RESEARCH ARTICLE Agricultural Science Digest, Volume 46 Issue 2: 301-307 (April 2026)

Investigating The Influence of Temporal Dynamics and Nutrient Levels on Soil Health, Plant Uptake and Yield Attributes of Toria in the Trans-gangetic Region of Punjab Towards Sustainable Development Goals

Akshay Jaiswal[1], Rohit Thakur[1], Anita Jaswal[1]

10.18805/ag.D-6155

ABSTRACT

Background: Toria is a widely grown *Brassica* sp. crop in India due to its rigidity. Production quality and quantity are the biggest obstacles to toria cultivation. Crop productivity is influenced by genes, environment and nutrition.

Methods: In 2021-22 and 2022-23, the experimental farm at Lovely Professional University's School of Agriculture in Jalandhar, Punjab carried this investigation. The experiment adopted a randomized block design (Factorial) with 3 sowing dates and 4 fertilizer levels, replicated 3 times.

Result: D_1 (1st October) and 100% fertilizer levels had the highest values for siliqua plant^{-1} (189.83), Siliqua length (4.32 cm), seeds (13.83), test weight (4.03 g), seed yield (1191.25 kg ha^{-1}) and harvest index (36.02%), while stover yield (2249.25 kg ha^{-1}) was highest in 2nd DOS (15th October). The 1st DOS and 100% RDF interaction yielded optimal yield, nutrient absorption and concentration values. Thus, 100% RDF should be applied to toria plants on October 1 for better production.

Key words: Food security, Good health, Nutrient levels, Production, Responsible consumption, Temporal dynamics, Well-being.

INTRODUCTION

Indian mustard (*Brassica sp.*) is an important oilseed crop in the Cruciferae family. Rapeseed and mustard are two major categories for Indian mustard (Jadhav and Jadhav, 2021). Oilseeds are India's second most important agricultural commodity after wheat (Shehzad *et al.,* 2023). The rapid increase in population has increased the demand for oilseed crops because they are used in various forms in our ecosystem and the reason for the lesser production of oilseed crops is lack of knowledge and resources which is required for cultivation of oilseeds. Hence, it is important to enhance the production by obtaining maximum knowledge about the cultivation (Rai *et al.,* 2022).

At present, the major obstacle in the cultivation of toria is the quality and quantity of produce. Fluctuations in the dates of sowing led to fluctuation in thermic environments of different cultivars which changes the growing and developmental stages of the plant and leads to modifications in the life cycle of plants (Kumar and Meena, 2020). Seasonal variations, including fluctuations in temperature, precipitation and seasonal timing, significantly impact crop phenology, growth phases and overall output. These temporal fluctuations can modify the essential growth phases of toria, resulting in variability in productivity during growing seasons. Nutrient imbalances-resulting from excessive or insufficient fertilizer applications-negatively impact soil health, plant nutrient absorption and total crop yield. Extended nutrient mismanagement diminishes production and degrades produce quality, hence challenging sustainable agricultural techniques.

[1]Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 401, Punjab, India.

Corresponding Author: Anita Jaswal, Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara-144 401, Punjab, India. Email: anita.27139@lpu.co.in
ORCIDs: 0000-0002-7290-2121, 0009-0003-1839-5055, 0000-0002-7214-8747

How to cite this article: Jaiswal, A., Thakur, R. and Jaswal, A. (2026). Investigating The Influence of Temporal Dynamics and Nutrient Levels on Soil Health, Plant Uptake and Yield Attributes of Toria in the Trans-gangetic Region of Punjab Towards Sustainable Development Goals. *Agricultural Science Digest.* **46(2):** 301-307. doi: 10.18805/ag.D-6155.

Submitted: 17-08-2024 **Accepted:** 01-02-2025 **Online:** 29-03-2025

Modern agronomic techniques, including excessive use of chemical fertilizers and a restricted emphasis on soil amendments, along with fluctuating climatic variables such as erratic climate patterns, are compromising the yield potential of toria. These actions require a shift to more balanced and adaptive nutrient management systems.

The major factors which regulate the production of any crop are its genes, environmental factors and nutrition. We can't change its genes, but we can provide excellent growing environment and nutrition so that we get maximum output from the crop. Nitrogen is the most essential nutrient responsible for the crop's growth, yield and oil and protein content. Phosphorus is also readily used in nitrogen availability. It also aids in blossoming, siliqua setting and

siliqua elongation (Dubey *et al.,* 2021). Just after nitrogen, potassium plays a key role in influencing performance and productivity of production by enhancing photosynthetic activities (Rana *et al.,* 2021 and Chandranath *et al.,* 2020). To find the best nutrient levels and favorable dates for sowing. We chose three different dates and four different nutrient levels to evaluate the response of toria under different temporal dynamics in combination with different nutrient levels.

MATERIALS AND METHODS

The investigation was conducted during the *rabi* season in 2021-22 and 2022-23 at Agricultural Farm of Lovely Professional University, Phagwara, Punjab, India. The experiment was laid out in factorial RBD design with three sowing dates, D_1 (1st October), D_2 (15th October) and D_3 (30th October) and four distinct fertilizer levels, 75%RDF, 100% RDF, 125% RDF and 150% RDF. 12 treatment combinations of dates of sowing and fertilizer levels were replicated three times. The total number of plots were 36 in numbers with plot size of 5×3 m and row spacing 45 cm and plant-to-plant distance 10 cm. The soil of the experimental site was sandy loam in nature. The analysis of soil was done before the start of the experiment to evaluate the initial status of the soil. To procure an optimum yield 60 kg N, 40 kg P, 30 kg K and 30 kg S ha^{-1} applied. Nitrogen is given in split doses; P and S are applied during land preparation as basal doses. The PAU recommended variety TL-17 of Toria had been selected as planting material for the experiment.

Yield attributes and yield parameters

The number of siliqua per plant was counted by removing the 3 tagged plants and recorded the mean values.10 randomly chosen siliqua was plucked from the plant's shoot and measured in cm using a cm-scale. After threshing, a seed counter counted 1000 seeds, which were weighted by an atom weighing machine and the average value computed. The crop was harvested from net plot and threshed. The value was multiplied by 10,000 to get values per hectare. The harvest index was calculated using the Donald,1976 formula and recorded.

Properties of soil on the experimental site

Before sowing, all plots were augured 15-20 cm deep for soil samples. The experimental location is sandy loamy with 78% sand, 8% silt and 14% clay. The soil was alkaline (8.2), EC (0.26 dSm^{-1}), medium organic carbon (0.42%), medium available N (340 $kgha^{-1}$), K (321 $kgha^{-1}$), high available P (20 $kgha^{-1}$) and low available S (5.6 $kgha^{-1}$). pH and EC meters measured soil pH and EC (Jackson,1973). Wet digestion method was used to measure organic carbon (Walkley and Black, 1934). Available nitrogen, P, K and S were measured using Alkaline permanganate, Olsen, Neutral normal ammonium acetate and Turbidimetric methods, respectively.

Uptake and concentration of nutrients

At toria maturity, the concentrations of nitrogen, phosphorus, potassium and sulfur in stover were estimated. The samples were powdered in Willey's mill to pass through a 30-mesh screen after being oven-dried at 65-70°C. Nitrogen was determined using the Micro-Kjeldahl method (Bremner, 1960), phosphorus was measured by the Vanadate Molybdate method using a colorimeter/spectrophotometer, potassium was analyzed through Flame Photometry (Jackson, 1973) and sulfur estimation followed the method described by (Palasker *et al.,* 1981).

Nutrient uptake (kg/ha) =

$$\frac{\text{N, P, K concentration (\%)} \times \text{Grain yield (kg ha}^{-1})}{100}$$

Statistical analysis

The recorded pooled data of 2 years was tabulated treatment-wise under three replications. The generalized linear model estimated the differences between the mean values under full factorial univariate techniques with SPSS 22 version. To find out the most efficient treatment, Duncan's multiple range test (DMRT) was employed. A mean separation technique was applied with a probability of $p<0.05$. Fisher's LSD test as a post hoc test was used to test the significance of the various components.

RESULTS AND DISCUSSION

The impact of various dates of sowing and different nutrient levels on the yield attributes

In both years, 1st DOS and 100% RDF produced more siliqua per plant (208). Table 1 reveals that 3rd DOS with 75% RDF had the lowest plant siliqua (139.33). Enough nutrients and peak planting time improved photosynthetic accumulation and reproductive duration. Vegetative development and reproduction at the ideal temperature may increase yield. The findings support Sau *et al.* (2022) and Jadhav and Jadhav (2021) who concluded that using 75% of RDF from chemical fertilizers along with FYM at a dose of 5t/ha in combination with Azotobacter improved growth and productivity in toria crops grown in the trans-Gangetic plains of Punjab. 1st DOS and 100% RDF yielded the longest siliqua (4.8 cm). Siliqua has the shortest average length (3.02 cm) in 3rd DOS and 125% RDF. Weather and nutrition greatly impact yield. Environmental factors promote abiotic restrictions. Abiotic stresses affects physiological, morphological, biochemical and molecular changes that may affect plant reproduction and yield variables like average siliqua length, seeds per siliqua and test weight. Chaudhary *et al.* (2023) results corroborate with the findings of this result who conclude that significantly higher yield attributes *viz.* siliquae $plant^{-1}$, seed per siliquae, siliqua length and 1000 seed weight recorded with early sown crop. Crop sown on 26th October recorded 27% and 40% higher seed yield than 5th and 15th November sown

crop, respectively. Similarly, the per cent increase in stover yield was 27% and 29% in 26th October sown crop over 5th and 15th November sown crop respectively, though the difference between the late sown crops remained comparable. Interaction effects of planting dates and fertilizer doses showed the highest siliqua (16) in 1st DOS and 100% RDF and the lowest (12) in 3rd DOS × 75% RDF, statistically comparable to 1st DOS × 75% RDF and 3rd DOS × 125% RDF. A balanced diet enhances cell elongation/division, photosynthetic activity and physiological activity, which boosts yield. Sharma and Kumar, (2023) found similar results. Planting dates and fertilizer levels produced the highest test weight (4.33 g) in the 100% RDF and 1st DOS interaction. Conversely, the 75% RDF × 3rd DOS interaction had the lowest test weight (3.33 g). Due to nutrients and planting time, chlorophyll content increased. Ideal temperatures boosted vegetative growth and reproduction, which may increase test weight. Similar results were found by Tripathi *et al.* (2021) and Kour *et al.* (2016) who reported that highest growth attributes (plant height, dry matter accumulation, Days taken to 50% flowering, number of tillers, LAI and yield and yield attributes [No. of siliqua (cm) per plant, length of siliqua (cm) test weight, seed yield (q/ha) grain yield, stover yield, biological yield and harvest index] was recorded under 1st week of october in varuna variety. DOS with 100% RDF produced the more seeds (1255 kg ha^{-1}) and was statistically superior to all other combinations. However, 75% RDF and 3rd DOS produced the less seeds (790 kg ha^{-1}). The crop sown on the right date had an expanded reproductive phase under optimal climatic circumstances with ample nutrients, resulting in a better seed set, larger siliquae and maximal potential growth, which may have increased seed output. Jadhav and Jadhav (2021) found similar results. A combination of fertilizer levels and planting dates led to the highest stover yield (2314.66 kg ha^{-1}) with the 1st DOS × 100% RDF level, outperforming other combinations. However, 150% RDF with 3rd DOS produced the least stover (1951.66 kg ha^{-1}). The 2nd and 3rd DOS crop may have experienced unfavorable climatic circumstances like temperature and moisture stress that hindered nutrient uptake and created stress in the plants, resulting in poor plant growth, a quick stover production reduction in delayed sowing and misbalanced nutrition in toria. Sharma *et al.* (2020) and Anuroop (2022) reported similar results as per late sowing in their regions and balancing fertilizer doses increase the production of Toria. Due to fertilizer amounts and planting dates, 1st DOS and 100% RDF yielded the highest HI (40.67%). Maurya *et al.* (2022) reported comparable results who reported that NRCHB-

Table 1: Effect of interaction between nutrient levels and temporal dynamics on yield attributes of toria (*Brassica campestris*) pooled analysis of two-year data (2021-22 and 2022-23).

Treatment details		Number of siliqua per plant	Length of siliqua (cm)	No. of seeds per siliqua	Test weight (gm)	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Harvest index (%)
D_1	F1	164.33	3.53	12.00	3.66	1090	2158.66	33.56
	F2	208.00	4.8	16.00	4.33	1255	2314.66	40.67
	F3	194.66	4.46	13.00	4.26	1200	2301.66	34.27
	F4	192.33	4.50	14.33	3.86	1220	2210.00	35.59
D_2	F1	151.00	3.73	12.66	3.46	1010	2118.00	32.30
	F2	172.33	4.53	14.33	3.96	1145	2298.00	33.25
	F3	160.33	4.23	12.33	3.63	1110	2293.33	32.64
	F4	161.66	4.00	14.00	3.76	1125	2288.00	32.96
D_3	F1	139.33	3.10	12.00	3.33	790	1976.66	28.60
	F2	149.33	3.40	12.66	3.70	865	2020.00	30.00
	F3	142.33	3.03	12.00	3.43	850	2004.33	29.84
	F4	140.00	3.20	12.33	3.66	835	1951.66	29.97
Mean table								
D_1		189.83^{a}	4.32^{a}	13.83^{a}	4.03^{a}	1191.25^{a}	2246.25^{a}	36.02^{a}
D_2		161.33^{b}	4.12^{a}	13.33^{ab}	3.70^{b}	1097.50^{b}	2249.33^{a}	32.79^{b}
D_3		142.75^{c}	3.18^{b}	12.25^{b}	3.53^{b}	835.00^{c}	1988.16^{b}	29.60^{c}
F1		151.55^{c}	3.45^{b}	12.22^{b}	3.48^{b}	963.33^{c}	2084.44^{b}	31.49^{b}
F2		176.55^{a}	4.24^{a}	14.33^{a}	4.00^{a}	1088.33^{a}	2210.88^{a}	34.64^{a}
F3		165.77^{b}	3.91^{a}	12.44^{b}	3.77^{ab}	1053.33^{b}	2199.77^{a}	32.25^{b}
F4		164.66^{b}	3.90^{a}	13.55^{ab}	3.76^{ab}	1060.00^{ab}	2149.88^{ab}	32.84^{b}
CD at 5%								
D		2.055	1.222	1.222	0.279	25.97	86.5	1.344
F		2.373	1.412	1.412	0.322	29.990	NS	1.552
D×F		4.110	NS	NS	NS	NS	NS	2.687

Note: D_1= 1st date of sowing, D_2= 2nd date of sowing, D_3= 3rd date of sowing, F1= 75% RDF, F2= 100 % RDF, F3=125% RDF, F4=150% RDF.

101 variety of toria shows better performance in terms of growth as compared to variety PM-28 during Ist week of October.

The impact of various dates of sowing and different nutrient levels on the uptake and concentration in stover

Planting dates greatly affects stover nitrogen absorption and concentration. The first DOS-sown plants had the highest nitrogen (2.47%). Plants grown on 3rd DOS had the lowest nitrogen (2.06%). Stover N uptake was highest in the first DOS crop (55.68 kg ha^{-1}). Table 2 reveals the 3rd DOS crop had the lowest stover N uptake (41.08 kg ha^{-1}). Fertilizer levels affects stover nitrogen absorption and concentration. 100% RDF had the highest stover nitrogen (2.47%). The lowest nitrogen concentration was 2.02% in 75% RDF stover. Different fertilizer amounts and sowing dates had minimal effect on stover nitrogen level. The first DOS-sown plants had the highest phosphorus (0.259%). The lowest phosphorus concentration (0.182%) was in 3rd DOS plants. However, 1st DOS plants absorbed the most stover phosphorus (5.81kg ha^{-1}) and 3rd DOS plants the least (3.61 kg ha^{-1}). Different fertilizer doses influenced stover phosphorus uptake and concentration. Stover phosphorus was highest (0.257%) with 100% RDF and similar (0.226%) at 125% RDF. Stover with 75% RDF has the lowest phosphorus (0.169%). The highest stover phosphorus uptake was 5.70 kg ha^{-1} for plants fertilized with 100% RDF, whereas the lowest was 3.53 kg ha^{-1} for plants fertilized with 75% RDF. Stover phosphorus uptake was unaffected by sowing date or fertilizer amount. The 1st DOS harvest has the most stover potassium (2.66%). The crop grown on 3rd DOS had the lowest stover potassium concentration (2.13%). The highest stover potassium uptake was found in 1st DOS plants (60.05 kg ha^{-1}) and the lowest in 3rd DOS plants (42.48 kg ha^{-1}). Stover potassium absorption varied with fertilizer dosage. 100% RDF amendment had the highest stover potassium (2.64%). Stover potassium was lowest at 75% RDF (2.01%). The highest stover potassium uptake (58.81 kg ha^{-1}) was with 100% RDF, while the lowest was 42.12 kg ha^{-1} with 75%. Stover potassium uptake depends on sowing date and fertilizer. Stover potassium content reached at 3.23% in the first DOS × 100% RDF interaction. Lowest potassium content (1.89%) in stover was found at 3rd DOS × 75% RDF level. Stover potassium uptake was highest (74.80 kg ha^{-1}) with 1st DOS and 100% RDF. In the 3rd DOS × 75% RDF interaction in stover, the minimum potassium uptake was 37.45 kg ha^{-1}. The 1st DOS harvest had the greatest stover potassium (0.437%). Third DOS plants had 0.314% stover sulfur. The largest stover sulfur uptake (9.86 kg ha^{-1}) was on 1st DOS and the lowest (6.23 kg ha^{-1}) on 3rd DOS. Stover

Table 2: Influence of planting dates and nutrient levels on the uptake of nutrients and nutrient content in stover pooled analysis of two-year data (2021-22 and 2022-23).

Treatment details		Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Sulfur (kg ha^{-1})	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulfur (%)
D_1	F1	46.91	4.15	48.49	6.90	2.17	0.194	2.24	0.320
	F2	65.10	7.08	74.80	13.26	2.81	0.307	3.23	0.573
	F3	55.58	6.19	60.20	9.73	2.41	0.269	2.61	0.423
	F4	55.16	5.83	56.71	9.58	2.50	0.265	2.57	0.433
D_2	F1	42.65	3.43	40.42	6.72	2.01	0.162	1.91	0.317
	F2	56.22	5.52	55.60	10.41	2.44	0.240	2.41	0.453
	F3	49.80	5.21	51.84	9.17	2.17	0.227	2.25	0.400
	F4	52.25	4.96	52.92	9.64	2.28	0.217	2.31	0.422
D_3	F1	37.07	3.00	37.45	5.45	1.87	0.151	1.89	0.277
	F2	43.71	4.50	46.04	7.13	2.16	0.223	2.28	0.353
	F3	41.78	3.67	43.36	6.15	2.08	0.183	2.16	0.307
	F4	41.75	3.30	43.05	6.19	2.14	0.169	2.20	0.317
Mean table									
D_1		55.68[a]	5.81[a]	60.05[a]	9.86[a]	2.47[a]	0.259[a]	2.66[a]	0.437[a]
D_2		50.23[b]	4.78[b]	50.19[b]	8.98[b]	2.22[b]	0.211[b]	2.22[b]	0.398[b]
D_3		41.08[c]	3.61[c]	42.48[c]	6.23[c]	2.06[c]	0.182[c]	2.13[b]	0.314[c]
F1		42.21[c]	3.53[c]	42.12[c]	6.36[c]	2.02[c]	0.169[c]	2.01[c]	0.304[c]
F2		55.01[a]	5.70[a]	58.81[a]	10.26[a]	2.47[a]	0.257[a]	2.64[a]	0.460[a]
F3		49.05[b]	5.02[ab]	51.80[b]	8.35[b]	2.22[b]	0.226[ab]	2.34[b]	0.376[b]
F4		49.72[b]	4.70[b]	50.89[b]	8.47[b]	2.30[b]	0.217[b]	2.36[b]	0.391[b]
CD at 5%									
D		2.502	0.594	3.05	0.53	0.078	0.02	0.12	0.021
F		2.889	0.685	3.52	0.61	0.090	0.03	0.14	0.024
D×F		NS	NS	6.10	1.06	NS	NS	0.24	0.041

Note: D_1= 1st date of sowing, D_2= 2nd date of sowing, D_3= 3rd date of sowing, F1= 75% RDF, F2= 100 % RDF, F3=125% RDF, F4=150% RDF.

sulfur absorption varied with fertilizer dosage. The highest stover sulfur (0.460%) was with 100% RDF. 100% RDF has the highest stover sulfur uptake (10.26 kg ha^{-1}). The stover uptake of sulfur was lowest at 75% RDF (6.36 kg ha^{-1}). Sowing dates and fertilizer levels affects stover sulfur uptake. When paired with 1st DOS (1 October) and 100% RDF, stover sulfur content reached at 0.573 per cent. The stover sulfur level was lowest (0.277%) in the 3rd DOS × 75% RDF interaction. Ist DOS and 100% RDF caused stover sulfur uptake to be greatest (13.26 kg ha^{-1}). The 3rd DOS × 75% RDF interaction led to the lowest stover sulfur uptake (5.45 kg ha^{-1}). Maximum stover NPKS uptake with 100% RDF may be due to balanced diet and fertility. If dosed properly, all nutrients interact and increase absorption. These findings corroborate with the findings of Kumar *et al.* (2020) who reported that higher fertiliser doses may raise soil pH and disrupt fertiliser interaction, reducing nutrient uptake. Nutrient concentration in plant samples improves with balanced fertilizer doses, which may explain why balanced and recommended fertilizer doses generate the maximum NPKS concentration. Kumar *et al.* (2021) and Dubey found similar results which conclude that among the nutrient sources application of 75% RDF+ 25% N through PM +Azotobacter + PSB maximum total nitrogen, phosphorus, potassium and sulphur uptake was recorded as compared with other nutrient sources.

Available NPKS in the soil after harvest

The 3rd DOS had the highest soil N (280.33 kg ha^{-1}). The 1st DOS had the least N (261.66 kg ha^{-1}). The 1st DOS had the greatest soil phosphorus (21.95 kg ha^{-1}). Table 3 demonstrates that the 3rd DOS had the lowest soil phosphorus (19 kg ha^{-1}). 1st DOS soil potassium was highest (312.16 kg ha^{-1}). 3rd DOS had lowest soil potassium and was statistically similar to 2nd DOS. Different nutrient levels affects soil NPK. The 150% RDF yielded the greatest N (291.22 kg ha^{-1}). Nitrogen was lowest at 75% RDF (250.77 kg ha^{-1}). Phosphorus was highest at 150% RDF (22.44 kg ha^{-1}). The least phosphorus (18.50 kg ha^{-1}) was observed in 75% RDF, which was statistically equal to 100% and 125%. The highest soil potassium (323.33 kg ha^{-1}) has 150% RDF. Fertilizer quantities and sowing dates affected nitrogen and potassium levels but not phosphorus. The 3rd DOS and 150% RDF interaction produced the most soil nitrogen (304.66 kg ha^{-1}). Minimum soil N (244.66 kg ha^{-1}) was found in the 2nd DOS × 75% RDF interaction. However, 2nd DOS and 150% RDF interlinkage produced the most soil phosphorus (23.16 kg ha^{-1}). Low soil phosphorus (17.16 kg ha^{-1}) was observed in the 2nd DOS × 75% RDF interaction. The 1st DOS × 150% RDF interaction had the most soil potassium (328.66 kg ha^{-1}). 3rd DOS had the greatest soil sulfur (6.42 kg ha^{-1}) and was statistically comparable to 2nd

Table 3: Effect of various nutrient levels and different dates of sowing on the available NPKS in soil after harvest pooled analysis of two-year data (2021-22 and 2022-23).

Treatment details		Nitrogen (Kg ha^{-1})	Phosphorus (Kg ha^{-1})	Potassium (Kg ha^{-1})	Sulfur (Kg ha^{-1})
D_1	F1	248.33	20.83	297.00	5.93
	F2	261.00	21.83	299.66	6.16
	F3	269.00	22.16	323.33	6.33
	F4	268.33	23.00	328.66	6.43
D_2	F1	244.66	17.16	295.00	5.80
	F2	271.00	18.33	297.66	6.86
	F3	290.00	18.16	315.33	7.30
	F4	300.66	23.16	317.00	6.50
D_3	F1	259.33	17.50	283.33	5.73
	F2	273.0	18.50	302.16	6.40
	F3	284.33	18.83	309.50	6.46
	F4	304.66	21.16	324.33	7.10
Mean table					
D_1		261.66^{b}	21.95^{a}	312.16^{a}	6.21^{b}
D_2		276.58^{a}	19.20^{b}	306.25^{b}	6.61^{a}
D_3		280.33^{a}	19.00^{b}	304.83^{b}	6.42^{ab}
F1		250.77^{d}	18.50^{b}	291.77^{d}	5.82^{b}
F2		268.33^{c}	19.55^{b}	299.83^{c}	6.47^{a}
F3		281.11^{b}	19.72^{b}	316.05^{b}	6.70^{a}
F4		291.22^{a}	22.44^{a}	323.33^{a}	6.68^{a}
CD at 5%					
D		5.437	1.683	3.239	0.316
F		6.278	1.943	3.740	0.365
D×F		10.874	NS	6.477	0.632

Note: D_1= 1st date of sowing, D_2= 2nd date of sowing, D_3= 3rd date of sowing, F1= 75% RDF, F2= 100% RDF, F3=125% RDF, F4=150% RDF.

DOS. The lowest soil sulfur was 6.21 kg ha^{-1} in 1st DOS. Fertilizer levels affected soil sulfur. The maximum soil sulfur (6.61 kg ha^{-1}) was calculated with 100% RDF and statistically similar with 125% RDF. Soil sulfur was lowest at 75% RDF (5.82 kg ha^{-1}). Fertilizer and sowing dates altered soil sulfur. Maximum soil sulfur (7.30 kg ha^{-1}) was observed in the 2nd DOS × 125% RDF interaction. In contrast, the 3rd DOS × 75% RDF interaction yielded the lowest soil sulfur (5.73 kg ha^{-1}). Overfertilization can harm soil. Nutritional boosts defect toria oil. Similar results were observed by Bora *et al*. (2021) who conclude that overfertilization raises soil salinity, which may affect plant development and microbial activity. Mukherjee (2020) and Mishra *et al.* (2022) reported similar results who conclude that integration of inorganic fertilizer both macro and micro with organic manure and biofertilizer is the better option for balance nutrition of the rapeseed mustard crop that enriches the soil fertility status, improves growth and yield attributes of crop and also accelerates the nutrient uptake and availability in soil and ultimately the productivity and profitability and quality of food.

CONCLUSION

The study found that toria (*Brassica campestris* var Toria) benefited from planting on the 1st DOS (1st October) in terms of siliqua per plant, length of siliqua, seeds per siliqua, seed yield, nutrient uptake, concentration and soil nutrient availability. This suggests that the 1st October is the optimal date for sowing for optimal growth and development. During the experiment period late September in Punjab experienced residual heat from the monsoon. Sowing on 1st October might ensure slightly cooler temperatures, reducing heat stress during germination and early vegetative growth. Changes in monsoon patterns might have shifted the ideal moisture availability to early October, making it favorable for seed germination and crop establishment. For photoperiod-sensitive crops like mustard, a slight delay in sowing may align with cooler nights and shorter days in October, promoting optimal vegetative and reproductive development. Thus, yield and nutrient availability are optimum with 100% RDF. The research found that the interaction between 1st DOS (1st October) and 100% RDF was the most effective treatment.

ACKNOWLEDGEMENT

The present study was supported by Lovely Professional University, Phagwara.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Bremner, J.M. (1960). Determination of nitrogen in soil by the Kjeldahl method. *The Journal of Agricultural Science*. **55(1):** 11-33. https://doi.org/10.1017/S0021859600021572.

Anuroop, M., Dawson, J. and Debbarma, V. (2022). Influence of dates of sowing and crop geometry on growth and yield parameters of yellow mustard (*Sinapi's alba*). *The Pharma Innovation Journal*. **11(5):** 371-374.

Bora, P., Ojha, N. J. and Phukan, J. (2021). Mustard and rapeseed response to integrated nutrient management: A review. *Journal of Pharmacognosy and Phytochemistry.* **10(1):** 1801-1805.

Chaudhary, B.K., Yadav, R.K.S.P. and Nayak, H. (2023). Yield, quality and economics of Indian mustard (*Brassica juncea* L.) as influenced under different sowing date and planting geometries in irrigated condition of eastern Uttar Pradesh. *Journal of Oilseed Brassica*. **14(1):** 27-32.

Chandranath, H. T., Babalad, H. B. and Hegde, Y. (2020). Growth, yield and oil quality of mustard in chickpea (*Cicer arietinum*) and mustard (*Brassica juncea* L.) intercropping system under different row ratio in northern transition zone of Karnataka. *Indian Journal of Agricultural Research.* **54(3):** 322-328. doi: 10.18805/IJARe.A-5453.

Donald, C.M. and Hamblin, J. (1976). The biological yield and harvest index of cereals as agronomic and plant breeding criteria. Advances in Agronomy. **28:** 361-405. doi: 10.1016/S0065-2113(08)60559-3.

Dubey, S., Siddiqui, M.Z., Bhatt, M., Shukla, G., Rana, S. and Singh, D.K. (2021). Effect of INM on quality, nutrient content and uptake of various nutrients by *Brassica juncea* L. (Indian mustard). *International Journal of Chemical Studies.* **9(1):** 3625-3629. doi:10.22271/chemi. 2021.v9.i1ay. 11794.

Jackson, M. L. (1973). Soil Chemical Analysis. Advanced Course Ed. 2. A Manual of Methods Useful for Instruction and Research in Soil Chemistry, Physical Chemistry of Soils, Soil Fertility and Genesis Revised from Original Edition of 1965.

Jadhav, A.S. and Jadhav, P.B. (2021). Sowing date-A key for increasing mustard (*Brassica juncea* L.) productivity. *J. Agric Res Technol.* **46(2):** 201-204.

Kour, R., Sharma, B. C., Kumar, A., Kour, P. and Nandan, B. (2016). Study of physiological growth indices of chickpea in chickpea (*Cicer arietinum*) + mustard (*Brassica juncea*) intercropping system under different weed management practices. *Legume Research-An International Journal.* **39(3):** 453-458. doi: 10.18805/ijare.v0iOF.8433.

Kumar, S. and Meena, R.S. (2020). Impact of various sowing environment and nutrient sources on growth performance of Indian mustard (*Brassica juncea*). *Indian Journal of Agronomy*. **65(4):** 465-470.

Kumar, S., Meena, R.S. and Jatav, S.S. (2020). Effect of sowing dates and nutrient sources on nutrient uptake of Indian mustard (*Brassica juncea*). *Indian Journal of Agricultural Sciences.* **90(10):** 1902-1907.

Kumar, S., Meena, R.S., Singh, R.K., Munir, T.M., Datta, R., Danish, S., Yadav, G.S. and Kumar, S. (2021). Soil microbial and nutrient dynamics under different sowings environment of Indian mustard (*Brassica juncea* L.) in rice-based cropping system. *Scientific Reports*. **11(1):** 5289. doi: 10.1038/s41598-021-84742-4.

Maurya, S.K., Kalhapure, A., Sah, D., Chaudhary, M., Verma, S., Yadav, R.K. and Gupta, D. (2022). Effect of irrigation scheduling and varieties on yield, yield attribute and profitability of Indian mustard [*Brassica juncea* (L.)]. *International Journal of Plant and Soil Science.* **34(21):** 379-386. doi: 10.9734/ijpss/2022/v34i2131275.

Mishra, P.K. and Singh, R. (2022). Effect of nitrogen and zinc levels on yield and economics of mustard (*Brassica juncea* L.). *International Journal of Plant and Soil Science.* **34(15):** 8-17. doi: 10.9734/ijpss/2022/v34i1531001.

Mukherjee, D. (2020). Effect of cultivars and fertility levels on growth, nutrient uptake and quality of mustard [*Brassica juncea* (L.) Czem and Coss.] grown in rice fallow in gangetic plains. *Annals of Agricultural Research*. **41(4):** 382-390.

Palaskar, M.S., Babrekar, P.G. and Ghosh, A.B. (1981). A rapid analytical technique to estimate sulphur in soil and plant extracts. *Journal of the Indian Society of Soil Science*. **29(2):** 249-256.

Rai, P.K., Yadav, P., Kumar, A., Sharma, A., Kumar, V. and Rai, P. (2022). *Brassica juncea*: A Crop for Food and Health. In: The *Brassica juncea* Genome. Cham: Springer International Publishing. doi: 10.1007/978-3-030-91507-01. (pp. 1-13).

Rana, A., Sharma, G.D., Kumar, N. and Sankhyan, N.K. (2021). Performance of new genotype of Indian mustard [*Brassica juncea* (L.) Czernj. Cosson] as influenced by sowing time and nutrient management. *Himachal Journal of Agricultural Research.* **47(2):** 206-213.

Sau, S., Barkha, C.S. and Mallick, M. (2022). Growth and yield of toria (*Brassica campestris* var. toria) under various Integrated nutrient management schedules in trans-gangetic Plains of Punjab. *Biological Forum-An International Journal.* **14(3):** 923-927.

Sharma, S.K. and Kumar, A. (2023). Effect of date of sowing on growth, seed yield and economics of Indian mustard (*Brassica juncea*) Varieties under rainfed conditions. *Indian Journal of Agricultural Research.* **57(1):** 56-59. doi: 10.18805/IJARe.A-5947.

Sharma, S., Chaudhray, S. and Singh, R. (2020). Effect of boron and sulphur on growth, yield and nutrient uptake of mustard (*Brassica juncea* L.). *International Journal of Chemical Studies.* **8(4):** 1998-2001. doi: 10.22271/chemi.2020.v8.i4u.9923.

Shehzad, J., Mustafa, G., Arshad, H., Ali, A., Naveed, N.H., Riaz, Z. and Khan, I. (2023). Morpho-physiological and biochemical responses of Brassica species toward lead (Pb) stress. *Acta Physiologiae Plantarum.* **45(1):** 8. doi: 10.1007/s11738-022-03493-5.

Tripathi, K.B.M., Gaur, T., Pandey, L., Singh, A., Tiwari, A., Prakash, V., Rathore, U.S. and Singh, R.K. (2021). Effect of sowing dates on growth and yield of Indian mustard (*Brassica juncea* L.). *International Journal of Current Microbiology and Applied Science*. **10(01):** s3046-3057. doi: 10.20546/ijcmas.2021.1001.355.

Walkley, A. and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science.* **37(1):** 29-38.