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Ashok K Saini
Assistant Research Scientist, Centre for Natural Resources Management, SDAU, S. K. Nagar, Gujarat, India

Lalita H Saini
Assistant Research Scientist, Agroforestry Research Station, SDAU, S. K. Nagar, Gujarat, India

Brihma Nand
Assistant Professor, Department of Agronomy, Janta College Bakewar, Etawah, Uttar Pradesh, India

Pratikkumar J Vaghela
Department of Agronomy, C. P. College of Agriculture, SDAU, S. K. Nagar, Gujarat, India

SH Malve
Scientist, Krushi Vigyan Kendra, SDAU, Deesa, Gujarat, India

Corresponding Author:
Ashok K Saini
Assistant Research Scientist, Centre for Natural Resources Management, SDAU, S. K. Nagar, Gujarat, India

Response of mustard to levels of irrigation and nitrogen with and without mulch

Ashok K Saini, Lalita H Saini, Brihma Nand, Pratikkumar J Vaghela and SH Malve

Abstract
A field experiment was conducted during *rabi* season of 2021-22 on loamy sand of Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar, Gujarat to assess the impact of levels of irrigation and nitrogen with & without mulch on growth, yield attributes, yield, field water use efficiency and economics of mustard. The soil was normal in EC (0.112 dS/m), low in organic carbon (0.30%), available nitrogen (187.56 kg/ha), medium in available phosphorus (49.80 kg/ha), available potash (256.40 kg/ha) with slightly alkaline (7.6 pH) in reaction. The experiment was laid out in split plot design and replicated four times. Twelve treatment combinations consisting three levels of irrigation (0.6, 0.8 and 1.0 IW/CPE), two levels of nitrogen (75 and 100% RDN) with and without mustard straw mulch (2 and 0 t/ha) were embedded. The results indicated that significantly higher growth and yield parameters *viz*., plant height at harvest (195.6, 191.9 cm), dry matter accumulation at harvest (46.69, 49.26 g/plant), CGR, RGR, number of primary branches per plant (5.50, 5.58), number of siliquae per plant (277.0, 279.3), number of seeds per siliqua (13.50, 13.48), seed yield (2106, 1999 kg/ha) and stover yield (4783, 4765 kg/ha) with irrigation scheduled at 1.0 IW/CPE and 100% RDN with mustard straw mulch @ 2 tonne per ha, individually. Siliqua length, test weight and harvest index of mustard were not affected by irrigation and nitrogen levels with & without mulch. Higher FWUE was found with irrigation scheduled at 0.6 IW/CPE and 100% RDN with mulch. Total N, P and K uptake as well as available N, P_2O_5 and K_2O after harvest were found highest with higher level of inputs *i.e.*, irrigation, nitrogen and mulch. Maximum net return (₹ 107647/ha) and BCR (3.47) was secured with irrigation scheduled at 1.0 IW/CPE along with 100% RDN with mustard straw mulch @ 2 tonne per ha. Thus, it is concluded that mustard crop should be irrigated at 1.0 IW/CPE and fertilized with 75% RDN (three splits, *i.e.*, 50% as basal and 25% each after 25 and 55 DAS) along with 2 tonne per ha mustard straw mulch for securing higher yield in loamy sand soil.

Keywords: Irrigation, mustard, yield, mulch

Introduction
Indian mustard is the member of Brassica group and commonly known as rai or laha and grown under wide range of agro-climatic conditions. Among the nine edible oilseeds cultivated in India, rapeseed-mustard (*Brassica spp*.) contributes 28.6% in the total production of oilseeds. In India, rapeseed-mustard is grown in 6.69 million hectare of area with 10.11million tonnes of total production and productivity of 1511kg/ha (Anonymous, 2021[a]) [1]. Rajasthan and Uttar Pradesh are the major mustard producing states in the country.

Irrigation scheduling is one of the important managerial activities and affects the effective and efficient utilization of water by crops. It determines the process to decide when to irrigate the crop and how much water is to be applied. It optimizes agricultural production with minimizing yield loss due to water shortage and improving performance and sustainability of any irrigation system through conserving the moisture.

Rapeseed-mustard group of crops have relatively high demand for N than many other crops owing to larger N content in seeds and plant tissues (Malagoli *et al.*, 2005) [9]. Yield increases in Indian mustard at various locations in India have been reported with application of N as high as 150 kg/ha or more (Singh *et al.*, 2008) [17]. Since N fertilizers are costly, poor nitrogen use efficiency is of great concern and therefore, attempts are needed to improve the contribution of applied N in production of grain and this approach will reduce the environmental hazards and production costs in agriculture.Application of optimum dose of nitrogen may be an important factor which can be used for exploration of the yield potential as well as economical crop production.

Mulching plays an important role to increase yield of the crop especially in the arid and semi-arid regions as it may be proved beneficial by reducing water losses. Mulching has been advocated as an effective means for conserving soil moisture. It works as an insulating material against heat or cold and also as a surface barrier to check evaporation from soil surface. Application of organic mulch of paddy straw significantly increased growth parameters, yield and yield attributes and water use efficiency of mustard (Yadav *et al.*, 2010) [22].

Material and methods

The field experiment was conducted during *rabi* season of 2021-22 on loamy sand of Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar, Gujarat to assess the impact of levels of irrigation and nitrogen with & without mulch on growth, yield attributes, yield, field water use efficiency and economics of mustard. The soil was normal in EC (0.112 dS/m), low in organic carbon (0.30%), available nitrogen (187.56 kg/ha), medium in available phosphorus (49.80 kg/ha), available potash (256.40 kg/ha) with slightly alkaline (7.6 pH) in reaction. The experiment was laid out in split plot design and replicated four times. Twelve treatment combinations consisting three levels of irrigation (0.6, 0.8 and 1.0 IW/CPE), two levels of nitrogen (75 and 100% RDN) with and without mustard straw mulch (2 and 0 t/ha) were embedded. Mustard variety GDM 4 was selected for experimental purpose.

Results and Discussion

Plant height

Effect ofirrigation levels

A perusal of data presented in Table 4.2 revealed that irrigation levels exerted significant influence on plant height at30, 60,90 DAS and at harvest. Treatment I_3(1.0 IW/CPE) recorded significantly higher plant height of 45.13, 134.8, 171.3 and 195.6 cm which remained statistically at par with treatment I_2 (0.8 IW/CPE)at 30, 60, 90 DAS and at harvest, respectively. The lowest plant height of 40.61, 121.1, 152.4 and 166.8 cm was recorded at 30, 60, 90 DAS and at harvest, respectively with treatment I_1 (0.6 IW/CPE).

Such increase in plant height was due to sufficient moisture availability in rhizosphere providing congenial growth environment which improved the cell elongation, cell turgidity, opening of stomata and finally partitioning of photosynthates efficiently to the sink. There was decline in plant height with irrigation scheduled at 0.6 IW/CPE (I_1) which might have exposed the crop to relatively more moisture stress as its various stage of water requirement. Results are corroborated with the finding of Digra *et al.* (2016) [4], Barrick *et al.* (2020) [2] and Srujana (2021) [19].

Effect of nitrogen levels with & without mulch

Data outlined in Table 1 indicated that the effect of nitrogen levels with & without mulch on plant height of mustard at 30, 60, 90 DAS and at harvest. However, plant height was found non-significant at 30 DAS. Significantly maximum plant height of 138.4, 173.9 and 191.9cm was recorded at 60, 90 DAS and at harvest, respectively with N_4 treatment (100% RDN with straw mulch). Plant height also significantly responded to different rate of nitrogen with and without straw mulch application. At all crop growth stages, plant height was significantly higher with treatment N_3 (100% RDN without mulch)over treatment N_1 (75% RDN without mulch) which may be due to the fact that nitrogen plays vital role in plant cell division and elongation, as a result, shoot growth of mustard was stimulated. Similar findings were also reported by Mohiuddin *et al*. (2011) [13] and Singh and Singh (2012) [23].

On the other hand, plant height at 30 DAS was unaffected by application of mulch. This might be due to the fact that mustard straw mulch was applied in the respective plots at 30 DAS which failed to bring any significant effect on plant height within this time span. Plant height increased as usual advancement of crop age and maximum plant height observed at harvest. This might be due to fact that application of mulch improved soil moisture, nutrients and other growth factors that altogether promoted plant height. The results are conformity with the findings of Yadav (2005) [20], Regar *el al.* (2007) [15] and Digra *et al.* (2016) [4].

Dry matter accumulation

Effect of irrigation levels

The dry matter accumulation per plant, in general, increased consistently with advancement of the crop age and reached at its maximum at maturity. Application of irrigation increased the dry matter accumulation per plant significantly at all the stages of crop growth. Significantly higher dry matter accumulation of 3.67, 15.34, 33.23 and 46.69 g/plant was recorded at 30, 60, 90 DAS and at harvest, respectively with treatment I_3(1.0 IW/CPE).Whereas, irrigation scheduled at 0.6 IW/CPE (I_1)showed the lowest dry matter accumulation of 3.17, 11.72, 23.29 and 32.23 g/plant was recorded at 30, 60, 90 DAS and at harvest, respectively.

Effect of nitrogen levels with & without mulch

A perusal of data presented in Table 4.3 revealed that various levels of nitrogen with & without mulch exerted significant influence on dry matter accumulation at 60, 90 DAS and at harvest except at 30 DAS. Significantly higher dry matter accumulation 15.47, 33.96 and 49.26g/plant was recorded at 60, 90 DAS and harvest, respectively with treatment N_4 (100% RDN with straw mulch).Whereas, treatment N_1(75% RDN without mulch)showed least dry matter accumulation per plant at 30, 60, 90 DAS and harvest. Dry matter accumulation was significantly higher with treatment N_3 (100% RDN without mulch) over treatment N_1 (75% RDN without mulch). The increase in dry matter accumulation with increase in levels of nitrogen might be due to more supply of nitrogen to crop resulting in rapid synthesis of carbohydrates which increase in size of cell which is expressed morphologically through increase in dry matter accumulation. The results are closely conformed with findings of Dongarkar *et al*. (2005) [24] and Kishore *et al*. (2014) [25].

Treatment N_4 (100% RDN with straw mulch) increasing dry matter accumulation over treatment N_3 (100% RDN without mulch) except at 30 DAS. Dry matter accumulation of plants was favorably affected by mulching which may be attributed to improved crop microenvironment created by mulch application with respect to soil moisture, nutrients and other growth factors that altogether promoted growth and resulted in more plant dry matter accumulation.

Seed yield

Effect of irrigation levels

A perusal of data presented in Table 3 revealed that various

levels of irrigation significantly influenced seed yield of mustard. Treatment I_3 (1.0 IW/CPE) recorded significantly higher seed yield (2106 kg/ha), while lowest seed yield (1583 kg/ha) recorded with treatment I_1 (0.6 IW/CPE). Irrigation scheduled at 1.0 IW/CPE showed 11.25 and 33.03% higher seed yield compared to irrigation scheduled at 0.8 IW/CPE and 0.6 IW/CPE, respectively. The above findings by Panda *et al.* (2005) [26], Chaudhari *et al.* (2016) [27], Digra *et al.* (2016) [4], Parmar *et al.* (2016) [14] and Jat *et al.* (2017) [5].

Effect of nitrogen levels with & without mulch

A study of data with respect to seed yield presented in Table 3 showed that application of nitrogen with & without mulch. Significantly higher seed yield (1999kg/ha) was recorded with treatment N_4 (100% RDN with straw mulch), while lowest seed yield (1721kg/ha) was recorded with treatment N_1(75% RDN without straw mulch). Treatment N_3 (100% RDN without mulch) produced 7.03%higher seed yield as compared to treatment N_1 (75% RDN without mulch).Higher seed yield in this treatments might be due to cumulative effect of elevated growth structure as well as yield structure. Increment in seed yield was mainly because of remarkable improvement in plant height, number of primary branches per plant and seeds per siliqua ultimately resulted from higher nitrogen levels that provide nutrition to the plant ultimately resulted in maximum seed yield. This result was corroborated by Dawson *et al.* (2009). The significant increment in mustard seed yield up to 8.52% with treatment N_4(100% RDN with straw mulch) over treatment N_3 (100% RDN without mulch). This might be due to fact that mulch application may be attributed to enhancement in crop growth as well as yield attributes. Application of mulch conserved soil moisture and suppressing weed growth which might have favourably influenced the seed yield of mustard crop. Significant increase in nutrient uptake by the crop due to mulch application also exhibited profound positive effect on seed yield as seed yield was found to significantly correlate with uptake of nutrients by the crop.This result was corroborated by Singh *et al.* (2014) [29], Digra *et al.* (2016) [4], Devedee *et al.* (2019) [3] and Roy (2019) [16].

Stover yield

The data of stover yield as influenced due to levels of irrigation and nitrogen with & without mulch are accommodated in Table 3 and graphically depicted in fig 1

Effect of irrigation levels

A perusal of data presented in Table 4.9revealed that different levels of irrigation significantly influence stover yield of mustard. Treatment I_3 (1.0 IW/CPE) recorded significantly higher stover yield (4783 kg/ha), which remained at par with treatment I_2 (0.8 IW/CPE).The lowest stover yield (3844 kg/ha) recorded with treatment I_1 (0.6 IW/CPE). Irrigation scheduled at 1.0 IW/CPE showed 10.10 and 24.42% higher stover yield compared to irrigation scheduled at 0.8 IW/CPE and 0.6 IW/CPE, respectively. The stover yield also significantly increased with successive increase in number of irrigations. This increase attributed to enhanced availability of moisture which led to better nutritional environment and better moisture availability, which in turn resulted in better vegetative growth. Similar result found by Digra *et al.* (2016) [4], Parmar *et al.* (2016) [14], Barrick *et al.* (2020) and Srujana (2021).

Effect of nitrogen levels with & without mulch

A study of data with respect to stover yield presented in Table 4.9 showed that effect of nitrogen levels with and without straw mulch. Significantly higher stover yield (4765 kg/ha) produced with treatment N_4 (100% RDN with straw mulch), which remained at par with treatment N_2 (75% RDN with straw mulch). Lowest stover yield (3862 kg/ha) was recorded with treatment N_1 (75% RDN without mulch).

Treatment N_3 (100% RDN without mulch) produced 10.33%higher stover yield over treatment N_1 (75% RDN without mulch).This might be due to yield is the resultant outcome of the effect of various growth factors and yield parameters. With the increment in supply of nitrogen to mustard, nutrient availability, acquisition, mobilization and influx into the plant tissues increased and thus improved growth attributes and yield components. It was confined with the findings of Dongarkar *et al.* (2005) [24] and Shirale *et al.* (2014) [28]. The significant increment upto 11.82% in mustard stover yield with with treatment N_4 (100% RDN with straw mulch) over treatment N_3 (100% RDN without mulch) which may be due to increased availability of soil moisture, efficient suppression of weed growth by the virtue of mulch application might have facilitated the vegetative growth of crop and thereby, the stover yield of crop. Similar result found by Singh *et al.* (2014) [29], Digra *et al.* (2016) [4], Kumar *et al.* (2018) [30] and Srujana (2021) [19].

Harvest index

The data of harvest indexas influenced by different irrigation and nitrogen levels with & without mulch have been presented in Table 3

Effect of irrigation level

A perusal of data presented in Table 3 revealed that various levels of irrigation did not exert significant influence on harvest index of mustard. Treatment I_3 (1.0 IW/CPE) recorded maximum harvest index (30.66%), while minimum harvest index (29.31%) recorded with treatment I_1 (0.6 IW/CPE).

Effect of nitrogen levels with & without mulch

The results presented in Table 4.9revealed that several of nitrogen levels with & without mulch did not exert significant influence on harvest index of mustard. Application of 75% RDN without mulch recorded maximum harvest index (30.82%), while minimum harvest index recorded with 100% RDN with straw mulch (29.55%).

Economics

Effect of irrigation levels

Maximum economic return with successive increase in irrigation application was noted. Maximum gross return (₹ 141673/ha) and net return (₹ 102501/ha)were obtained with treatment I_3(1.0 IW/CPE). Whereas, the minimum gross return (₹ 106739/ha) and net return (₹72290/ha) observed with the treatment I_1 (0.6 IW/CPE). Benefit cost ratio also followed same trend and recorded maximum with treatment I_3(1.0 IW/CPE) and the lowest in treatment I_1 (0.6 IW/CPE). Higher seed and stover yield with increasing levels of irrigation might be resulted in better benefit cost ratio. This might be due to fact that increment in irrigation levels increase yield. The results are conformity with the finding of Parmar *et al.* (2016) and Barrick *et al.* (2020) [2].

Effect of nitrogen and mulch levels

Increased economic return with successive increase in N with mulch application was observed. Treatment N_4 (100% RDN with straw mulch) to mustard crop recorded maximum gross return, net return and BCR. This might be due to least treatment cost and higher productivity under this treatment. The results are conformity with the finding of Jat *et al.* (2018) [6] and Shirale *et al.* (2014) [28].

Economics of treatment combinations

Gross return, net return and benefit cost ratio of different treatment combinations have been worked out and presented in Table 6. Irrigation at 1.0 IW/CPE along with 100% RDN with straw mulch (I_3N_4) recorded maximum gross return (₹ 151150/ha), net return (₹ 107647/ha) and BCR (3.47). Whereas least gross return (₹ 98944/ha) and net return (₹ 64000/ha) with I_1N_1(0.6 IW/CPE along with application of 75% RDN and without straw mulch), whereas least benefit cost ratio (2.79) was observed with I_1N_2(0.6 IW/CPE along with application of 75% RDN and with straw mulch).

Table 1: Effect of irrigation and nitrogen levels with & without mulch on mustard plant height

Treatments		Plant height (cm)			
		30 DAS	60 DAS	90 DAS	At harvest
A.	**Irrigation levels**				
	I_1: 0.6 IW/CPE	40.61	121.7	152.4	166.8
	I_2: 0.8 IW/CPE	43.51	128.0	162.7	185.3
	I_3: 1.0 IW/CPE	45.13	134.8	171.3	195.6
	S.Em. ±	0.90	2.64	3.52	3.88
	C.D. at 5%	3.12	9.13	12.19	13.44
	C.V.%	8.37	8.25	8.69	8.51
B.	**Nitrogen levels with & without mulch**				
	N_1:75% RDN without mulch	41.65	117.2	150.6	174.7
	N_2:75% RDN with straw mulch	41.75	125.4	159.7	180.3
	N_3:100% RDN without mulch	44.31	130.7	164.5	183.6
	N_4: 100% RDN with straw mulch	44.63	138.4	173.9	191.9
	S.Em. ±	0.94	2.63	3.82	4.05
	C.D. at 5%	NS	7.62	11.09	11.76
Interaction					
S.Em. ±		1.63	4.55	6.62	7.02
C.D. at 5%		NS	NS	NS	NS
C.V.%		7.55	7.11	8.17	7.69

Table 2: Effect of irrigation and nitrogen with & without mulch levels on periodical dry matter accumulation of mustard

Treatments		Dry matter accumulation (g/plant)			
		30 DAS	60 DAS	90 DAS	At harvest
A.	**Irrigation levels**				
	I_1: 0.6 IW/CPE	3.17	11.72	23.29	32.23
	I_2: 0.8 IW/CPE	3.55	13.70	28.75	40.82
	I_3: 1.0 IW/CPE	3.67	15.34	33.23	46.69
	S.Em. ±	0.08	0.28	0.70	0.84
	C.D. at 5%	0.27	0.98	2.41	2.90
	C.V.%	8.93	8.30	9.81	8.39
B.	**Nitrogen levels with & without mulch**				
	N_1:75% RDN without mulch	3.40	11.97	23.64	31.53
	N_2:75% RDN with straw mulch	3.38	13.54	28.50	40.60
	N_3:100% RDN without mulch	3.56	13.37	27.60	38.27
	N_4: 100% RDN with straw mulch	3.51	15.47	33.96	49.26
	S.Em. ±	0.08	0.36	0.89	0.78
	C.D. at 5%	NS	1.05	2.57	2.26
Interaction					
S.Em. ±		0.15	0.63	1.53	1.35
C.D. at 5%		NS	NS	NS	NS
C.V.%		8.47	9.22	10.79	6.76

Table 3: Effect of irrigation and nitrogen levels with & without mulch on seed yield, stover yield and harvest index of mustard

Treatments		Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
A.	**Irrigation levels**			
	I_1: 0.6 IW/CPE	1583	3844	29.31
	I_2: 0.8 IW/CPE	1893	4344	30.53
	I_3: 1.0 IW/CPE	2106	4783	30.66
	S.Em. ±	54.47	146.18	0.91
	C.D. at 5%	189	506	NS
	C.V.%	11.71	13.52	12.13
B.	**Nitrogen levels with & without mulch**			
	N_1:75% RDN without mulch	1721	3862	30.82
	N_2:75% RDN with straw mulch	1880	4408	29.89
	N_3:100% RDN without mulch	1842	4261	30.18
	N_4: 100% RDN with straw mulch	1999	4765	29.55
	S.Em. ±	55.59	142.29	0.87
	C.D. at 5%	161	413	NS
Interaction				
S.Em. ±		96.29	246.45	1.51
C.D. at 5%		NS	NS	NS
C.V.%		10.35	11.40	10.04

Table 4: Effect of irrigation, nitrogen and mulch levels on economics of mustard

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha	Net return (₹/ha)	B: C ratio
Main factor (I)						
I_1	1583	3844	34449	106739	72290	3.10
I_2	1893	4344	36810	127389	90579	3.46
I_3	2106	4783	39172	141673	102501	3.62
Sub factors (N)						
N_1	1721	3862	29090	115727	86637	3.98
N_2	1880	4408	32697	126608	93911	3.87
N_3	1842	4261	29271	123991	94721	4.23
N_4	1999	4765	32876	134700	101824	4.10

Table 5: Effect of treatment combinations on economics of mustard

Treatment combinations (I × NM)	Seed yield (kg/ha)	Stover yield (kg/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha	Net return (₹/ha)	B: C ratio
I_1N_1	1470	3444	34994	98994	64000	2.83
I_1N_2	1598	3909	38601	107779	69178	2.79
I_1N_3	1569	3775	35174	105760	70587	3.01
I_1N_4	1695	4249	38780	114424	75645	2.95
I_2N_1	1725	3778	37356	115903	78548	3.10
I_2N_2	1885	4392	40962	126917	85955	3.10
I_2N_3	1907	4319	37535	128274	90739	3.42
I_2N_4	2058	4886	41142	138656	97515	3.37
I_3N_1	1970	4362	39717	132412	92696	3.33
I_3N_2	2158	4922	43323	145192	101869	3.35
I_3N_3	2051	4690	39897	138005	98109	3.46
I_3N_4	2246	5160	43503	151150	107647	3.47

(Selling price of mustard seed - ₹ 65/kg, selling price of mustard stover- ₹ 1/kg)

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