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Influence of terminal clipping and nano-urea on seed yield and quality of rapeseed (*Brassica rapa* var. yellow sarson)

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Abstract

An experiment was conducted on rapeseed (*Brassica rapa* var. yellow sarson) to study the effect of terminal clipping and nano-urea on seed yield and seed quality parameters. The field experiment was laid out during the *Rabi* seasons of 2021-22 and 2022-23 in split plot design with three replications, considering clipping of terminal bud as first factor and five treatments of nano-urea, including control, as second factor. The analysis of data revealed significant influences of clipping on morphological traits, while non-significant effects were observed on physiological traits. Among the treatments, T_2 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4 ml L^{-1} nano urea at 30 and 45 days after sowing) and T_4 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4 ml L^{-1} nano-urea + 0.1 % Boron at 30 and 45 DAS) exhibited significant impacts on both the morphological and physiological traits. Overall, the application of nano-urea at a concentration of 4 ml L^{-1}, supplemented with 0.1% Boron, twice at 30 and 45 DAS, along with terminal clipping, emerged as the most effective treatment. This approach not only minimizes excess fertilizer application but also contributes to the reduction of environmental hazards.

Keywords: *Boron, clipping, foliar spray, growth, nano-urea, rapeseed, seed quality, yield*

Introduction

Oilseed crops are the most significant ones worldwide. Their importance in human consumption and industrial applications cannot be overstated. Rapeseed and mustard rank third among the world's key edible oilseed crops. Belonging to the Cruciferae or Brassicaceae family within the Brassica genus, these crops play a pivotal role in meeting the growing demand for edible oils across the world. According to USDA report global oilseed production has reached 625 million tons in the year 2022-23. India, despite having 20.8% of the world's oilseed agricultural land, contributes only around 10% to global production (Oilseeds-Indian trade portal, https://www.ibef.org) ranking fourth worldwide. Rapeseed (*B. rapa*) and mustard (*B. juncea*) are major *Rabi* oilseed crops in India, extensively grown in states like Rajasthan, Madhya Pradesh, Haryana, Uttar Pradesh, and West Bengal. Rapeseed is generally planted in mid-October, ideally after the monsoon rains have passed. In eastern India, where winters are mild and short, farmers favour rapeseed since these crops can be cultivated with one or two critical irrigations. Still, the area has not explored the potential yield due to inadequate fertilizer utilization. Late harvesting of *Kharif* rice in those areas especially the Gangetic alluvial zone delays rapeseed sowing, leading to insufficient dry matter accumulation. This results in low seed yield and reduced seed vigour.

Nitrogen is a crucial factor limiting global agricultural production. Despite numerous efforts, agricultural nitrogen utilization efficiency (NUE) remains below 50% as it is lost through various processes upon soil application, causing significant problems due to economic losses and ecological imbalance. Boron, a key micronutrient, plays a vital role in plant development, sucrose separation, pollen expansion, and the transfer of photosynthates and growth regulators from source to sink, contributing to increased seed yield (Shireen *et al.,* 2018). Boron deficiency has been identified as the world's second most serious micronutrient limitation in crops (Ahmad *et al.,* 2012) causing substantial crop losses in both yield and quality. Different techniques, including soil, foliar, and seed treatments, have been employed to address nitrogen and boron deficiencies. However foliar fertilization is preferred over soil application due to its direct nutrient supply to leaves, quick absorption, and independence from root activity and soil water availability (Romheld and El-fouly, 1999). The use of nano-form of nutrients in foliar application is suggested for enhanced nutrient absorption and reduced environmental toxicity (Naderi and Danesh-Shahraki, 2013). Utilizing the clipping technique can promote branch and flower development, which ultimately leads to higher seed yield and improved quality (Lakshmi *et al.,* 2015). This study aimed to assess the effects of foliar application of nano-urea and boron in combination with clipping on yield, yield attributes, and seed quality parameters of rapeseed (*Brassica rapa* var. yellow sarson).

Materials and Methods

The field experiment was conducted during the *Rabi* seasons of 2021-22 and 2022-23 at the instructional farm of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, situated in the New Alluvial Zone (22.95°N latitude, 88.54°E longitude, 9.73 m altitude). The site is under a subtropical humid climate with oppressive summer temperatures, high humidity, unpredictable rainfall, and a short and moderate winter. The long-term average rainfall at the experimental site is 1375 mm, with 70-80% falling during the monsoon season. May is the hottest month, with typical summer temperatures ranging from 25°C to 36°C and winter temperatures ranging from 10°C to 25°C. The soil is sandy loam texture, with a good drainage facility having pH 7.04, organic carbon (0.71%), low in available nitrogen (200 kg ha^{-1}), medium in available phosphorus (32.4 kg ha^{-1}) and potassium (185 kg ha^{-1}). Following thorough ploughing to ensure optimal seedbed preparation, fertilizers were applied at a ratio of N: P_2O_5:K_2O @ 50:50:50 kg ha^{-1} as a basal treatment. Seeds of *Yellow Sarson* variety 'Anushka' sourced from the Pulses and Oilseed Research Station, Govt. of West Bengal, Berhampore, were sown using the line sowing method with 50 cm row-to-row intervals. Thinning was performed 20 days after sowing (DAS) to maintain a plant-to-plant distance of 10 cm. The cultivation adhered to recommended agronomic practices and included plant protection measures to establish a robust crop population. The experiment was set up in a split-plot design with three replications, with clipping/without clipping treatments assigned to main plots and four nutrient treatments, *viz* T_1 (50% N, full P_2O_5, K_2O at basal + foliar spray of 2 ml L^{-1} nano-urea at 30 and 45 DAS), T_2 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4 ml L^{-1} nano-urea at 30 and 45 DAS), T_3 (50% N, full P_2O_5, K_2O at basal + foliar spray of 6 ml L^{-1} nano-urea at 30 and 45 DAS), T_4 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4 ml L^{-1} nano-urea + 0.1 % Boron at 30 and 45 DAS), along with Control as T_5 (50% N, full P_2O_5 and K_2O at basal + 50% N top dressed) assigned to sub-plots.

Ten randomly selected plants from each replication and treatment were used to collect data on morphological and yield-attributing characters such as, days to 50% flowering, plant height, number of primary, secondary branches and siliqua per plant, seeds per siliquae. Seed quality parameters *viz.* germination percentage, seedling root and shoot length, fresh weight and dry weight, and vigour index were studied in the postgraduate laboratory of the Department of Seed Science and Technology, Bidhan Chandra Krishi Viswavidyalaya following ISTA guidelines. Harvested seeds were placed in Petri dish for germination test. On the 7^{th} day from placing the number of normal seedlings were counted and germination percentage was calculated using formula: [(no. of normal seedlings/ total no. of seeds placed) × 100]. The Vigour index I and II was computed by using the formula suggested by Abdul-Baki and Anderson (1973).

Vigour index I = Germination percentage × Average seedling length (cm)

Vigour index II = Germination percentage × Average seedling dry weight (mg)

Data on various characters underwent statistical analysis using analysis of variance (Panse and Sukhatme 1985) and the OPSTAT software program (Sheoran *et al.,* 1998).

Results and Discussion

Effect of clipping and foliar nutrition on morphological characters and economics

The study investigating the effects of clipping on various morphological characters in 'Anushka' variety of rapeseed (Table. 1) indicated significant impacts on majority of traits, excluding days to 50% flowering, days to maturity, and siliqua length-to-breadth (L/B) ratio. Nevertheless, plants subjected to clipping exhibited delayed flowering and maturity. The non-pinched plants (108 cm) recorded slightly higher plant height at maturity than pinched plants (105 cm). This might be due to the removal of apical bud which restricted the growth of pinched plants. Similar findings were observed by Aikins *et al*. (2017) and Tripathi *et al*. (2013) while working on okra and sunhemp respectively. Primary and secondary branch development was also influenced by clipping. In plants, the development of auxiliary buds is inhibited normally by Indole Acetic Acid (IAA) synthesized in the apical meristem. Clipping accelerated lateral branching by inhibiting auxin production in the apical meristem, as supported by Kokilavani *et al.* (2007) in sesame. Moreover, when plants are pinched the majority of the nutrition is dislocated from the apical region of the plant and this nutrient redistribution plays a crucial role in branch formation. Positive effects of clipping were also observed in the case of siliquae $plant^{-1}$, seeds $siliqua^{-1}$, and test weight. The effectiveness of clipping may probably be due to the change induced in the rate of cell division in the meristematic region (Ahamad *et al.,* 2007) thereby increasing the number of healthy branches and flowers (Pathania *et al.,* 2000). This, in turn, contributed to an increased siliqua number per plant. Data pertaining to siliqua length-to-breadth ratio, as influenced by clipping of the terminal bud, revealed no significant effect, but clipping treatment numerically exhibited a higher length-to-breadth ratio (11.3). Pinched plants showed comparatively higher values for siliquae $plant^{-1}$ (54.5), seeds $siliqua^{-1}$ (20.5), test weight (3.95g), and yield (1.06 t ha^{-1}) than non-pinched ones. Clipping enhanced the seed yield. This improvement could be a result of the proportionate increase in yield contributing characters *i.e.*, a higher number of productive branches, a higher number of

Table 1: Effects of clipping and foliar nutrition on morphological characters, seed yield and B:C ratio

Clipping of terminal bud	Days to 50% flowering	Days to maturity	Plant height (cm)	Primary branches $plant^{-1}$	Secondary branches $plant^{-1}$	Siliquae $plant^{-1}$	Seeds $siliqua^{-1}$	Siliqua L/B ratio	Test weight (g)	Seed yield ($t\ ha^{-1}$)	B:C ratio
P_1	40.0	84.0	105.7	1.91	0.95	54.5	20.5	11.3	3.95	1.06	1.80
P_0	39.7	83.8	108.4	1.87	0.93	54.2	19.6	10.5	3.91	1.04	1.81
SEm (±)	0.2	0.3	0.04	0.01	0.01	0.04	0.05	0.2	0.00	0.00	0.00
LSD (0.05)	NS	NS	0.29	0.03	0.01	0.26	0.33	NS	0.01	0.01	NS
Treatments											
T_1	40.3	83.0	104.7	1.77	0.69	51.9	19.5	10.9	3.96	1.01	1.79
T_2	39.8	85.1	109.4	2.08	1.26	59.0	21.3	10.4	4.01	1.13	1.90
T_3	39.2	84.2	109.5	2.01	0.94	52.5	20.2	11.1	3.99	1.03	1.67
T_4	39.0	84.2	109.3	2.00	1.21	58.7	21.4	10.9	4.00	1.11	1.88
T_5	41.0	82.5	102.3	1.59	0.59	49.6	17.9	11.4	3.69	0.96	1.78
SEm ±	0.4	0.3	0.08	0.02	0.01	0.1	0.1	0.1	0.00	0.01	0.01
LSD (0.05)	1.2	0.9	0.25	0.05	0.02	0.2	0.3	0.3	0.01	0.03	0.01
Interactions											
P_1T_1	40.3	83.1	102.9	1.80	0.73	51.9	19.9	11.4	3.99	1.02	1.79
P_1T_2	40.0	85.3	108.4	2.10	1.28	58.9	21.6	10.7	4.02	1.14	1.90
P_1T_3	40.0	84.1	108.4	2.03	0.93	53.1	20.0	11.4	4.00	1.04	1.66
P_1T_4	38.7	84.3	108.3	2.02	1.20	59.1	21.7	11.4	4.02	1.12	1.87
P_1T_5	41.0	82.4	100.4	1.61	0.61	49.7	19.2	11.9	3.71	0.97	1.77
P_0T_1	40.3	82.9	106.5	1.74	0.66	51.8	19.1	10.4	3.94	0.99	1.79
P_0T_2	39.7	85.0	110.4	2.06	1.24	59.2	20.9	10.2	4.01	1.11	1.90
P_0T_3	38.3	84.3	110.5	1.99	0.95	52.0	20.2	10.9	3.98	1.03	1.68
P_0T_4	39.3	84.1	110.3	1.98	1.22	58.3	21.1	10.5	3.99	1.11	1.90
P_0T_5	41.0	82.6	104.2	1.57	0.58	49.6	16.6	10.9	3.67	0.95	1.79
SEm ± P x T	0.4	0.7	0.1	0.01	0.01	0.1	0.1	0.4	0.00	0.00	0.01
T x P	0.5	0.5	0.1	0.01	0.01	0.1	0.1	0.2	0.00	0.01	0.01
LSD (0.05) P x T	NS	NS	0.4	NS	0.04	0.4	0.5	NS	0.02	0.01	NS
T x P	NS	NS	0.4	NS	0.05	0.4	0.5	NS	0.02	0.04	NS

P1- with clipping, P0- without clipping, T1- 50% N, 100% P and K at basal + foliar spray of 2ml L^{-1} nano-urea at 30 and 45 DAS, T2- 50% N, 100% P and K at basal + foliar spray of 4ml L^{-1} nano-urea at 30 and 45 DAS, T3- 50% N, 100% P and K at basal + foliar spray of 6ml L^{-1} nano-urea at 30 and 45 DAS, T4- 50% N, 100% P and K at basal + foliar spray of 2ml L^{-1} nano-urea + 0.1% boron at 30 and 45 DAS, T5- 50% N,100% P and K at basal + 50% N top

Table 2: Effects of clipping and foliar nutrition on physiological parameters

Clipping of terminal bud		Germination % (Tr value)	Seedling root length (cm)	Seedling shoot length (cm)	Fresh weight of seedling (mg seedling^{-1})	Dry weight of seedling (mg seedling^{-1})	Vigour index I	Vigour index II
P1		83.0	8.5	2.0	73.1	3.74	1038	367.4
P0		83.6	9.0	1.8	72.6	3.72	1066	366.6
SEm ±		1.2	0.2	0.1	0.2	0.02	17	1.5
LSD (0.05)		NS	NS	NS	NS	NS	NS	NS
Treatments								
T1		79.6	8.3	1.9	67.1	3.16	996	308.1
T2		90.0	9.4	2.0	81.7	4.28	1165	428.2
T3		83.4	8.9	1.9	72.4	3.89	1055	381.3
T4		85.9	9.2	2.0	82.1	4.31	1109	425.2
T5		77.6	7.9	1.7	60.9	3.01	936	292.5
SEm (±)		1.3	0.2	0.1	0.3	0.03	17	3.2
LSD (0.05)		4.0	0.5	0.2	0.8	0.08	51	9.6
Interactions								
SEm ±	P x T	2.7	0.4	0.1	0.4	0.04	38	3.4
	T x P	2.1	0.3	0.1	0.4	0.04	27	4.3
LSD (0.05)	P x T	NS	NS	NS	NS	NS	NS	NS
	T x P	NS	NS	NS	NS	NS	NS	NS

P1- with clipping, P0- without clipping, T1- 50% N, 100% P and K at basal + foliar spray of 2ml L^{-1} nano-urea at 30 and 45 DAS, T2- 50% N, 100% P and K at basal + foliar spray of 4ml L^{-1} nano-urea at 30 and 45 DAS, T3- 50% N, 100% P and K at basal + foliar spray of 6ml L^{-1} nano-urea at 30 and 45 DAS, T4- 50% N, 100% P and K at basal + foliar spray of 2ml L^{-1} nano-urea + 0.1% boron at 30 and 45 DAS, T5- 50% N,100% P and K at basal + 50% N top dressed, NS- non-significant.

flowers per plant, and optimized distribution of photosynthates.

A significant impact of foliar treatments was noticed for all characteristics. The earliest maturity was observed in T_5 (82.5 days), while T_2 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4 ml L^{-1} nano-urea at 30 and 45 DAS) took the highest days for maturity (85.1 days). While considering the mean value, the highest number of primary and secondary branches (2.1 and 1.3 respectively) were recorded for treatment T_2 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea at 30 and 45 DAS). Analysis of data revealed that T_2 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea at 30 and 45 DAS) showed the maximum number of siliquae per plant (59) and test weight (4.01 g), followed by T_4 (50% N, full P_2O_5,K_2O at basal + foliar spray of 4ml L^{-1} nano-urea + 0.1 % boron at 30 and 45 DAS). The number of seeds per siliqua is a crucial factor that is directly related to seed yield. Each seed has some influence over its own growth, which is usually defined by the rate and duration of growth. Among the treatments, the highest number of seeds siliqua^{-1} (21.4) was observed in T_4 (50% N, full P_2O_5, K_2O at basal + foliar spray of (4ml L^{-1} nano-urea + 0.1 % boron) at 30 and 45 DAS), followed closely by T_2 (21.3), may be due to the positive effect of boron on pollen grain expansion and seed setting. Test weight is an important predictor of yield (Deivasigamani and Swaminathan, 2018). The tabulated data showed that T_2 had the highest test weight (4.01 g), followed by T_4 (4.00 g), with no significant statistical difference between them. Minimum test weight recorded in T_5 (50% N, full P_2O_5 and K_2O at basal + 50% N top dressed). A notably higher seed yield (1.13 t ha^{-1}) was recorded for T_2(50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea at 30 and 45 DAS), followed by T_4 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea + 0.1 % boron at 30 and 45 DAS) (1.11 t ha^{-1}) which were statistically at par. The lowest seed yield was observed in T_5 (50% N, full P_2O_5 and K_2O at basal + 50% N top dressed) (0.96 t ha^{-1}). Similar higher seed yield and better-quality seeds due to foliar application of nitrogen and other micro-nutrients was also observed by Kaur *et al*. (2019) and Bhinda *et al*. (2023). The increased seed yield might be due to the enhanced nutrient use efficiency resulting from the application of nano-form nitrogen. Furthermore, boron improved the number of seeds set in a siliqua which may causes the yield rise.

When evaluating the benefit-cost (B:C) ratio, it was observed that the clipping treatment exhibited non-significant values. However, regarding the foliar treatments, the highest B:C ratio (1.90) was obtained from treatment T_2(50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea at 30 and 45 DAS), followed by treatment T_4 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea + 0.1 % boron at 30 and 45 DAS).

Effect of clipping and foliar nutrition on physiological characters

The results presented in Table 2 revealed that the physiological characteristics differed considerably by foliar treatments. However, there was no significant difference observed between pinched and non-pinched plants. Seed germination is a parameter of prime significance that plays a vital role in biomass and yield. Among the treatments, T_2 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea at 30 and 45 DAS) exhibited the highest germination percentage (90.0), followed by T_4 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea + 0.1 % boron at 30 and 45 DAS). T_2 also recorded maximum root and shoot length (9.4 cm and 2.0 cm respectively), followed by T_4 which were statistically at par. However, the characters, fresh and dry weight of seedlings were found maximum (82.1 and 4.31 mg seedling^{-1} respectively) for T_4 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea + 0.1 % boron at 30 and 45 DAS). The enhanced seedling fresh and dry weight might be due to the positive influence of boron in facilitating the transfer of photosynthates and growth regulators from the source to sink and optimizing nitrogen uptake. Seed vigour is a crucial quality parameter that needs to be measured in addition to germination and viability tests in order to acquire insight into a seed lot's performance in the field or storage. From the findings of the seed vigour test, it was noted that T_2(50% N, full P_2O_5, K_2O at basal + foliar spray of 4ml L^{-1} nano-urea at 30 and 45 DAS) showed higher values for both vigour index I (1165) and vigour index II (428.2). Conversely, the minimum value of the vigour index was observed for T_5 (50% N, full P_2O_5 and K_2O at basal + 50% N top dressed).

Conclusion

The application of clipping treatment profoundly impacts the morphological characteristics of rapeseed, while it does not exhibit a significant impact on the studied physiological indices. Regarding treatments, T_2 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4 ml L^{-1} nano-urea at 30 and 45 DAS) and T_4 (50% N, full P_2O_5, K_2O at basal + foliar spray of 4 ml L^{-1} nano-urea + 0.1 % boron at 30 and 45 DAS) show significant effects on both morphological and physiological characteristics of the plant. The application of nano-urea at a concentration of 4 ml L^{-1}, combined with 0.1% boron during the initial growth stage, twice with an interval of 15 days, emerges as the most effective treatment and thus can be recommended to farmers aiming to boost productivity of rapeseed.

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