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Effect of nutrient management and irrigation scheduling on productivity of Indian mustard (*Brassica juncea* L.)

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Abstract
A field experiment was conducted to study the effect of Effect of Nutrient Management and Irrigation Scheduling on Performance of Indian mustard (*Brassica juncea* L.) during *Rabi* season of 2020-21 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.). The soil of the experimental field was well drained, sandy loam in texture and slightly alkaline in nature. It was low in organic carbon and nitrogen but medium in available phosphorus and potassium with anelectrical conductivity (1:2, soil: water) of 1.65 ds/m. The experiment was laid out in split design with three replications. The *rabi* season experiment comprised of five levels of irrigation scheduling Growth stage (I_1), Pre flowering stage (I_2), Growth + siliqua stage (I_3), Pre- flowering + siliqua stage (I_4), Growth + Pre- flowering + siliqua (I_5). and five level of nutrient management *viz*.; Control (N_1), RDF (120:60:40:40) (N_2), RDF + Zn + B (N_3) 75% RDF + 6 tonne (FYM) 25% (N_4), 75% RDF + 6 tonne (FYM) + Zn + B (N_5) were tested in Split Plot Design (SPD) with three replications. The mustard variety Pusa Vijay was grown. The growth and yield, nutrient uptake as influenced by different treatments were assessed. The yield attributing characters like length of siliqua^{-1}, number of siliquae plant $^{-1}$, seed siliqua^{-1}, and 1000- seed weight exhibited variations due to different irrigation scheduling and nutrient management the highest mean length of siliqua, number of siliqua plant^{-1}, seed siliqua^{-1}, and 1000- seed weight was recorded under the treatment of Growth + Pre- flowering + siliqua (I_5) and 75% RDF + 6 tonne (FYM) + Zn + B (N_5). The highest seed yield, stover yield and biological yield was recorded in Growth + Pre- flowering + siliqua (I_5) and 75% RDF + 6 tonne (FYM) + Zn + B (N_5) and the lowest seed yield, stover yield and biological yield was recorded in Growth stage (I_1) and Control (N_1). Gross income and net profit were found significantly higher with the combine application of Growth + Pre- flowering + siliqua (I_5) and 75% RDF + 6 tonne (FYM) + Zn + B (N_5) (Rs. 108318 and Rs. 82688), respectively over rest of treatment and benefit: cost ratio was significantly affected by application of Growth + Pre-flowering + siliqua (I_5) and 75% RDF + 6 tonne (FYM) + Zn + B (N_5) alone with mean value 2.53 followed by remaining treatments. Thus, it may be concluded that application of Growth + Pre-flowering + siliqua (I_5) and 75% RDF + 6 tonne (FYM) + Zn + B (N_5) treatment, seems to be best option for achieving higher yield and net returns by mustard crop.

Keywords: Irrigation scheduling, nutrient management, mustard

Introduction
Indian mustard (*Brassica juncea* L.) belonging to the family *cruciferae* is one of the important oil seed crops and currently ranked as the world's third important oil seed crop in terms of production and area. Oil content in rapeseed & mustard varies from 33% to 46% and average oil recovery is around 32% to 38%. After oil extraction, the remaining part of the seed is used to produce rapeseed/ mustard meal, an important component of cattle and poultry feed. In India, the annual production of rapeseed-mustard was about 58.03 lakh tonnes covering an area of about 61.90 lakh hectares with a total productivity of 0.94 tonnes ha-1 (Anonymous, 2015) [1]. It is estimated that 58 mt of oil seeds will be required by the year 2020, wherein the share of mustard will be around 24.2mt (Bartaria *et al*., 2001) [2]. Therefore, it becomes imperative to increase the productivity of rapeseed-mustard per unit area and per unit time. Amongst the agronomic factors known to augment crop production, fertilizer stands first and considered one of the most productive inputs in agriculture as a source of nutrient elements particularly nitrogen which is insufficient in most of our Indian soils and plays appreciably an important role in Brassica crops (Singh and Meena, 2004) [8]. Mustard crop responded favorably to nitrogen and sulphur fertilization increases yield by influencing different growth parameters and *viz*. increasing plant height, number of flowering branches, total plant weight, leaf area index, number and weight of siliquae and seeds per plant.

Adequate supply of sulphur to rapeseed-mustard promotes the synthesis of sulphur containing essential amino acids, proteins and oil. Moreover, nitrogen and sulphur are closely related with one another because both of these elements are required for protein synthesis and their amount in plant tissue always maintained at constant ratio. Application of fertilizers containing these two nutrient elements have been recognized to be the most important constraints and often inadequate application of nitrogen and sulphur at farmer's field reduce the yield levels of mustard. Under sulphur deficient soils, the full yield potential of mustard cannot be realized regardless of other nutrients applied or adoption of improved crop management practices. Therefore, the present study was conducted to investigate the effects of N and S fertilization on growth and yield of mustard.

Methodology

The field experiment was conducted during *Rabi* season of 2020-21 at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.). The experiment was laid out in Split Plot Design (SPD) with three replications. The treatment consisted of five levels of irrigation scheduling at Growth stage (I_1) Pre flowering stage (I_2) Growth + siliqua stage (I_3) Pre – flowering + siliqua stage (I_4) Growth + Pre- flowering + siliqua (I_5) and five level of nutrient management *viz*.; Control (N_1) RDF (120:60:40:40) (N_2) RDF + Zn + B (N_3) 75% RDF + 6 tonne (FYM) 25% (N_4) 75% RDF + 6 tonne (FYM) + Zn + B (N_5). The soil of the experimental field was well drained, sandy loam in texture and slightly alkaline in nature. It was low in carbon and nitrogen but medium in available phosphorus and potassium with an electrical conductivity (1:2, soil: water) of 1.65 ds/m. The mustard variety Pusa Vijay was grown and growth and yield, economics as influenced by different treatments were assessed.

Results and Discussion

Data recorded on number of length of siliqua (cm) as influenced by irrigation scheduling and nutrient management. It is observed from the data in the table given below that irrigation scheduling significantly influenced the length of siliqua. Amongst the treatments, I_5 (Growth + Pre- flowering + siliqua) recorded maximum length of siliqua (4.28 cm), which was statistically at par with I4 (Pre – flowering + siliqua stage) treatments. The treatment I_1 (Growth stage) recorded significantly lowest siliqua length (4.13 cm). Application of 75% RDF + 6 tonne (FYM) + Zn + B (N_5) recorded significantly highest length siliqua (4.34 cm), which was statistically at par with N4 (75% RDF + 6 tonne (FYM) 25%). The significantly lowest length of siliqua (3.90 cm) was found under the treatment N_1 (Control).

Length of siliqua (cm)

Data recorded on number of length of siliqua (cm) as influenced by irrigation scheduling and nutrient management are presented in Table 1.

Number of seeds siliqua^{-1}

Data recorded on number of seeds siliqua^{-1} as influenced by irrigation scheduling and nutrient management are presented in Table 1. It is obvious from the data in the table that irrigation scheduling significantly influenced the number of seeds siliqua^{-1} production. Amongst the treatments, the treatment I_5 (Growth + Pre- flowering + siliqua) recorded higher number of seeds siliqua^{-1}(13.32) followed by I_4 (Pre – flowering + siliqua stage). The treatment I_1 (Growth stage) recorded lowest (11.81) number of seeds siliqua^{-1}. Variation in number of seeds siliqua^{-1} due to nutrient management treatments was also observed. The treatment I_5 (75% RDF + 6 tonne (FYM) + Zn + B) recorded significantly higher number of seeds siliqua^{-1} (12.88) as followed by N_4 and N_3. The significantly lowest number of seed siliqua^{-1} was found under the treatment N_1 (Control).

Number of siliqua plant^{-1}

Data recorded on number of siliqua plant^{-1} as influenced by irrigation scheduling and nutrient management are given in Table 1. It is obvious from the data in the table that number of siliqua plant^{-1} significantly varied due to irrigation scheduling. Amongst all the irrigation treatments, the significantly higher number of siliqua plant^{-1} (236.03) was recorded under I_5 (Growth + Pre- flowering + siliqua), which was statistically at par with I_4 (Pre-flowering + siliqua stage). The significantly lowest number of siliqua plant^{-1} (201.92) was recorded under the treatment I_1 (Growth stage). Variations number of siliqua plant^{-1} due to nutrient management treatment was significant. Amongst the nutrient treatments, the treatment N_5 (75% RDF + 6 tonne (FYM) + Zn + B) recorded superior number of siliqua plant^{-1} (230.52), which was statistically at par with N_4 (75% RDF + 6 tonne (FYM) 25%) and N_3 (RDF + Zn + B). However, the significantly lowest number of siliqua plant^{-1} (190.83) was found under the treatment N_1 (Control).

Test weight (g)

Data recorded on test weight of mustard under different treatments are presented in Table 1. It is clear from the data given in the table that test weight of mustard varied significantly due to irrigation scheduling. Amongst all the treatments, the highest test weight (4.10 g) was recorded under I_5 (Growth + Pre- flowering + siliqua) followed by I_4 (Pre-flowering + siliqua stage) and I_3 (Growth + siliqua stage). The variations in test weight due to nutrient management treatment were also observed. The significantly higher test weight (4.12 g) was observed in treatment N_5 (75% RDF + 6 tonne (FYM) + Zn + B) followed by N_4 (75% RDF + 6 tonne (FYM) 25%) and N_3 (RDF + Zn + B). The significantly lowest test weight (3.20 g) was recorded under the treatment N_1 (Control).

Table 1: Effect of nutrient management and irrigation scheduling on yield attributes of mustard crop

Treatments	Yield attributes			
	Siliqua length (cm)	Number of seed/siliqua	Number of siliqua/plant	Test weight (g)
Irrigation Scheduling				
Growth stage (I_1)	4.13	11.81	201.92	3.32
Pre flowering stage (I_2)	4.18	12.21	214.96	3.66
Growth + siliqua stage (I_3)	4.22	12.32	224.50	3.75
Pre – flowering + siliqua stage (I_4)	4.24	12.82	228.01	3.92
Growth + Pre- flowering + siliqua (I_5)	4.28	13.32	236.03	4.10

S.Em ±	0.01	0.06	3.40	0.02
C D (P= 0.05)	0.04	0.18	10.1	0.06
Nutrient Management				
Control (N_1)	3.90	10.30	190.83	3.20
RDF (120:60:40:40) (N_2)	4.19	12.34	217.82	3.85
RDF + Zn + B (N_3)	4.23	12.68	221.34	3.98
75% RDF + 6 tonne (FYM) 25% (N_4)	4.26	12.74	224.35	4.01
75% RDF + 6 tonne (FYM) + Zn + B (N_5)	4.34	12.88	230.52	4.12
S.Em ±	0.03	0.24	4.08	0.03
C D (P= 0.05)	0.10	0.70	12.20	0.09

Biological yield

It is evident from the table 2 that the biological yield significantly differed with irrigation treatments. The biological yield increased with increase in level of irrigations. The significantly higher biological yield (10106 kg ha^{-1}) was recorded in treatment I_5 (Growth + Pre- flowering + siliqua) followed by I_4 (Pre-flowering + siliqua stage) and I_3 (Growth + siliqua stage), respectively. The lowest biological yield (6633 kg ha^{-1}) was observed under treatment I_1 (Control). The biological yield significantly varied with the nutrient management treatments. The treatment N_5 (75% RDF + 6 tonne (FYM) + Zn + B) recorded significantly higher biological yield (9354 kg ha^{-1}) The lowest biological yield (5219 kg ha^{-1}) was found under the treatment N_1 (Control).

Seed yield (kg ha^{-1})

It is evident from the data given in Table 2 that the seed yield significantly varied with irrigation treatments. The maximum seed yield (1882 kg ha^{-1}) was recorded under the treatment I_5 (Growth + Pre- flowering + siliqua) followed by I_4 (Pre – flowering + siliqua stage) and I_3 (Growth + siliqua stage), respectively. The significantly lowest seed yield (1004 kg ha^{-1}) was observed under the treatment I_1 (Growth stage). About 87.45 (%) increases over I_1 (Growth stage) was recorded by grain yield, respectively It is clear from the results that seed yield significantly influenced due to the nutrient management treatments. Amongst all the nutrient management treatments, the treatment N_5 (75% RDF + 6 tonne (FYM) + Zn + B) obtained significantly higher seed yield followed by the treatment N_4 (75% RDF + 6 tonne (FYM) 25%) and N_3 (RDF + Zn + B). The significantly lowest seed yield (684 kg ha^{-1}) was recorded under the treatment N_1 (Control). Interaction effects between irrigation scheduling and nutrient management in respect to seed yield were non-significant during the year of experimentation.

Stover yield (kg ha^{-1})

It is evident from the Table no. 2 that the stover yield significantly differed with irrigation scheduling treatments. The stover yield increased with increase in levels of irrigations. The maximum stover yield (8224 kg ha^{-1}) was recorded in treatment I_5 (Growth + Pre-flowering + siliqua) followed by I_4 (Pre-flowering + siliqua stage) and I_3 (Growth + siliqua stage), respectively. The significantly lowest stover yield (5629 kg ha^{-1}) was observed under treatment I_1. It is evident from the results in the table that stover yield significantly varied with the nutrient management treatments. The treatment N_5 (75% RDF + 6 tonne (FYM) + Zn + B) recorded the higher stover yield (7693 kg ha^{-1}) followed by N_4 (75% RDF + 6 tonne (FYM) 25%) and N_3 (RDF + Zn + B). The lowest stover yield (4535 kg ha^{-1}) was found under the treatment N_1 (Control). Interaction effects between irrigation scheduling and nutrient management in respect to stover yield were non-significant during the year of experimentation.

Table 2: Effect of nutrient management and irrigation scheduling on grain, stover and biological yield (kg ha^{-1}) and harvest index of mustard crop

Treatments	Yield (kg ha^{-1})			
	Seed	**Stover**	**Biological**	**Harvest index (%)**
Irrigation Scheduling				
Growth stage (I_1)	1004	5629	6633	15.14
Pre flowering stage (I_2)	1349	6595	7944	16.98
Growth + siliqua stage (I_3)	1420	6858	8278	17.15
Pre – flowering + siliqua stage (I_4)	1430	6894	8324	17.18
Growth + Pre- flowering + siliqua (I_5)	1882	8224	10106	18.62
S.Em ±	9.71	28.55	38.28	0.02
C D (P= 0.05)	29.03	85.15	114.14	0.06
Nutrient Management				
Control (N_1)	684	4535	5219	13.11
RDF (120:60:40:40) (N_2)	1344	6731	8075	16.64
RDF + Zn + B (N_3)	1465	6930	8395	17.45
75% RDF + 6 tonne (FYM) 25% (N_4)	1493	7021	8514	17.54
75% RDF + 6 tonne (FYM) + Zn + B (N_5)	1661	7693	9354	17.76
S.Em ±	14.94	69.89	84.76	0.12
C D (P= 0.05)	42.71	199.82	242.35	0.36

Cost of cultivation (Rs ha^{-1})

The data pertaining to cost of cultivation is presented in Table 4. The data indicates the highest cost of cultivation (Rs. 25630) was observed in the treatment I_5 (Growth + Pre- flowering + siliqua) which was applied in the treatment followed by I_4 (Pre – flowering + siliqua stage). The lowest cost of cultivation (Rs. 18520) observed in I_1 (Growth stage). Under different nutrient management the highest cost of cultivation (Rs. 24800) was observed in N_5 (75% RDF + 6 tonne (FYM) + Zn + B) which was applied in the treatment followed by N_4 (75% RDF + 6 tonne (FYM) 25%) and N_3 (RDF + Zn + B). The lowest cost of cultivation (Rs. 17458) observed in N_1 (Control) treatment.

Gross return (Rs ha^{-1})

The data pertaining to gross return is presented in Table 4. The data indicates the highest gross return (Rs. 108318) was observed in the treatment I5 (Growth + Pre- flowering + siliqua) followed by I_4 (Pre – flowering + siliqua stage). The lowest gross return (Rs 59648) observed in I_1 (Growth stage) plots. Among different nutrient management the highest gross return (Rs. 96251) was observed in N_5 (75% RDF + 6 tonne (FYM) + Zn + B) treatment followed by N_4 (75% RDF + 6 tonne (FYM) 25%). The lowest gross return (Rs. 41687) observed in N_1 (Control) treatment.

Net returns (Rs ha^{-1})

The data pertaining to net return is presented in Table 4. The data indicates the highest net return (Rs. 82688) was observed in the treatment I5 (Growth + Pre- flowering + siliqua) followed by I4 (Pre – flowering + siliqua stage). The lowest net return (Rs. 41128) observed in I_1 (Growth stage) plots. Different nutrient management the highest net return (Rs. 71451) was observed in N_5 (75% RDF + 6 tonne (FYM) + Zn + B) followed by N_4 (75% RDF + 6 tonne (FYM) 25%). The lowest net return (Rs. 24229) observed in N_1 (Control) treatment.

B: C ratio

The data pertaining to B: C ratio is presented in Table 4. The data indicates the highest B: C ratio (3.23) was observed in the treatment I_5 (Growth + Pre- flowering + siliqua) followed by I_4 (Pre – flowering + siliqua stage). The lowest B: C ratio (2.22) observed in I_1 (Growth stage). Different nutrient management the highest B: C ratio (2.88) was observed in N_5 (75% RDF + 6 tonne (FYM) + Zn + B) followed by N_4 (75% RDF + 6 tonne (FYM) 25%). The lowest B: C ratio (1.39) observed in N_1 (Control) treatment.

Table 3: Effect of nutrient management and irrigation scheduling on cost of cultivation, gross income, net income and benefit cost ratio of mustard

Treatments	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B: C ratio
Irrigation Scheduling				
Growth stage (I_1)	18520	59648	41128	2.22
Pre flowering stage (I_2)	22350	78692	56342	2.52
Growth + siliqua stage (I_3)	23710	82707	58997	2.49
Pre – flowering + siliqua stage (I_4)	23400	83271	59871	2.56
Growth + Pre- flowering + siliqua (I_5)	25630	108318	82688	3.23
S.Em ±	-	1613	1541	0.08
C D (P= 0.05)	-	5156	4924	0.25
Nutrient Management				
Control (N_1)	17458	41687	24229	1.39
RDF (120:60:40:40) (N_2)	21900	78641	56741	2.59
RDF + Zn + B (N_3)	22860	85110	62250	2.72
75% RDF + 6 tonne (FYM) 25% (N_4)	23140	86675	63535	2.75
75% RDF + 6 tonne (FYM) + Zn + B (N_5)	24800	96251	71451	2.88
S.Em ±	-	1463	1374	0.06
C D (P= 0.05)	-	4238	3980	0.16

Discussion

Effects on yield attributes and yield of mustard

The yield of *Brassica* species is a function of yield attributes like number of branches/ plant, length of siliqua, number of siliqua/ plant, number of seeds/ siliqua and 1000- seed weight. For these again a good mustard crop is required, which is turn depends upon optimum growth of photosynthetic organs, translocation of nutrients and photosynthesis to developing plant parts and finally larger frame to accommodate number of yield attributes. The length of siliqua, number of siliqa/plant, number of seed/plant and 1000-seed weight, where found highest with the application of irrigation at growth + pre flowering + siliqua (I_5) and nutrient management 75% RDF + 6 tonne FYM + Zn + B (N_5). However the minimum number recorded in growth stage (I_1) and control (N_1) stage plot, which was significantly lower than other treatments at all the stages. These results are in close conformity with the findings by Tomar *et al*. (1992) [9].

The balanced nutrient management practices contributed to a great extent influencing the seed yield of mustard. The seed yield increased with the increasing nutrient management and recorded highest grain, stover and biological yield with the application of growth + pre flowering + siliqua (I_5) and 75% RDF + 6 tonne FYM + Zn + B (N_5) the might be due to more number of siliqua/plant, number of seed /siliqua and 1000 sed weight under this treatment which ultimately resulted in to higher yield. However the minimum yield was recorded in treatment growth stage (I_1) and control (N_1) plot which was significantly lower than other treatment. These results are in close conformity with the findings of Rashid *et al.* (2012) [6], Kumar *et al.* (2014) [4], Rathore *et al.* (2015) [7].

Effect on the economic feasibility

The total variable cost of cultivation increased slightly with different sources of fertilizer. The highest cost of cultivation, gross income, net income and benefit cost ratio was noted at irrigation schedule at growth + pre flowering + siliqua (I_5) and nutrient management at 75% RDF + 6 tonne FYM + Zn + B (N_5) while the lowest cost of cultivation, gross income, net income and B:C ratio was observed in irrigation schedule at growth stage (I_1) and control (N_1). The highest net income of mustard was recorded in irrigation schedule at growth + pre flowering + siliqua (I_5) and nutrient management 75% RDF + 6 tonne FYM + Zn + B (N_5) because of highest quantity of seed and stover yield and rates of respective yields. Similar trends were also observed by Parihar *et al.* (2014) [4], Puste *et al*. (2015) [5].

Conclusion

On the basis of experimental findings it is clear that maximum crop yield and benefit cost ratio was achieved with irrigation at growth + pre-flowering + siliqua stage (I_5). Among the nutrient management, the highest crop yield was recorded with the application of 75% RDF + 6 tone FYM + Zn + B (N_5). Thus, it may be concluded that application of 75% RDF + 6 tone FYM + Zn + B (I_5) along with irrigation at growth + pre- flowering + siliqua stage (I_5) seems to best option for achieving higher yield and net returns from mustard crop.

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