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Research article

Effect of different doses of triacontanol on growth and yield of kohlrabi (*Brassica oleracea* L. var. *gongylodes*)

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ABSTRACT

Triacontanol (TRIA), an endogenous plant growth regulator, promotes various metabolic activities in plants, resulting in improved growth and development in kohlrabi. The objective of this study was to assess the effect of different doses of triacontanol on the growth and yield of kohlrabi. This study was carried out in a randomized complete block design (RCBD) with five replications at Purkot Daha, Gulmi, Nepal, from October 2020 to January 2021. The treatments consisted of four doses of triacontanol (Niraculan 0.05% EC) diluted in water *viz* 0 mL L^{-1} (control), 1 mL L^{-1}, 1.5 mL L^{-1} and 2 mL L^{-1}. The results showed that triacontanol application significantly increased plant height, number of leaves, leaf length, and width of the large leaf at 40 days after transplanting (DAT). Plants treated with triacontanol at the dose of 1 mL L^{-1} produced the highest plant height (14.61 cm), which was statistically at par with 0 mL L^{-1} (12.76 cm) and 2 mL L^{-1} (14.26 cm). Similarly, at 40 DAT, plants treated with triacontanol at the dose of 2 mL L^{-1} produced the highest number of leaves (5.56), which was statistically at par with 1 mL L^{-1} (5.4) and 1.5 mL L^{-1} (4.96). Likewise, at 40 DAT, the highest length of large leaf (13.95 cm) and width of the large leaf (5.09 cm) were found in plants treated with triacontanol at the dose of 1 mL L^{-1}, which was statistically similar with 2 mL L^{-1}. The yield was found to be higher (6.75% to 40.4%) in plants treated with triacontanol as compared to plants treated with triacontanol at the dose of 0 mL L^{-1}. A significant difference was found in the harvest index. The highest harvest index (0.39) was found in plants treated with triacontanol at the dose of 2 mL L^{-1}, which was statistically similar with 1 mL L^{-1} (0.35) and 1.5 mL L^{-1} (0.39). The lowest harvest index (0.31) was found in plants treated with 0 mL^{-1}. This study suggests that farmers can apply triacontanol at the dose of 1 mL L^{-1} to enhance the growth and yield of kohlrabi.

1. Introduction

Kohlrabi (*Brassica oleracea* var. *gongylodes* L.), a member of the Crusader family of plants, is said to have originated on northern coast of Europe. It can withstand a wide range of temperatures and can be grown in both the early and late seasons (Al-Shammari et al., 2020). The Enlarged stem above the soil surface is the edible section of the kohlrabi, which has a great nutritional and medical value due to its high level of vitamins like Vitamin A, B1, B2, B5, and B6, minerals like Iron, Magnesium, and Zinc, and antioxidants that prevent cancer formation (Al-Khafaji and Abdul-Hadi al-Mukhtar, 1989).

Triacontanol (TRIA), a synthetic growth regulator, is a long-chain primary alcohol ($C_{30}H_{61}OH$). Tomatoes, lettuce, cucumber, potatoes, cauliflower, brinjal, chillies, opium, and hyacinth bean are among the horticultural crops for which TRIA has been proven to be efficient (Nagoshi and Kawashima, 1996) for enhancing their yields. TRIA can improve not just yield but also quality metrics in crops, as seen in wheat, tomato, cotton, and other crops (Ries, 1985). It has a broad effect on the enzymes that control plant growth (Chen et al., 2002) and metabolic processes (Morre et al., 1991). The 9-beta-L (+) Adenosine (a naturally occurring plant growth substance) was found to be elicited when plants were sprayed with triacontanol (Ries et al., 1990). At picomolar concentrations, 9-b-L (+) adenosine stimulated growth as determined by dry weight measurement of several plant species (Ries et al., 1990). Triacontanol increased dry weight, free amino acids, reducing sugars, and water-soluble protein of rice and maize plants within 5 min after treatment (Ries, 1991). The objective of this study was to evaluate the effect of different doses of foliar application of triacontanol (Niraculan 0.05% EC) on the growth and yield of kohlrabi.

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2. Materials and methods

2.1. Experimental site

Geographically, the experimental site was located at 28 8′48″ N latitude and 83 4′ 31″ E longitude, Gulmi, Nepal. The site was characterized by subtropical highland climate or temperate oceanic climate with dry winters. The average monthly mean temperature, rainfall, humidity and sun hours of the experimental site during the experiment period is given in Table 1.

The mean maximum daily temperature and night temperature during October 2020 was recorded as 32 °C and 25 °C respectively with an average of 29 °C, which continued to decrease afterward due to the onset of the winter season and dropped to a full day and night temperature of 24 °C and 14 °C respectively with an average of 20 °C in January 2021. However, no rainfall or little rainfall of 0.2 mm (October) was received during this research period. Similarly, relative humidity as high as 65% was recorded in October 2020, which dropped to 55% at the end of January 2021. The average sun hours during October (the maximum sun hours) and January (the minimum sun hours) were recorded as 372 and 313 h, respectively. The weather parameters, especially relative humidity and rainfall, were more concerned for the research since the triacontanol was applied as foliar nutrition. Temperature and sun hours had much more effective in the growth performance of the crop.

2.2. Experimental layout and design

Triacontanol (Niraculan 0.05% EC) was obtained from Dawadi Agrovet, Narayangarh, Chitwan, Nepal. The experiment was laid out in a randomized complete block design (RCBD) with five replications with four doses of triacontanol (Niraculan 0.05% EC) diluted in water as treatments *viz*; 0 mL L^{-1} (control), 1 mL L^{-1}, 1.5 mL L^{-1}, and 2 mL L^{-1}. The recommended dose of Niraculan 0.05% EC to the farmers for the foliar spray is 1–2 mL L^{-1} of water as per the commercial label on the product so, various formulations were prepared in the range of 1 mL and 2 mL to assess the most suitable concentration. The experiment consisted of 20 plots altogether, where each plot measured an area of 2 m × 1 m. Each plot consisted of 9 columns and 5 rows with 45 plants per plot. The distance between adjacent blocks and plots was maintained 0.5 m each. The variety 'Napa Boll' was seeded in the nursery bed on the 19th of October, 2020. Thirty-three days old healthy nursery seedlings were transplanted into the main field in a sunken bed system on 22nd November 2020. The recommended spacing of the variety Napa Boll, i.e., 20 cm × 20 cm, was followed with the recommended dose of NPK [N (100 kg ha^{-1}; Urea and Di-Ammonium Phosphate), P_2O_5 (60 kg ha^{-1}; Di-Ammonium Phosphate) and K (50 kg ha^{-1}; Muriate of Potash)] was applied (MoALD, 2020). Urea was applied in three equal split doses; first at the time of transplanting, second at 30 DAT, and third at 50 DAT. The sunken bed was prepared to conserve moisture and accomplished by excavating about 10 cm layer of topsoil at the respective plots. Soil pH was measured initially using kit-box and was recorded as 5.4. So, it was corrected to 6.1 using a dust mixture of 1 kg agricultural lime and an equal quantity of wood ashes during primary tillage. Irrigation was provided with the help of sprinklers on a daily basis. Hand hoeing operation was performed twice before the application of the second and third split doses of urea. Foliar application of triacontanol was made thrice at 15 DAT, 35 DAT, and 50 DAT with the help of battery operated knapsack sprayer.

2.3. Data observation

The data on plant growth (plant height, number of leaves, the spread of the plant, stem length; stem diameter, length of the large leaf, breadth of the large leaf) were recorded in between the foliar application dates at 20 DAT, 40 DAT and finally at the harvest. Yield parameters (diameter of bulb, thickness of bulb, yield, and harvest index) were also recorded during harvest, along with root volume and root length. Data on plant growth and yield observations (except productivity and harvest index) was collected from 5 randomly selected plants per plot.

2.4. Data analysis

The mean values of all the treatments were calculated, and the analysis of variance through one-way ANOVA was carried out using GenStat 15th edition. The multiple comparisons were performed using Duncan's Multiple Range Test at 5% level of significance.

3. Results and discussion

The effect of different doses of triacontanol on plant height, the number of leaves, and the spread of plant is given in Table 2. Application of triacontanol exhibited no significant effect on plant height and number of leaves of kohlrabi at 20 DAT and at harvest; however, it significantly influenced at 40 DAT. At 40 DAT, the maximum plant height (14.61 cm) was observed in 1 mL L^{-1} spray, which was statistically similar to that of control (12.76 cm) and 2 mL L^{-1} (14.26 cm). Similarly, the number of leaves was recorded as the maximum (5.56) in 2 mL L^{-1} at 40 DAT, which was statistically at par with 1 mL L^{-1} (9.04) and 2 mL L^{-1} (4.96). However, no significant difference in value was observed for the spread of plant at 20 DAT, 40 DAT, and at harvest (Table 2).

The effect of different doses of triacontanol on stem length, stem diameter and length of the large leaf is given in Table 3. Triacontanol showed no significant influence on stem length and stem diameter of kohlrabi at any data collection stage. Similarly, the length of the large leaf was also not affected by various doses of triacontanol at 20 DAT and harvest. However, at 40 DAT, the length of the large leaf was recorded the maximum (13.95 cm) in 1 mL L^{-1} spray, which was statistically at par with 2 mL L^{-1} (13.28 cm), and the lowest value (11.6 cm) was found in the control plot, i.e., plot without the application of triacontanol.

The effect of different doses of triacontanol width of the large leaf, root volume and root length is given in Table 4. The use of different doses of triacontanol was found non-significant for the width of the large leaf at 20 DAT and at harvest. However, at 40 DAT, the treatments 1 mL L^{-1} and 2 mL L^{-1} showed the maximum value for the width of large leaf, i.e., 5.09 cm and 4.88 cm, respectively. Root length and root volume were also not affected significantly by the application of triacontanol.

The effect of different doses of triacontanol on yield and yield parameters is given in Table 5. The application of triacontanol exhibited a non-significant influence on yield and yield parameters. Harvest index was calculated the highest with the application of triacontanol @ 2 ML

Table 1. Average monthly mean temperature, rainfall, humidity and sun hours of Purkot daha during the experiment.

Months	Maximum temperature (°C)	Minimum temperature (°C)	Average temperature (°C)	Rainfall (mm)	Relative humidity (%)	Average sun hours (h)
October, 2020	32	25	29	2	65	372
November, 2020	28	19	25	0	53	359
December, 2020	24	16	21	0	52	372
January, 2021	24	14	20	0	55	313

World Weather Online (2020/21).

Table 2. Effect of different doses of triacontanol on plant height, number of leaves and spread of plant.

Doses of Triacontanol	Plant height (cm)			Number of leaves			Spread of plant (cm)		
	20 DAT	40 DAT	Harvest	20 DAT	40 DAT	Harvest	20 DAT	40 DAT	Harvest
1 mL L^{-1}	10.94	14.61[a]	23.26	3.68	5.4[ab]	9.04	12.2	21.15	26.11
1.5 mL L^{-1}	10.73	12.67[b]	21.98	3.56	4.96[ab]	9.28	12.35	18.66	26.68
2 mL L^{-1}	11.16	14.26[ab]	23.27	3.8	5.56[a]	9.28	14.34	20.85	26.35
Control	10.48	12.76[ab]	21.40	3.8	4.88[b]	8.8	12.76	19.06	25.74
CV (%)	11.3	9.6	8.8	8.8	8.3	11.8	13	10.4	12.3
F test	ns	*	ns	ns	*	ns	ns	ns	ns

* Significant at 5% level of significance, ns: non-significant at 5% level of significance, means in the same column followed by the same letters are not significantly different at 5% level of significance according to Duncan's Multiple Range Test.

Table 3. Effect of different doses of triacontanol on stem length, stem diameter and length of large leaf.

Doses of Triacontanol	Stem length (cm)		Stem diameter (cm)		Length of large leaf (cm)		
	20 DAT	40 DAT	20 DAT	40 DAT	20 DAT	40 DAT	Harvest
1 mL L^{-1}	0.57	0.82	0.25	0.5	10.36	13.95[a]	21.86
1.5 mL L^{-1}	0.46	1.03	0.24	0.42	10.43	11.94[bc]	19.93
2 mL L^{-1}	0.48	0.81	0.23	0.48	10.27	13.28[ab]	21.7
Control	0.45	0.78	0.26	0.44	9.7	11.6[c]	20.24
CV (%)	45.8	54	16.3	12.9	11.6	7.7	8.7
F test	ns	ns	ns	ns	ns	**	ns

** Highly significant at 1% level of significance, ns: non-significant at 5% level of significance, means in the same column followed by the same letters are not significantly different at 5% level of significance according to Duncan's Multiple Range Test.

Table 4. Effect of different doses of triacontanol width of large leaf, root volume and root length.

Doses of Triacontanol	Width of large leaf (cm)			Root length (cm)	Root volume (cm^3)
	20 DAT	40 DAT	Harvest	Harvest	Harvest
1 mL L^{-1}	3.03	5.09[a]	12.6	11.37	8.24
1.5 mL L^{-1}	2.92	4[b]	11.56	10.63	6.85
2 mL L^{-1}	3.23	4.88[a]	11.81	11.6	8.83
Control	3.06	4.26[b]	11.53	10.67	7.78
CV(%)	10.4	9.7	8.1	9.8	19.3
F test	ns	**	ns	ns	ns

** Highly significant at 1% level of significance, ns: non-significant at 5% level of significance, means in the same column followed by the same letters are not significantly different at 5% level of significance according to Duncan's Multiple Range Test.

Table 5. Effect of different doses of triacontanol on yield parameters.

Doses of triacontanol	Diameter of bulb (cm)	Thickness of bulb (cm)	Average bulb weight (g)	Yield (mt/ha)	Harvest index
1 mL L^{-1}	4.02	3.12	156.8	35.28	0.35[ab]
1.5 mL L^{-1}	4.0	3.06	149	33.52	0.33[ab]
2 mL L^{-1}	4.5	3.37	196	44.1	0.39[a]
Control	3.77	2.9	139.6	31.4	0.31[b]
CV(%)	13.8	14.3	35.3	35.3	13.8
F test	ns	ns	ns	ns	*

* Significant at 5% level of significance, ns: non-significant at 5% level of significance, means in the same column followed by the same letters are not significantly different at 5% level of significance according to Duncan's Multiple Range Test.

L^{-1} (0.39), which was statistically at par with 1 mL L^{-1} (0.35) and 1.5 mL L^{-1} (0.33). The lowest harvest index (0.31) was recorded in the control plot.

The results followed by the analysis exhibited that the plant height and the number of leaves did not differ significantly from the control plot at 20 DAT and harvest (Table 2). Similar findings were found in an experiment assessing the effect of triacontanol in tomatoes (Kapitsimadi and Vioryl, 1995). Harvest index was found to be significantly different in the treated plots as compared to the control one. The higher value of harvest index in the treated plots, although yield being statistically similar, signifies that the economic yield of plots treated with triacontanol is higher than the biological yield concerning the economic yield of the control plot. Several research involving medicinal plants have demonstrated the growth-promoting effects of triacontanol on several traits, particularly shoot and root lengths, fresh and dry weights (Mishra and Srivastava, 1991; Kumaravelu et al., 2000; Muthuchellan et al., 2003; Naeem and Khan, 2005). Enhancement of carbonic anhydrase activity in treated plants might have been responsible for the enhanced rate of CO_2 fixation and hence have resulted in a significant increase in fresh and dry weights of treated plants (Mohd et al., 2010). TRIA application increased the plant dry weight, chlorophyll contents, and net photosynthetic rate in rice (*Oryza sativa* L.) (Chen et al., 2002). This might be the reasonable cause of the increased yield and greater harvest index.

Various studies have provided strong evidence that the application of TRIA, applied either through the root medium or to the leaves, enhanced the growth and yield of vegetables and cereal crops (Ries et al., 1978; Ries and Wert, 1977). The increase in yield is due to the rapid increase in the net assimilation rate observed in tomatoes after TRIA spray (Ries, 1985). Similarly, in an experiment of chrysanthemum, TRIA treated plots reported increased growth, number of inflorescences, and quality of flowers (Skogen et al., 1982). A higher amount of leaf nutrients in TRIA-treated plants could be attributed to the higher metabolic activity and increased dry matter production, resulting in enhanced water and nutrient uptake from soil subsequently (Sharma et al., 2002). The results of 46 field experiments, conducted in several parts of the world, generally showed no significant increase in crop yield, except one study conducted in Japan, where the yield of rice was increased by 17–21% on account of soil application of TRIA at 0.057–4 g ha^{-1} (Naeem et al., 2012).

4. Conclusion

The effect of different doses of triacontanol (as treatment) on kohlrabi was assessed in this experiment. The treatments had no significant effect on the yield and yield parameters (diameter of bulb, thickness of bulb, average head weight) but significant effects on plant height, number of leaves, length of the large leaf, the width of the large leaf at 40 DAT and harvest index. The application of triacontanol at the dose of 1 mL L^{-1} increased the growth and yield of kohlrabi. Therefore, farmers can apply such a dose of triacontanol to increase kohlrabi production in the Gulmi district.

Declarations

Author contribution statement

Santosh Bhandari; Aashish Bhandari: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Jiban Shrestha: Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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