Indian Journal of Ecology (2025) 52(1): 82-88
DOI: https://doi.org/10.55362/IJE/2025/4460

Manuscript Number: 4460
NAAS Rating: 5.38

Quantifying Response of Irrigation and Anti-Transpirants on Quality, Water Use Efficiency and Economics of Indian Mustard (*Brassica juncea* L.) Czern & Coss

Y.A. Tamboli, J.S. Yadav[1], Parveen Kumar[2], Ajeet Singh[3] and Kapil Malik[4]

School of Agricultural Sciences, Jaipur National University, Jaipur-302 017, India
[1]School of Agricultural Sciences, K. R. Mangalam University, Gurugram-122 103, India
[2]CCS Haryana Agricultural University, Hisar-125 004, India
[3]School of Agricultural Sciences, Jaipur National University, Jaipur-302 017, India
[4]Division of Soil and Crop Management, Central Soil Salinity Research Institute, Karnal-132 001, India
E-mail: yasirtamboli786@gmail.com

***Abstract*:** The present investigation was carried out during 2017-18 and 2018-19 at Regional Research Station, Bawal to study the effect of irrigation regimes and anti-transpirants on quality, WUE and economics of Indian mustard. The experiment was laid out in spilt plot design with three irrigation regimes (control, one irrigation at 40 DAS and two irrigations at 40 and 75 DAS) and two varieties (RH-725 and RH-749) in main plots, whereas, anti-transpirants (Control, PMA @ 250 ppm, 6 % kaolin and PMA @ 250 ppm + 6% kaolin at 45 and 90 DAS) in sub plots. The significantly higher oil content and oil yield, maximum consumptive use of water (CU), water use efficiency (WUE), gross returns (GR), net returns (NR), B-C ratio as well as net income per day (NIPD) were in crop irrigated at 40 and 75 DAS. In anti-transpirants, highest oil yield, CU, WUE, gross return and net returns, B-C ratio and net income per day (NIPD) were with application of PMA @ 250 ppm + 6% kaolin at 45 and 90 DAS as compared to control but it was statistically at par with application of kaolin 6 % at 45 and 90 DAS t. Variety RH-749 performed better over to RH-725 with respect to the yield, CU, WUE and economic returns. However, varieties did not exhibit a significant influence on the seed oil and glucosinolate content.

***Keywords*:** Anti-transpirants, Indian mustard, Varieties, Water use efficiency

Indian mustard is a *rabi* season crop grown in diverse agro-climatic conditions, ranging from northern hills to down south under irrigated and rainfed conditions. In global oilseeds scenario, India occupies 12-15 per cent of oilseeds area, 6-7 per cent of vegetable oils production, 9-11 per cent of the total edible oil consumption and 14 per cent of vegetable oil imports (Bhukhar et al., 2022). It is cultivated on 10 million hectares of area with 12.90 million tonnes of production and 1209 kg/ha productivity in India during 2023-24, whereas in Haryana, crop grown on 0.72 million hectares area and produce 1.40 million tonnes with average productivity of 1944 kg/ha (Anonymous 2023).

The production of mustard is not being fully exploited because of the lack of proper information of water requirement. Adequate supply of irrigation water helps in proper utilization of plant nutrients, resulting in better crop growth and higher yield. Therefore, there is need to find out some appropriate solution to fulfil the irrigation requirement of mustard crop. Application of irrigation at flowering and siliqua development stage significantly increases the CU and oil content (Shivran et al., 2018). For increasing the productivity of mustard crop the improved varieties which are capable of giving high yields need to be cultivated. Kumar et al. (2017) observed that mustard variety RH-749 registered significantly higher yield, oil content and net returns and B-C ratio. Kumar et al. (2018) revealed that genotypes RH-725 recorded higher oil content, oil yield and net returns.

The anti-transpirants are used in agricultural field which reduce transpiration rate by reducing the size and number of stomata and gradually hardening them to stress (Kumar et al., 2018). Spraying of anti-transpirants, reduces transpiration loss of water from vegetative parts of the plant, go a long way in economizing water and making more water available to the plant for productive purpose. The combined spray of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS recorded significantly higher oil content, net returns, B-C ratio, WUE and nutrient use efficiency (Rajput 2012) and Kumar et al. (2017). The present investigation was carried out to evaluate the Indian mustard varieties under different irrigation regimes and anti-transpirants.

MATERIAL AND METHODS

Study area: The experiment was conducted at Regional Research Station, Bawal (Fig. 1) CCSHAU, Hisar (India) during rabi season 2017-18 and 2018-19. The site is located in south-west (SW) zone of Haryana which comes under arid and semi-arid region having latitude and longitude of 28.10N, 76.50 E, respectively above mean sea level of 266 meters.

Weather: The climate of the site is arid and semi-arid type, with severe cold days in winter and hot sunny days in summer season. The mean maximum temperature touches as high as 48^{0}C during summer season. However, minimum temperature of 2-3^{0}C is recorded during winter months. The south-west monsoon (SWM) brings rain from July-September providing 80-85 % of total annual rainfall of the region. The weather remains dry except light rainfall during the months from October-April. However, the high temperature is prevailing in June month.

Sampling and analyses: The experimental soil was sandy loam in texture. The composite soil sample was collected before sowing and brought to laboratory. The soil samples were air dried, grinded and passed through 2 mm sieve for the analysis of physico-chemical properties. The pH of the experimental soil was neutral in nature (8.24) having electrical conductivity of 0.19 ds/m (Rechard, 1954). The determination of organic carbon by Walkely and Black (1947), available nitrogen by Subbaiah and Asija (1956), available phosphorus by Olsen et al. (1954) and available potassium by Jackson, 1973 and it indicated that soil content 0.23 %, 148 kg/ha, 14.22 kg/ha and 208 kg/ha of organic carbon, available nitrogen, available phosphorus and available potassium, respectively.

Experimental setup: The experiment was laid out in split plot design having twenty-four treatment combinations with three replicates. The experiment had three irrigation regimes (I_1: control, I_2: one irrigation at 40 DAS, I_3: two irrigations at 40 and 75 DAS), and two varieties (V_1: RH-725, V_2: RH-749) in main plots, whereas, four anti-transpirants (A_1: control, A_2: PMA @ 250 ppm at 45 and 90 DAS, A_3: 6 % kaolin at 45 and 90 DAS and A_4: PMA @ 250 ppm + 6% kaolin at 45 and 90 DAS) in sub plots. Pre-sowing irrigation was applied before seed bed preparation to ensure adequate soil moisture. Mustard variety RH-749 and RH-725 was sown at 30 cm row spacing. Application of irrigation and anti-transpirants as per the treatment. The seed and stover yield per plot were recorded and then converted into kg/ha.

Observation Recorded

Oil content (%): The oil content was determined in percentage by steam distillation method (AOAC 1995).

$$\text{Oil yield (kg/ha)} = \frac{\text{Weight of empty flask}}{\text{Weight of flask with oil}} \times 100$$

Oil yield (kg/ha): The seed yield obtained for each treatment was multiplied by the percent oil content in seed of respective plot for calculation of oil yield which was reported in kg/ha.

$$\text{Oil yield (kg/ha)} = \frac{\text{Oil content in seed} \times \text{Seed yield (kg/ha)}}{100}$$

Glucosinolate content (%): Spectrophotometric estimation was done using methanolic extract[15] prepared from the same genotypes by homogenizing 0.2 g defatted seed meal in a 2 ml vial with 80 % methanol. Total glucosinolates was calculated by putting the OD of each sample at 425 nm into the predicted formula y = 1.40 + 118.86 × A425 (Kumar et al., 2004).

Moisture content (%): Soil profile moisture content was determined by gravimetrical method. Plot wise soil samples were drawn at depth intervals of 0 to 15, 15-45 and 45-90 cm soil layers before and after each irrigation. Soil moisture content of soil samples was worked out by using the following formula:

$$\text{Soil moisture content (\%)} = \frac{W1-W2}{W2} \times 100$$

Where, W_1 = Fresh weight of soil (g), W_2 = Dry weight of soil (g)

Consumptive use (mm): The CU was computed from the

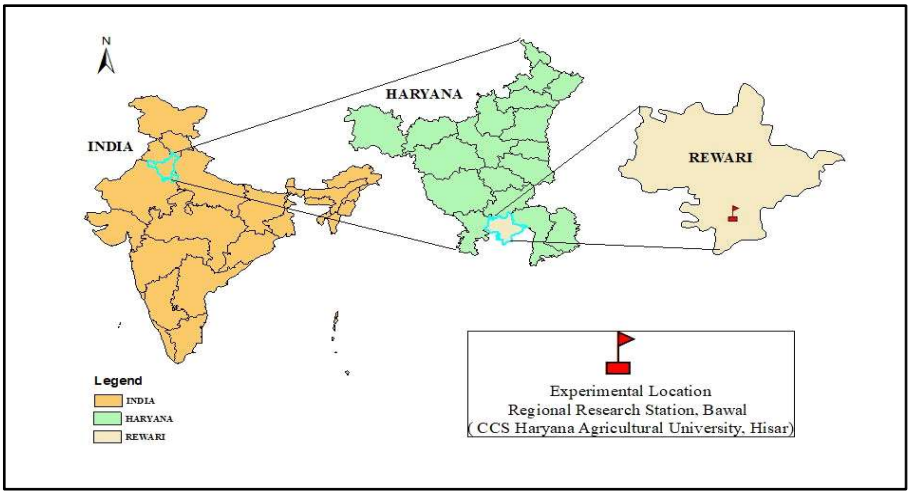

Fig. 1. Experimental Location, RRS, Bawal, CCS Haryana Agricultural University, Hisar, Haryana

water balance (Dastane 1972).

$$CU = \sum_{i=1}^{n} \frac{M_{1i} - M_{2i}}{100} xAsi\ x\ Di$$

Where,

CU =Consumptive use of water between two successive sampling periods (cm)

M_{1i} = Soil moisture at first sampling in i^{th} layer (%)

M_{2i} = Soil moisture at second sampling in i^{th} layer (%)

Asi = Apparent specific gravity of the i^{th} soil layer

Di = Depth of the i^{th} layer of soil (cm)

N = Number of soil layers in the root zone

Water use efficiency (kg/ha/mm): The WUE was worked out with the help of the following formula:

$$\text{WUE (kg/ha/mm)} = \frac{\text{Seed yeild (kg/ha)}}{\text{consumptive water use (mm)}}$$

Statistical analysis: Experimental data were statistically analyzed by using SPSS software.

Table 1. Average mean weekly values of weather parameters during cropping season (2017-18 and 2018-19)

Parameters		Unit	2017-18	2018-19
Rainfall		(mm)	18.8	34.4
Temperature		(max.)	27.14	24.75
Temperature		(min.)	9.30	9.00
Relative humidity	M	(%)	84.75	87.16
	E	(%)	30.62	38.83
Bright sunshine		(hrs.)	6.62	5.90
Wind speed		(km/h)	2.22	2.78

RESULTS AND DISCUSSION

Effect of irrigation: The successive increase in number of irrigations at different phenological stages increased the oil content in both the years (Table 2). Application of two irrigations at 40 and 75 DAS established its superiority by producing significantly the highest oil yield. In general, oil yield decreased significantly with each number of irrigations at different phenological stages in both the years and was statistically at par with one irrigation at 40 DAS only during 2018-19. The different irrigation regimes did not exert their significant influence on the glucosinolate content, respectively during both years. Probably adequate supply of moisture helps in the greater uptake of nitrogen, which in turn, higher the oil content in seed. Therefore, the higher seed yield was responsible for higher oil yield under I_3, whereas, increased in temperature at maturity stage under control condition, increased the loss of oil through volatilization might have reduced the oil content of seed. Contrarily, a significant response of irrigation on oil content and oil yield of mustard was Observed in earlier studies (Tyagi and Upadhyay 2017, Shivran et al., 2018, Mishra et al., 2019, Piri et al., 2019 and Kumar and Dhillon 2023).

The soil moisture content under in control declined consistently from sowing till harvest (Table 3). The decline in moisture content was faster in beginning and at crop maturity stage than during mid-season. The irrigation frequency increased the soil moisture content considerably by application of two irrigations at 40 and 75 DAS followed by one irrigation at 40 DAS. At harvest, soil profile under both

Table 2. Oil content (%), oil yield (kg/ha) and glucosinolate content (%) of Indian mustard as influenced by irrigation levels, varieties and anti-transpirants(Pooled of 2017-18 and 2018-19)

Treatment	Oil content (%)	Oil yield (kg/ha)	Glucosinolate content (µmol/g)
Irrigation levels (I)			
I_1- Control (No post-sowing irrigation)	38.7	543.0	79.1
I_2- One irrigation at 40 DAS (At pre-bloom stage)	39.4	673.3	80.1
I_3- Two irrigation at 40 and 75 DAS (At pre-bloom + pod filling stage)	39.7	788.7	82.2
CD (p=0.05)	0.6	95.9	NS
Varieties (V)			
V_1-RH-725	39.1	626.5	79.7
V_2-RH-749	39.4	710.3	81.2
CD (p=0.05)	NS	78.3	NS
Anti-transpirants (A)			
A_1- Control	39.1	592.2	79.7
A_2- PMA @ 250 ppm at 45 and 90 DAS	39.2	652.7	81.2
A_3- Kaolin 6 % at 45 and 90 DAS	39.3	683.6	79.8
A_4- PMA @ 250 ppm + Kaolin (6%) at 45 and 90 DAS	39.4	744.8	81.1
CD (p=0.05)	NS	71.7	NS

control and irrigated condition exhausted completely. Soil moisture use was maximum under 0-15 cm layer and it declined with the increased in profile depth during both years. The increase in soil moisture content might be due to timely water supply through irrigation. The moisture content at pre-bloom stage before irrigation under all the irrigation treatments remained more or less same because at this stage none of the plots were irrigated. However, at pod filling stage moisture content in all the three depths (0-15, 15-45 and 45-90 cm) were higher under I_3 treatment because at this stage crop had received two irrigations at pre-bloom and pod filling stage, whereas, under I_2 treatment received only one irrigation at pre-bloom stage.

The increase in consumptive water use and water use efficiency by application of two irrigations at 40 and 75 DAS was 30.3 per cent and one irrigation at 40 DAS was 14.8 per cent over control (Table 4). Consumptive use of water by the crop increased progressively and appreciably with increase

Table 3. Soil moisture content (%) at varying depth of Indian mustard as influenced by irrigation levels, varieties and anti-transpirants (Pooled of 2017-18 and 2018-19)

Treatments	Initial	1st Irrigation						2nd Irrigation						Harvest		
		Before irrigation			After irrigation			Before irrigation			After irrigation					
		0-15 cm	15-45 cm	45-90 cm	0-15 cm	15-45 cm	45-90 cm	0-15 cm	15-45 cm	45-90 cm	0-15 cm	15-45 cm	45-90 cm	0-15 cm	15-45 cm	45-90 cm
Irrigation levels (I)																
I_1	13.4	7.0	8.4	10.4	6.8	8.1	10.1	5.0	6.1	7.9	4.8	5.8	7.6	3.0	3.8	5.5
I_2	12.7	7.2	8.6	10.5	10.7	12.4	14.9	9.5	10.4	12.0	6.8	8.0	9.7	5.9	6.1	6.5
I_3	12.5	7.1	8.0	10.4	10.9	11.3	13.6	9.0	11.9	12.2	11.6	13.4	16.0	7.7	8.6	10.7
Varieties (V)																
V_1	12.7	7.1	8.3	10.0	9.4	10.5	12.7	7.8	9.6	10.8	7.6	9.1	11.1	5.6	6.3	7.5
V_2	13.1	7.1	8.4	10.9	9.5	10.7	13.0	7.8	9.4	10.6	7.9	9.0	11.1	5.5	6.0	7.6
Anti-transpirants (A)																
A_1	12.8	7.1	8.7	10.3	9.6	10.5	12.5	8.0	9.7	10.8	7.7	9.3	11.2	5.6	6.4	7.5
A_2	12.4	7.2	8.7	10.2	9.5	11.2	12.9	7.9	9.6	10.3	7.9	9.4	11.1	5.5	6.2	7.7
A_3	13.1	6.9	7.9	10.5	9.2	10.2	13.3	7.8	9.2	11.2	7.5	8.6	11.0	5.4	5.9	7.4
A_4	13.3	7.3	8.0	10.7	9.6	10.6	12.8	7.7	9.3	10.5	7.8	9.0	11.1	5.6	6.0	7.7

See Table 2 for treatment details

Table 4. Consumptive use of water (mm), water use efficiency (kg/ha/mm) and economics of Indian mustard as influenced by irrigation levels, varieties and anti-transpirants (Pooled of 2017-18 and 2018-19)

Treatment	Consumptive use of water (cm)			Consumptive use of water (mm)	Water use efficiency (kg/ha/mm)	Gross returns (₹/ha)	Net returns (₹/ha)	Net income per day (₹/ha/day)	B: C ratio
	0-15	15-45	45-90						
Irrigation levels (I)									
I_1	6.9	6.3	5.1	180.7	7.8	67671	25557	184	1.6
I_2	8.1	7.1	5.7	207.3	8.3	82923	39609	281	2.0
I_3	9.5	7.8	6.3	235.3	8.4	95452	50938	357	2.2
Varieties (V)									
V_1	8.1	7.0	5.6	205.5	7.8	77574	34260	246	1.8
V_2	8.3	7.1	5.7	210.1	8.6	86456	43142	301	2.0
Anti-transpirants (A)									
A_1	8.2	6.9	5.6	205.0	7.4	73616	31508	226	1.8
A_2	8.1	7.1	5.6	206.8	8.1	80420	36728	261	1.9
A_3	8.1	6.9	5.8	207.2	8.4	83711	40775	287	2.0
A_4	8.3	7.2	5.7	212.2	8.9	90315	45795	322	2.0

See Table 2 for treatment details

in number of irrigations because irrigation increased the available water in the soil profile and this facilitated more loss of water through evapotranspiration as compared to no irrigation. Frequent irrigations though, necessary for yield maximization usually lower the water use efficiency because moist or wet surface of soils results in increased loss of soil moisture through evaporation but simultaneously increases consumptive use. These findings are in close proximity with Tyagi and Upadhyay (2017) and Shivran et al. (2018).

Significantly maximum gross monetary return, net realization, net income per day and benefit cost ratio was with the application of two irrigations at 40 and 75 DAS followed by one irrigation at 40 DAS (Table 4). The mean increase in net realization due to application of two irrigations at 40 and 75 DAS was to the extent of 28.8 per cent over I_2 and 99.2 per cent over I_1. The increase in seed yield under this treatment had appreciably been compensated by the increased expenses on account of increase in irrigation and hence, resulted in greater net return, net income per day and benefit cost ratio. These results are in consonance with Verma et al. (2014) and Tyagi and Upadhyay (2017).

Effect of variety: The significantly the highest oil yield was recorded under RH-749 over RH-725, respectively during both years. Percentage increase in oil yield with RH-749 were 13.3 per cent over RH-725. Whereas, varieties did not exhibit their significant influence on the oil content of seed and glucosinolate content (Table 2).

An appraisal data in Table 3 indicated that soil moisture content among genotypes there was very little difference in moisture extraction from different layers during both years. Whereas, among the different genotypes there was very little difference in moisture extraction from different layers, Consumptive use and water use of efficiency (Table 4) was recorded significantly higher with RH-749. Percentage increase in WUE with RH-749 were 10.3 and 11.0 per cent over RH-725. The data reveals in Table 4 that mustard variety RH-749 accrued the maximum gross and net realization, net income per day and B:C ratio. Percentage increase in net realization with RH-749 was 25.9 per cent over RH-725. Genetic potential of a particular variety plays a role in exploitation of higher yield and there by remuneration. Results are in concurrence with those of reported earlier by Kumar et al. (2017), Singh et al. (2017), Meena et al. (2017), Kumar et al. (2018), Yadav et al. (2018), Jaiswal et al. (2019), Rajyalakshmi et al. (2019), Maurya et al. (2022) and Tamboli et al. (2024).

Effect of anti-transpirants: The experimental results indicated that effect of different anti-transpirants was noted on oil yield but did not exhibit any influence on oil content and glucosinolate content (Table 2). As compared to control, application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS recorded significantly higher oil yield and was at par with both application of kaolin 6 % at 45 and 90 DAS only during 2018-19. The above treatment directly influenced the physiology of the crop and reduced the losses of moisture from field and increased moisture utilization and uptake of nutrients, which ultimately resulted in higher grain yield of mustard and its quality. The oil yield is dependent on oil content in seed and seed yield. Therefore, the higher seed yield was responsible for higher oil yield under application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS during both years. The results are also close agreement with those reported by Rajput (2012), Badukale et al. (2015), Kumar et al. (2017), Kumar et al. (2018) and Mphande et al. (2020).

The consumptive use of water and water use efficiency (Table 4) of mustard increased significantly due to application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS followed by application of kaolin 6 % at 45 and 90 DAS. The above treatment directly influenced the physiology of the crop and reduced the losses of moisture from field and increased moisture utilization. The application of PMA and kaolin alone and in combination through foliar spray may be an option to improve the biometric parameters by reducing the size and number of stomata and gradually hardening them to stress. Thus, it can be helpful in economizing water and making it available to the plant for growth and seed production. The present findings are agreement with Rajput (2012), Badukale et al. (2015), Kumar et al. (2017), Kumar et al. (2018) and Tamboli et al. (2024).

The highest gross and net monetary return, net income per day and benefit cost ratio (Table 4) accrued with application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS followed by application of kaolin 6 % at 45 and 90 DAS and PMA @ 250 ppm at 45 and 90 DAS over control. The mean increase in gross realization due to application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS was to the extent of 45.3 per cent over control. The above treatment directly influenced the physiology of the crop and reduced the losses of moisture from field and increased moisture utilization and uptake of nutrients, which ultimately resulted in higher grain yield of mustard, which might be responsible for higher net monetary return, net income per day and benefit cost ratio, which showed significant positive correlation with seed yield. These findings are in conformity with results reported by the present findings are agreement with Rajput (2012), Badukale et al. (2015), Kumar et al. (2017), Kumar et al. (2018) and Tamboli et al. (2024). Interaction effect on oil yield between levels of irrigation and anti-transpirants was significant (Table 5). The significantly higher oil yield was recorded when application of two irrigations at 40 and 75 DAS with PMA @

Table 5. Interaction between levels of irrigation and anti-transpirants on oil yield (kg/ha) of Indian mustard

Treatment		Oil yield (kg/ha)									
		2017-18					2018-19				
		Anti-transpirants (A)									
		A_1	A_2	A_3	A_4	Mean	A_1	A_2	A_3	A_4	Mean
Irrigation levels (I)	I_1	434.8	607.7	565.5	546.2	538.5	474.0	645.4	534.5	536.0	547.5
	I_2	609.7	578.2	656.5	740.9	646.3	673.8	615.2	737.1	774.7	700.2
	I_3	731.6	710.1	708.9	938.1	772.1	629.5	759.4	899.3	933.2	805.3
	Mean	592.0	632.0	643.6	741.7		592.4	673.4	723.6	747.9	
	CD (p=0.05)			115.5					132.7		

See Table 2 for treatment details

250 ppm + kaolin (6%) at 45 and 90 DAS, respectively during both year and was statistically at par with treatment combinations of I_3A_3only during 2018-19.

CONCLUSIONS

The higher oil content, oil yield, glucosinolate content, soil moisture content, consumptive use of water, water use efficiency, net return and B: C ratio could be obtained when mustard is grown with two irrigations, each at 40 and 75 DAS. The variety RH-749 proved to be better as compared to RH-725 in terms of oil yield, net return and consumptive use of water and water use efficiency. The application of PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS recorded significantly higher oil yield, soil moisture content, consumptive use of water and water use efficiency. Thus, higher quality, net return and consumptive use of water and water use efficiency can be achieved by sowing the mustard variety RH-749 along with application of two irrigations at 40 and 75 DAS and PMA @ 250 ppm + kaolin (6%) at 45 and 90 DAS on loamy sand soils.

AUTHOR'S CONTRIBUTION

Dr. Y.A. Tamboli: Conducted experiment, recorded data, data analysis; Dr. J.S. Yadav: Monitoring of experiment, formulation of experiment, correction, providing assistance and data analysis; Dr. Parveen Kumar: Guidance while conducting experiment, manuscript corrections; Dr. Ajeet Singh and Kapil Malik: Data analysis and article verification.

REFERENCES

AOAC 1995. *Official methods of analysis*. Association of official agricultural chemists, 11th Ed., Washington D. C, p 6.

Anonymous 2023. *Rapeseed and Mustard: All-India area, production and yield during 2023-24. Agricultural statistics at a glance 2023.* Government of India, Ministry of agriculture and farmers welfare, Department of agriculture, cooperation and farmers welfare, Directorate of economics and statistics, p 82-88.

Badukale KE, Mankar DD, Jaiswal SG, Jamankar AM and Desai A 2015. Yield, economics and consumptive use of mustard (*Brassica juncea* L.) as influenced by anti-transpirant and frequency of irrigations. *Journal of soils and crops* **25**(2): 341-343.

Bhukhar OS, Shivran AC, Kumawat P, Yadav LR and Dhaker DL 2022. Water use efficiency and economics of Indian mustard (*Brassica juncea* L.) influenced by drip irrigation and micronutrient application methods. *Indian Journal of Ecology* **49**(5): 1691-1695.

Dastane NG 1972. *A practical manual for water use research in agriculture (2nd Ed.)*. Navabharat Prakashan, Pune-2, India.

Hossain M, Alam MS and Ripon MA 2013. Effect of irrigation and sowing method on yield and yield attributes of mustard. *journal of Life and Earth and Agricultural Sciences* 41: 65-70.

Jackson ML 1973. *Soil chemical analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, p 183-192.

Jaiswal P, Mishra AN, Singh AK, Mishra SR, Kumar R, Singh G and Sharma KD 2019. Studies on mustard (*Brassica juncea* L.) varieties under various crop-growing environment in eastern plain zone. *International Journal of Chemical Studies* **7**(4): 1959-1963.

Kumar D and Dhillon BS 2023. Effect of irrigation schedules on productivity, quality and water use of Indian mustard (*Brassica juncea*) under staggered sowing in Northwest India. *Indian Journal of Agronomy* **68**(2): 199-204.

Kumar K, Kumar Y and Katiyar NK 2018. Effect of plant geometry, nitrogen level and anti-transpirants on physiological growth, yield attributes, WUE and economics of mustard (*Brassica juncea* L.) under semi-arid conditions of western Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry* **7**(2): 226-229.

Kumar S, Yadav SK, Chauhan JS, Singh AK, Khan NA and Kumar PR 2004. Total glucosinolate estimation by complex formation between glucosinolate and tetrachloropalladate (II) using ELISA reader. *Journal of Food Science and Technology* **7:** 63-65.

Kumar Y, Singh R, Kumar A and Dhaka and AK 2017. Effect of growth and yield parameters on Indian-mustard genotypes under varying environmental conditions in western Haryana. *Journal Applied Natural Sciences* **9:** 2093-2100.

Maurya SK, Kalhapure A, Singh N, Kumar A, Yadav P, Kumar M and Maurya BK 2022. Growth and yield response of different Indian mustard [*Brassica juncea* (L.)] varieties to irrigation scheduling. *Biological Forum-An International Journal* **14**(3): 434-439.

Meena BS, Tanwar SPS and Sharma GL 2001. Effect of nitrogen, irrigation and interculture on yield, nutrient content and uptake in mustard [*Brassica juncea* (L.) Czern&Coss]. *Journal of Soils and Crops* **11:** 184-187.

Meena H, Meena PKP and Kumhar BL 2017. Studies on response of mustard varieties to different sowing dates under humid southern plain zone of Rajasthan. *International Journal of Pure and Applied Bioscience* **5:** 385-391.

Mishra J, Singh RK, Nayak JK and Sahoo S 2019. Productivity of Indian mustard [*Brassica juncea* (L.) Czernj and Cosson] as influenced by tillage and irrigation frequency. *Journal of Pharmacognosy and Phytochemistry* **8**(1): 2273-2276.

Mphande W, Kettlewell PS, Grove IG and Farrell AD 2020. The potential of anti-transpirants in drought management of arable crops: *Agricultural Water Management* **23**(6): 106-143.

Olsen SR, Cole CV, Watanabe FS and Dean LA 1954. *Estimation of available phosphorus in soil by extraction with sodium bicarbonate*. U. S. Department of Agriculture, Washington DC, p 939.

Piri I, Nik MM, Tavassoli A and Rastegaripour F 2019. Effect of irrigation intervals and sulphur fertilizer on growth analyses and yield of *Brassica juncea*. *Advanced Journal of Microbiology Research* **13**(5): 11-17.

Piri I, Nik MM, Tavassoli MMA, Rastegaripour F and Babaeian M 2011. Effect of irrigation frequency and application levels of sulphur fertilizer on water use efficiency and yield of Indian mustard (*Brassica juncea*). *Advanced Journal of Microbiology Research* **5**(22): 3640-3646.

Rajput AL 2012. Effect of plant density, N levels and moisture conservation practices on the performance of Indian mustard (Brassica juncea) and available N status of soil. *Indian Journal of Agronomy* **57**(2): 171-175.

Rajyalakshmi B, Venkateswarlu B, Prasad PVN and Prasad PRK 2019. Yield, quality and sulphur uptake of mustard genotypes as influenced by seed rates in rice fallows. *International Journal of Chemical Studies* **7**(3): 2821-2824.

Ray K, Banerjee H, Paul T and Das TK 2016. Irrigation and sulphur fertilization effects on the productivity, profitability and greenhouse gases emissions in Indian mustard. *Journal of Plant Soil Environment* **52**(3): 434-446.

Richards LA 1954. Diagnosis and improvement of saline and alkaline soils. USDA hand Book No. 60, United States.

Shivran H, Kumar S, Tomar R and Chauhan V 2018. Effect of irrigation schedules on productivity and water use efficiency in Indian mustard (*Brassica juncea* L.). *International Journal of Chemical Studies* **6**(4): 15-17.

Subbaiah BV and Asija GC 1956. A rapid procedure for the estimation of available nitrogen. *Current Science* **25:** 259-260.

Tamboli YA, Yadav JS, Kumar P and Malik K 2024. Irrigation levels and anti-transpirants impact on growth attributes and phenology of different varieties of Indian. *Indian Journal of Ecology* **51**(4): 813-819.

Tyagi PK and Upadhyay AK 2017. Growth, yield and water use efficiency of Indian mustard (*Brassica juncea* L.) as influenced by irrigation frequency and row spacing. *Journal of Oilseed Brassica* **8**(1): 27-36.

Verma HK, Singh MM, Singh MK and Kumar S 2014. Response of Indian mustard (*Brassica juncea* L.) varieties to irrigation for better growth, yield and quality of mustard crop. *International Journal of Agricultural Sciences* **10**(1): 426-429.

Walkely A and Black IA 1947. Rapid titration method for organic carbon of soil. *Soil Science* **37:** 29-33.

Yadav A, Singh AK, Chaudhari R and Mishra SR 2018. Effect of planting geometry on growth and yield of mustard [*Brassica juncea* (L.)] varieties. *Journal of Pharmacognosy and Phytochemistry* **7**(3): 2624-2627.

Received 05 October, 2024; Accepted 17 January, 2025