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Effect of sowing time on growth and yield of Indian mustard (*Brassica juncea* L.) in relation to irrigation practices in central UP

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Abstract
A field experiment was conducted during the Rabi season of 2023-24 at the Agriculture Research Farm, Rama University, Kanpur, to investigate the "Effect of Sowing Time on Growth and Yield of Indian Mustard (*Brassica juncea* L.) in Relation to Irrigation Practices in Central UP" in Relation to Irrigation Practices in Central Uttar Pradesh." The experiment was designed using a randomized block design with three replications and 12 treatments. The treatments included combinations of sowing times and irrigation schedules as follows: T_1 = Early sowing + No irrigation, T_2 = Early sowing + One irrigation (20 DAS), T_3 = Early sowing + Two irrigations (20, 35 DAS), T_4 = Early sowing + Three irrigations (20, 35, 50 DAS), T_5 = Mid/Optimum sowing + No irrigation, T_6 = Mid/Optimum sowing + One irrigation (20 DAS), T_7 = Mid/Optimum sowing + Two irrigations (20, 35 DAS), T_8 = Mid/Optimum sowing + Three irrigations (20, 35, 50 DAS), T_9 = Late sowing + No irrigation, T_{10} = Late sowing + One irrigation (20 DAS), T_{11} = Late sowing + Two irrigations (20, 35 DAS), and T_{12} = Late sowing + Three irrigations (20, 35, 50 DAS). The results indicated that mid-sowing on 15th November combined with three irrigations at 20, 35, and 50 DAS (T_8) provided the best outcomes in terms of growth, development, yield, and economics of the mustard crop.

Keywords: Irrigation schedule, early sowing, late sowing and yield

Introduction
Indian mustard (*Brassica juncea* L.), a member of the *Brassicaceae* family with 36 chromosomes (2n), is a key Rabi oilseed crop in India, known as Rai or Raya. With seeds containing 33-49% oil, it ranks as the second most important oilseed crop after groundnut, contributing about 30% to India's oilseed production. India leads globally in rapeseed-mustard cultivation area and is second in production after China. However, the country faces a growing oil supply-demand gap, with per capita oil consumption rising from under 6 kg in 1992-93 to 18 kg recently.

In 2023-24, rapeseed-mustard was grown on 6.33 million hectares in India, producing 6.69 million tons at an average yield of 1145 kg/ha. In Uttar Pradesh, it covered 0.95 million hectares (19.81% of the national area) and yielded 0.79 million tons (20.23% of national output), with a lower average yield of 962 kg/ha (Anonymous, 2023-24). Oilseeds, including mustard, groundnut, linseed, castor, safflower, and Niger, are vital to India's economy, supporting diets and agricultural livelihoods.

Mustard is highly sensitive to weather, with sowing time significantly affecting growth and yield due to variations in temperature, humidity, rainfall, and light intensity. Optimal sowing aligns crop development with favorable conditions, boosting growth and seed yield. Sowing on November 10th yields higher than October 30th, as it better matches optimal winter conditions (October-March). Temperature and light intensity critically influence biomass partitioning.

Irrigation frequency also plays a major role in mustard productivity. Three irrigations increase seed yield by approximately 52% and 15% compared to one or two irrigations, respectively, by enhancing nutrient availability and supporting growth (Verma *et al*., 2014) [6].

Late sowing reduces yield due to a shorter growth period and high temperatures during reproduction. Crops sown in early October yield less than those sown in late September, as October sowing often faces suboptimal conditions. Understanding physiological and phenological factors behind yield losses can inform strategies to optimize seed production.

Irrigation frequency significantly affects mustard yield and quality, requiring a balanced schedule based on cultivar, soil, season, rainfall, and disease factors. Both over-and under-irrigation reduce productivity, emphasizing the need for efficient water use. Modern irrigation practices can improve outcomes, positively impacting growth and yield traits (Hossain *et al*., 2013) [2].

Materials and Methods

The study, titled "Effect of Sowing Time on Growth and Yield of Indian Mustard (*Brassica juncea L.*) in Relation to Irrigation Practices in Central UP" was carried out during the Rabi season of 2023-24 at the Agriculture Research Farm, Rama University, Kanpur. This chapter details the materials utilized and the experimental methodologies adopted, systematically presented under appropriate headings and subheadings.

Seed Yield

After threshing and winnowing, clean seeds from each plot were weighed, and the seed yield was recorded in kg per plot.

Stover Yield

Stover yield was calculated by subtracting the seed yield (kg/ha) from the biological yield (kg/ha).

Harvest Index

The harvest index was calculated as a percentage based on seed yield and total biomass production, using the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Grain Yield}}{\text{Biological Yield}} \text{X } 100$$

Economic Analysis

Net Returns (ha^{-1})

To identify the most profitable treatment, the economics of different treatments were calculated in terms of net returns (₹ ha^{-1}) based on prevailing market rates. This analysis aimed to recommend the most remunerative treatment. The net return was computed using the following formula:

Net Return (₹ ha^{-1}) = Gross Return (₹ ha^{-1})-Cost of Cultivation (₹ ha^{-1})

Benefit: Cost (B:C) Ratio

The benefit: cost ratio was calculated for each treatment to evaluate economic viability, using the following formula:

$$\text{B:C Ratio} = \frac{\text{Gross Return}}{\text{Cost of Cultivation}}$$

Findings, Summary and Conclusion

Seed Yield (q/ha)

The seed yield per hectare of mustard is influenced by sowing time and varying irrigation schedules, as shown in Table 1. The highest seed yield was recorded in sowing time S2 (mid-sowing on 15th November) at 12.858 q/ha and irrigation treatment I3 (irrigation at 20, 35, and 50 DAS) at 16.978 q/ha. These results are statistically significant compared to the control.

Stover Yield (q/ha)

Stover yield per hectare of mustard is also affected by different sowing times and irrigation schedules, as summarized in Table 2. The lowest stover yields were recorded in sowing time S3 (late sowing on 30th November) at 37.817 q/ha and irrigation schedule I0 (control) at 18.411 q/ha. The highest stover yields, 39.317 q/ha and 52.733 q/ha, were observed in S2 (mid-sowing on 15th November) and I3 (irrigation at 20, 35, and 50 DAS), respectively.

Biological Yield (q/ha)

Biological yield, the combined seed and stover yield, is influenced by sowing time and irrigation combinations. The highest biological yields were recorded in S2 (mid-sowing on 15th November) at 52.175 q/ha and I3 (irrigation at 20, 35, and 50 DAS) at 69.711 q/ha. These values are significant compared to the control.

Harvest Index

The harvest index, the ratio of seed yield to biological yield, is affected by sowing time and irrigation combinations. The highest harvest indices were recorded in S2 (mid-sowing on 15th November) at 27.698 and I0 (control) at 24.517. The elevated harvest index in the control irrigation (I0) is due to lower seed yield, which increases the ratio, as irrigation is a critical factor for plant growth, development, and yield.

Economics

Table 2 presents data on crop production, gross return, net return, and cost-benefit ratio. The cost of cultivation for different sowing times is consistent at 23,052 Rs., with all variables remaining the same across mustard sowing times. The highest cost of cultivation for irrigation schedules is recorded for three irrigations at 20, 35, and 50 DAS, amounting to 25,302 Rs. The maximum net returns of 41,880.9 Rs. and 60,436.9 Rs. were observed for mid-sowing time (S2, 15th November) and irrigation schedule I3 (20, 35, and 50 DAS), respectively. The treatment combination of S2 (mid-sowing on 15th November) with I3 (irrigation at 20, 35, and 50 DAS) was found to be the most profitable among all treatments.

Table 1: Effect of Irrigation and sowing time on yield of mustard

Treatments	Seed yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest Index
A. Sowing time				
S1(Early)	12.100	38.292	49.392	24.478
S2 (Mid)	12.858	39.317	52.175	24.724
S3(Late)	11.567	37.817	49.383	23.373
SE(m)	0.107	0.141	0.191	0.190
C.D.	0.433	0.568	0.769	0.766
C. Irrigation				
I0(Control)	5.989	18.411	24.400	24.516
I1(20 DAS)	11.356	37.311	48.667	23.335
I2(20, 35 DAS)	14.378	44.111	58.489	24.573
I3(20,35,50 DAS)	16.978	52.733	69.711	24.343
SE(m)	0.110	0.243	0.313	0.178
C.D.	0.328	0.729	0.938	0.533

Table 2: Cost of cultivation (Rs.), Gross Return(Rs.), Net Profit (Rs.) and B:C Ratio of Irrigation and sowing time of mustard

Treatments	Cost of Cultivation (Rs.)	Gross Return (Rs.)	Net Return (Rs.)	B:C Ratio
A. Sowing time				
S1(Early)	23052.00	61105	38053	2.650
S2 (Mid)	23052.00	64932.9	41880.9	2.816
S3(Late)	23052.00	58413.35	35361.35	2.533
B .Irrigation				
I0(Control)	22152.00	30244.45	8092.45	1.365
I1(20 DAS)	23502.00	57347.8	33845.8	2.440
I2(20, 35 DAS)	24402.00	72608.9	48206.9	2.975
I3(20,35,50 DAS)	25302.00	85738.9	60436.9	3.388

Summary and conclusion

Seed Yield: The highest seed yield was recorded in S2 (mid-sowing) at 12.858 q/ha and I3 (20, 35, and 50 DAS) at 16.978 q/ha, significantly higher than the control.

Stover Yield: The highest stover yield was observed in S2 (mid-sowing) at 39.317 q/ha and I3 (20, 35, and 50 DAS) at 52.733 q/ha. The lowest stover yields were recorded in late sowing (S3, 30th November) at 37.817 q/ha and control (I0) at 18.411 q/ha.

Biological Yield: The maximum biological yield was recorded in S2 (mid-sowing) at 52.175 q/ha and I3 (20, 35, and 50 DAS) at 69.711 q/ha, showing a significant effect over the control.

Harvest Index: The highest harvest index was recorded in S2 (mid-sowing) at 27.698 and control (I0) at 24.517. The elevated harvest index in the control is attributed to the low seed yield under zero irrigation, which increases the ratio of seed yield to total biomass, despite poor overall performance.

1. Seed Yield highest seed yield was recorded in S2 (mid-sowing) at 12.858 q/ha and I3 (20, 35, and 50 DAS) at 16.978 q/ha.
2. Stover Yield highest stover yield was recorded in S2 (mid-sowing) at 39.317 q/ha and I3 (20, 35, and 50 DAS) at 52.733 q/ha. The lowest yields were in late sowing (S3, 30th November) at 37.817 q/ha and control irrigation (I0) at 18.411 q/ha.
3. Biological Yield highest biological yield was recorded in S2 (mid-sowing) at 52.175 q/ha and I3 (20, 35, and 50 DAS) at 69.711 q/ha.
4. Harvest Index highest harvest index was recorded in S2 (mid-sowing) at 27.698 and control irrigation (I0) at 24.517, emphasizing the critical role of irrigation in growth, development, and yield.

The cost of cultivation for different sowing times of Indian mustard was consistent at ₹23,052. All variables remained the same across sowing times. The highest cost of cultivation for irrigation schedules was recorded for three irrigations at 20, 35, and 50 DAS, amounting to ₹25,302. The maximum net returns were ₹41,880.9 for mid-sowing time (S2, 15th November) and ₹60,436.9 for the irrigation schedule (I3, 20, 35, and 50 DAS). The treatment combination of mid-sowing time (S2) with the I3 irrigation schedule (20, 35, and 50 DAS) was the most profitable among all treatments.

Conclusion

The combination of mid-sowing time (15th November) and irrigation at 20, 35, and 50 DAS (I3) consistently resulted in the highest values for siliqua number, siliqua length, seeds per siliqua, test weight, seed yield, stover yield, and biological yield. These findings underscore the importance of optimal sowing timing and irrigation scheduling for maximizing mustard yield parameters, with mid-sowing and three irrigations proving most effective. The control (no irrigation) and late sowing (30th November) consistently underperformed, highlighting the critical role of irrigation in mustard production during the Rabi season.

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