering. Relatively early flowering was noticed under combination of micro-sprinkler and check basin. Maximum days to 50% flowering were observed under micro-sprinkler alone. Days to 50% flowering were significantly higher under micro-irrigation than check basin method due to 'stay-green' effect. Fertigation of N doses recorded reverse trends for days to 50% flowering and minimum days were required with higher N levels (120 kg/ha), probably due to rapid phenological development, balance between vegetative and reproductive phases and optimum plant growth. The moisture distribution in the soil under micro-sprinkler method promotes better root proliferation and thus, the plant structure under micro-sprinkler was more vigorous than drip irrigation method with higher number of primary and secondary branches. The water application under micro-irrigation coincides with the water requirement of the crops throughout the growth stages without causing any water stress. This resulted in better growth of Indian mustard under micro-irrigation system compared to the check basin method (Kumar and Singh, 2002; Aujla *et al.*, 2007). Fertigation distributes nutrients and water through the drippers directly into the root zone

**Table 2.** Effect of micro-irrigation and fertigation on growth parameters of 'Rohini' Indian mustard.

Treatment	Plant height (cm)	Dry weight (g/plant)	SPAD	Days to 50% flowering
<i>Irrigation system</i>				
Check basin (CB)	197.9	45.7	43.8	59.6
Drip system (DS)	207.1	52.6	43.8	58.8
Micro-sprinkler (MS)	190.1	57.1	43.7	60.8
Micro-sprinkler+Check basin (MS+CB)	198.0	58.0	43.2	58.3
Drip system+Check basin (DS+CB)	195.4	47.1	45.5	59.1
SEm±	3.15	2.1	0.75	0.4
CD (P=0.05)	10.0	6.6	NS	NS
<i>Fertigation of N (kg/ha)</i>				
Control	184.6	37.2	36.6	63.6
40	196.2	48.5	43.8	61.8
80	202.3	60.2	46.0	57.6
120	208.0	62.5	49.5	55.8
SEm±	2.71	1.0	0.50	0.35
CD (P=0.05)	7.95	2.9	1.50	1.03

of the plant, entering the soil through the combined forces of gravity and capillarity. This reduces the nutrient losses through volatilization and leaching (Hebbar *et al.*, 2004; Anitta Fanish *et al.*, 2011).

#### Differential chlorophyll levels (SPAD units)

The chlorophyll concentration is a very important indicator of photosynthetic potential. The difference in the chlorophyll levels, as measured by the SPAD meter, was found non-significant among the various irrigation systems. However, the SPAD units increased significantly with increasing N doses (Table 2). The higher SPAD units observed under higher N doses is likely associated with the efficient N uptake and better photosynthetic leaf function, especially during late seed filling which may lead to a longer 'stay-green' period, longer seed-fill interval corresponding higher seed yield (Balasubramanian *et al.*, 1999). Increasing levels of nitrogen also increased plant height and the maximum plant height was recorded under 120 kg N/ha. Nitrogen has direct role in synthesis of chlorophyll and due to this reason higher N levels resulted in better chlorophyll concentration and more SPAD value.

#### Yield attributes

Micro-sprinkler and drip irrigation systems alone or in combination with check basin resulted in higher yield attributes (Table 3). These pressurized irrigation systems improve plant water status and soil moisture relations due to which the plant seldom faces water stress resulting in higher significantly higher yield attributes (Rao *et al.* 2010). Maximum primary and secondary branches were recorded under the micro-sprinkler, combination of micro-sprinkler and check basin being at par with it, whereas

minimum primary and secondary branches were recorded under check basin irrigation system. Main shoot length was also significantly higher under micro-sprinkler (MS) over drip and combination of micro-irrigation with check basin. Siliquae on main shoot were higher in drip irrigation system but at par with micro-sprinkler irrigation system. However, they were found at par with micro-sprinkler and the combination of micro-sprinkler and check basin. Total siliquae/plant were also recorded maximum under combination of micro-sprinkler and check basin, being at par with the micro-sprinkler alone. Seeds/siliqua were in the range of 14–16 and maximum seeds/siliqua were recorded under the combination of micro-sprinkler and check basin. The 1,000-seed weight was the highest under micro-sprinkler, being at par with all micro-irrigation treatments and significantly higher than check basin. The effect of various irrigation treatments on harvest index was inconsistent and non-significant. The inconsistent behaviour is due to the variations in the vegetative growth produced under the variable soil moisture and rainfall patterns. Increasing level of N fertigation from 0 to 120 kg/ha resulted in gradual increase in most of the yield attributes (Table 3). The N level up to 80 kg/ha produced maximum number of primary branches, secondary branches, main shoot length, siliquae on main shoot, total siliquae/plant, 1,000-seed weight and harvest index.

#### Biological, seed and oil yield

Maximum biological, seed and oil yields were harvested from the crop grown under the combination of micro-irrigation and check basin (Table 4). Maximum biological yield was obtained under combination of micro-sprinkler and check basin method which was found at par

**Table 3.** Effect of micro-irrigation and fertigation on yield attributes of 'Rohini' Indian mustard.

Treatment	No. of primary branches	No. of secondary branches	Main shoot length (cm)	Siliquae on main shoot	Total siliquae/plant	Seeds/siliquae	1,000-seed weight (g)	Harvest index
<i>Irrigation system</i>								
Check basin (CB)	5.3	7.0	77.5	61.00	171.6	14.4	4.60	0.26
Drip system (DS)	5.9	8.0	80.7	68.30	210.3	14.8	4.95	0.28
Micro-sprinkler (MS)	7.5	11.7	87.6	66.55	230.4	15.8	5.10	0.25
Micro-sprinkler+Check basin (MS+CB)	7.3	11.3	78.8	63.90	241.6	15.9	5.00	0.24
Drip system+Check basin (DS+CB)	6.1	8.7	80.2	62.60	183.7	14.9	4.85	0.26
SEm±	0.37	0.55	2.05	1.30	7.6	0.35	0.12	0.01
CD (P=0.05)	1.20	1.70	6.35	4.15	23.9	0.95	0.40	NS
<i>Fertigation of N (kg/ha)</i>								
Control	5.8	6.6	73.4	54.00	134.60	13.45	4.75	0.25
40	6.15	9.0	80.6	63.65	191.80	14.95	4.85	0.26
80	6.95	11.2	84.3	71.55	228.80	16.60	5.05	0.27
120	6.90	10.8	85.1	68.65	274.40	15.60	4.95	0.26
SEm±	0.30	0.45	1.55	1.50	8.75	0.25	0.08	0.01
CD (P=0.05)	0.82	1.20	4.45	4.30	25.25	0.65	0.22	NS

with the micro-sprinkler alone. The highest seed and oil yield was obtained by micro-sprinkler alone, being at par with drip system and combination of micro-sprinkler and check basin. The higher yield under micro-sprinkler and drip irrigation systems might be owing to the frequent watering that resulted into higher water potential, thus minimizing fluctuation in soil moisture in effective root zone, which holds promise for increase in crop yield. Besides, micro-sprinkler irrigation might have created better microclimate, which facilitated better photosynthesis, root aeration and plant growth resulting in higher yield (Hanson *et al.*, 1997). Gradual increase in seed, biological and oil yield was recorded with the increase in N levels under fertigation, and the maximum seed, biological and oil yield was obtained at 120 kg N/ha. The rate of increase was higher between first two doses as compared to 120 kg N/ha. The yield advantage is attributed to the improved efficiency of irrigation and nutrient use and reduction in application costs through fertigation. It improves plant growth and nutrient uptake and limits nutrient losses.

The interaction of the seed yield obtained under various irrigation systems with the N doses indicates that at a given level of N, the yield obtained was higher for micro-sprinkler and drip system as compared to the check basin method (Fig. 1). Amongst the 2 micro-irrigation systems, the response was higher for micro-sprinkler due to uniform water distribution in the soil profile. The uniform moisture distribution helps in better growth, higher nutrient uptake, and reducing losses which ultimately improves the yield. For the similar response from drip system, the distribution of laterals within the rows must be standardized. In the given experiment, one lateral was laid after every 3 rows. Thus, the crop response to applied nutrient can be enhanced by using micro-irrigation method. In check basin method, the nutrient loss occurs through leaching and runoff resulting in the higher fertility gradient within the same field.

### Production efficiency

Significant variation in the production efficiency was

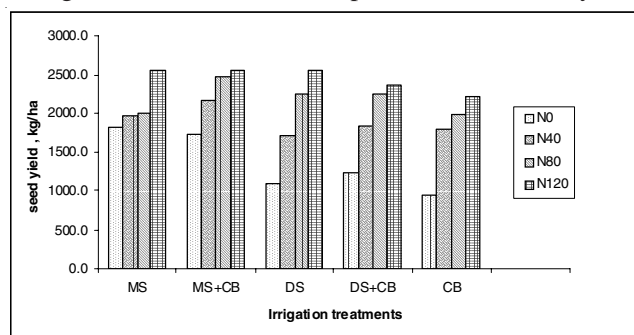


Fig. 1. Interaction effect of micro irrigation fertigation on seed yield of Indian mustard.

observed under various irrigation systems. Proper water management through micro-irrigation helps the crop in quick utilization of the readily available nutrients resulting in higher growth and dry-matter accumulation which increases the per day productivity of Indian mustard compared to check basin method. Micro-sprinkler irrigation system recorded maximum production efficiency, combination of micro-sprinkler and check basin irrigation system being at par with it. Production efficiency increased with the increase in level of N and maximum production efficiency was recorded at 120 kg N/ha, but statistically at par with 80 kg N/ha. Nitrogen supply to Indian mustard improved the integrity of plant structure and key physiological processes such as light interception by chlorophyll, energy for carbohydrate build-up and enhanced the hydraulic conductivity of the root cortical cells, thereby improving the yield.

### Water-use efficiency

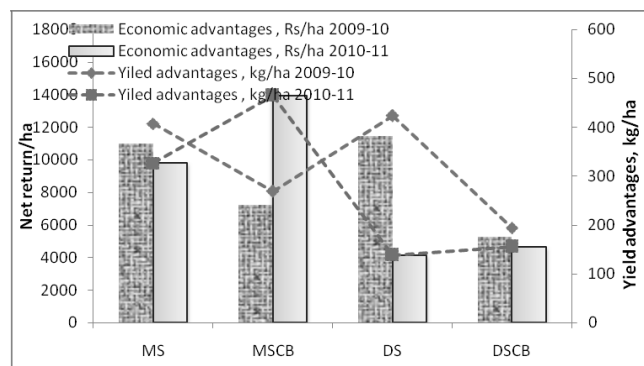
The higher irrigation water-use efficiency ( $WUE_i$ ) was recorded with micro-irrigation systems over check basin irrigation system (Table 4). The highest  $WUE_i$  was observed in micro-sprinkler system. A similar trend was observed for gross water-use efficiency (Table 5). Increase in levels of N enhances the irrigation water-use efficiency, gross water-use efficiency, water productivity and gross water productivity and the rate of increase was higher from 40 kg N/ha to 80 kg N/ha than 80 to 120 kg N/ha. Interaction for irrigation systems and levels of N fertigation was found significant for irrigation water-use efficiency. With micro-irrigation, up to 50% water saving was done, while maintaining a higher available soil moisture and low water tension during entire growth period (Patel *et al.*, 2006). Nazirbay *et al.*, (2005) reported high water-use efficiency and water saving under micro-irrigation systems when practiced with fertigation of N. Irrigation scheduling in micro-irrigation system provide water to the plants which matches the crop evapo-transpiration instead of providing irrigation only at critical growth stages resulted in high water use efficiency (Kar *et al.*, 2004).

### Economics

The irrigation systems and different levels of N fertigation to Indian mustard significantly improved the net return margins over the check treatments (Table 4). The maximum economic returns and yield advantages were higher under micro-irrigation system (Fig. 2). Least benefit: cost ratio and net returns were obtained under check basin irrigation. Both, the irrigation system and N fertigation levels significantly influenced the seed yield of Indian mustard. The highest net returns and benefit: cost ratio were recorded with micro-sprinkler irrigation sys-

**Table 4.** Effect of irrigation methods and fertigation on biological, seed and oil and irrigation water use efficiency, gross water use efficiency of 'Rohini' Indian mustard

Treatment	Biological yield (t/ha)	Seed yield (t/ha)	Oil yield (t/ha)	Production efficiency (kg/ha/day)	Irrigation water use efficiency (kg/ha-mm)	Gross water use efficiency (kg/ha-mm)	Net returns ( $\times 10^3$ ₹/ha)	Benefit: cost ratio
<i>Irrigation system</i>								
Check basin (CB)	6.28	1.51	0.50	9.7	12.7	8.5	28.73	2.29
Drip system (DS)	6.77	1.79	0.77	11.6	29.8	15.4	38.75	3.16
Micro-sprinkler (MS)	7.60	1.87	0.79	12.3	31.3	16.1	40.04	3.23
Micro-sprinkler+Check basin (MS+CB)	7.70	1.88	0.76	12.2	21.9	13.2	40.26	3.17
Drip system+Check basin (DS+CB)	6.54	1.68	0.70	11.0	19.8	11.9	35.00	2.80
SEm $\pm$	0.26	0.07	0.02	0.5	1.2	0.6	0.10	0.3
CD (P=0.05)	0.83	0.21	0.05	1.4	2.1	1.4	2.56	0.9
<i>Fertigation of N (kg/ha)</i>								
Control	5.53	1.29	0.65	8.9	17.3	9.7	24.33	2.01
40	6.72	1.65	0.67	10.8	21.7	12.2	34.32	2.75
80	7.57	1.93	0.68	12.8	25.6	14.7	43.43	3.48
120	8.45	2.11	0.82	13.2	27.8	15.3	45.63	3.49
SEm $\pm$	0.45	0.028	0.02	0.35	0.9	0.7	0.11	0.5
CD (P=0.05)	0.44	0.082	0.05	1.05	1.9	1.6	2.65	1.2

**Fig. 2.** Effect of micro irrigation over check basin on the economics and yield advantages of Indian mustard.

tems, followed by drip system (DS) alone and combination of micro-sprinkler (MS) with check basin (CB). An increment of 39.33% and 41.4% was recorded in net returns and benefit: cost ratio, respectively, with MS irrigated Indian mustard over CB. The higher above-ground dry matter and subsequent higher assimilate supply were obtained under MS and DS over CB owing to favourable soil-moisture conditions. Likewise, increasing levels of N fertigation increases the productivity of Indian mustard. The net returns at 40 and 80 kg N/ha were 41.03% and 78.48% higher, respectively, over the control. The benefit: cost ratio obtained under 40 and 80 kg N/ha was 3.48 and 2.75 respectively. However, the response beyond 80 kg N/ha was found at par in terms of both net return and benefit: cost ratio (Namara *et al.*, 2007).

To meet the ever-increasing demand of edible oils with

decreasing fresh water availability to agriculture, crops must produce more with less water. The use of pressurized irrigation technology could increase water-use efficiency and reduce cost. The yield enhancement of Indian mustard is possible through the use of pressurized irrigation system. With micro-sprinkler, the crop response can be obtained at higher levels of applied N, even up to 120 kg N/ha besides increasing the water use efficiency by two folds.

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