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Studies on the influence of different plant growth regulators on growth, yield and quality of ginger (*Zingiber officinale* Rosc.) variety Nadia in Gangetic alluvial plains of West Bengal

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Abstract
A field experiment was conducted to study the influence of different plant growth regulators on growth, yield and quality of ginger (*Zingiber officinale* Rosc.) *var.* Nadia at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during 2015-16. There were altogether ten treatments laid in RBD with three replications *viz.*, GA_3 (50, 100 and 150 ppm), Ethrel (50, 100 and 150 ppm) and Cycocel (CCC) (100, 200 and 500 ppm) and control (water spray) and were applied as foliar spray at 90 and 120 days after planting. The results revealed that spraying with GA_3 at 150 ppm recorded highest with almost all the growth and yield attributing parameters like plant height (77.16 cm), leaf length (23.96 cm), length of clump (20.54 cm), breadth of clump (10.62 cm), yield per plant (235.55 gm), yield per plot (11.30 kg) and yield per hectare (27.15 t/ha) respectively. Ethrel at 150 ppm and CCC at 200 ppm recorded highest number of leaves per tiller (23.48) and maximum leaf breadth (2.22 cm) respectively. Further, number of tillers per clump (18.53), number of fingers per clump (20.83), length of fingers (10.96) and girth of fingers (4.26) were found highest with CCC at 500 ppm respectively. The quality attributing parameters like essential oil (1.74 %), oleoresin content (5.15 %) and dry recovery (20.87 %) was recorded highest with CCC at 500 ppm respectively. This experiment led to a conclusion for obtaining maximum yield and good quality of ginger *var.* Nadia rhizomes, foliar application of GA_3 at 150 ppm and Cycocel (CCC) at 500 ppm could be recommended to the farmers of alluvial plains of West Bengal.

Keywords: ginger, GA_3, ethrel, cycocel, yield, quality

Introduction
Ginger *(Zingiber officinale* Rosc.) is one of the earliest known oriental spices and is being cultivated in India for underground modified stem called rhizomes which is used both as fresh vegetable and as a dried spice, since time immemorial (Sasikumar, 1996) [11]. Ginger is obtained from the rhizomes of *Zingiber officinale* Rosc., which belongs to the family Zingiberaceae. India is the largest producer in the world and the annual production is about 8.55 lakh tonnes from an area of about 1.33 lakh hectares, contributing approximately 25 to 30 per cent of the world production (NHB, 2016) [5]. In West Bengal, it is grown in an area of about 11,500 hectares with an annual production of 25,000 tonnes of fresh rhizome (NHB, 2016) [5]. It is mainly grown in Darjeeling, Kalimpong, Nadia, Bhagwanpur areas of West Bengal. Due to pleasant, pungent and spicy aroma ginger is used in the manufacture of a number of food products like ginger bread, confectionary, curry powders, certain curried meats, table sauces, pickle and in manufacturing of soft drinks like cordials, ginger cocktail, carbonated drinks, etc. It is also used in alcoholic beverages like ginger brandy, ginger wine and ginger beer (Pruthi, 1998) [9]. The use of synthetic growth regulators and chemicals that reduce the growth of the foliage and better partitioning of dry matter in to the rhizome is much emphasized (Maruthi *et al*., 2003a) [3]. Sengupta *et al*. (2008) [12] reported that the maximum plant height, maximum number of pseudostem and also maximum yield was recorded with the foliar application of GA_3 at 150 ppm in the hilly region of Darjeeling district of West Bengal. Velayutham *et al*. (2013) [13] found that the foliar application of CCC at 500 ppm gave highest yield with good quality of ginger rhizomes under Tamil Nadu conditions. How ever the information regarding the use of plant growth regulators and chemicals in ginger crop is very meagre.

Hence, the present investigation was taken up to investigate the influence of plant growth regulators on the growth, yield and quality components.

Materials and Methods

The experiment was laid out in randomized block design having 10 treatments with three replications during the year 2015-16. Three plant growth regulators GA_3 (50, 100 and 150 ppm), Ethrel (50, 100 and 150 ppm), Cycocel (100, 200 and 500 ppm) and control (water spray) were included. Ginger variety 'Nadia' was used in the experiment and seed rhizome bits of 25 g weight with one or two well-sprouted buds were sown on a raised bed of 3m x 1m at a spacing of 25 x 25 cm during the month of April. The crop was fertilized with the inorganic fertilizers *i.e.*, Nitrogen @ 80 kg/ha, Phosphorous @ 50 kg/ha and Potassium @ 60 kg/ha were applied along with well rotten Farm Yard manure (FYM) @ 30 tones/hectare and Neem Cake @ 2 tones/hectare by broadcasting and mixed thoroughly at the time of land preparation. Nitrogenous fertilizer was given in two equal splits i.e., at the time of planting and 90 days after planting. Mother rhizomes were removed from the plant at 90 days after planting with the help of hand fork. Foliar spray of plant growth regulators was given at two times 90 and 120 days after planting. Other cultural operations were done as per the common package of practices. The crop was harvested in the end of January month when the leaves are turned yellow and started drying up. Observations were recorded on growth, rhizome yield and quality parameters on ten randomly selected clumps in each treatment after harvest. Then the data collected from the field were subjected to statistical analysis and interpretation of data was done as given by Panse and Sukhatme (1985) [7]. The level of significance used in 'F' and 'T' test was at P=0.05. Quality parameters such as essential oil, oleoresin content and dry recovery percentage were estimated using standard procedures (AOAC, 1975) [1].

Results and discussion

The growth, yield and quality parameters of ginger rhizome *var*. Nadia recorded were shown significant differences among the treatments. The influence of different plant growth regulators on growth parameters recorded are given in table 1. For the plant height, GA_3 at 150 ppm recorded highest plant height (77.16 cm) as compared to control (53.34 cm). It was followed by GA_3 at 100 ppm (72.37 cm) and Ethrel at 150 ppm (70.25 cm). The minimum plant height was recorded in the plants sprayed with CCC at 100 ppm (52.06 cm) as compared to control (53.34 cm) respectively. Plant height is an important parameter that decides the rhizome growth of ginger. This might be attributed due to the reduction in intermodal length and the inhibition of cell division (Maruthi *et al*., 2003a) [3] and the anti-gibberlin activity of CCC (Ravisankar, 1983) [10]. These results are in conformity with Sengupta *et al*. (2008) [12] and Velayutham *et al*. (2013) [13] in ginger respectively. The spray of growth regulator Ethrel at 100 ppm recorded the highest number of leaves/tiller (23.48) followed by CCC at 500 ppm (22.52) and Ethrel at 150 ppm (22.27) as compared to control (16.57). The lowest values were recorded with GA_3 at 100 (13.78) and GA_3 at 150 ppm (15.09). This is in conformity with the findings of Sengupta *et al*. (2008) [12] and Maruthi *et al*. (2003a) [3] in ginger. For the trait leaf length, the plants sprayed with GA_3 at 150 ppm recorded the maximum of 23.96 cm which was *at par* with GA_3 at 100 ppm (23.62 cm) and CCC at 500 ppm (23.05 cm) as compared to control (20.82 cm) respectively. The lowest leaf length was found in the plants sprayed with Ethrel at 150 ppm (19.61 cm) and Ethrel at 100 ppm (19.77 cm). These findings were confirmed with Sengupta *et al*. (2008) [12]. Whereas, traits like leaf breadth and number of tillers/clump was found maximum in the ginger plants sprayed with CCC at 200 ppm (2.22 cm) and CCC at 500 ppm (18.53) as compared to control of about 2.14 cm and 13.21 respectively. CCC has decisive role in the suppression of apical dominance and diverting the polar transport of auxin towards the basal buds leading to increased tiller production. This is in accordance with the findings of Maruthi *et al*. (2003a) [3]; Sengupta *et al*. (2008) [12] and Velayutham *et al*. (2013) [13] in ginger respectively.

The experimental results on influence of different plant growth regulators on yield parameters from the table 2 revealed that, highest number of fingers per clump was found in the rhizomes sprayed with CCC at 500 ppm (20.83) and it was followed by GA_3 at 150 ppm (20.79). The lowest number of fingers per clump was noticed in control and lowest (13.87). Ginger rhizomes sprayed with the growth regulator CCC at 500 ppm showed the maximum length of fingers (10.96 cm) and girth of fingers (4.26 cm) respectively. This finding was almost *at par* in the rhizomes sprayed with GA_3 at 150 ppm which showed length of fingers and girth of fingers of about 10.89 cm and 4.20 cm respectively. The lowest length of fingers (8.98 cm) and girth of fingers (2.31 cm) were recorded with control. These findings are in accordance with Velayutham *et al*. (2013) [13]. Further, the other yield attributing parameters like length of clump (20.54 cm), breadth of clump (10.62 cm), yield per plant (235.55 gm), yield per plot (11.30 kg) and projected yield per hectare (27.15 t/ha) was recorded highest in the ginger rhizomes sprayed with GA_3 at 150 ppm respectively and it was found statistically significant between the other treatments in the experiment. Similarly, the second and third highest values regarding the yield attributing parameters were recorded highest in the rhizomes sprayed with CCC at 500 ppm and Ethrel at 50 ppm respectively. The lowest length of clump (16.36 cm), breadth of clump (8.59 cm), yield per plant (148.93 gm), yield per plot (7.14 kg) and projected yield per hectare (17.13 t/ha) was recorded with control. The highest yield might be due to positive influence on yield contributing characters like increased number of rhizomes, rhizome length and girth and size in terms of length and breadth of clump. The rapid proliferation of xylem parenchyma, formation of storage rhizomes earlier and production of more number of rhizomes also helpful in increasing the yield. These experimental findings were in consonance with the findings of Jayachandran and Sethumadhavan (1988) [2]; Phogat and Singh (1987) [8]; Maruthi *et al*. (2003b) [4]; Obasi, M. O. and Atanu, S. O. (2004) [6]; Sengupta *et al*. (2008) [12] and Velayutham *et al*. (2013) [13] in ginger.

It is evident from the results (Table 3) that the essential oil content (1.74 %) was found highest with CCC at 500 ppm and it was followed by CCC at 100 ppm (1.58 %) and Ethrel at 50 ppm (1.53 %) even though the data were non-significant. The lowest oil content was found with GA_3 at 100 ppm (1.31 %) and GA_3 at 50 ppm (1.38 %) as compared to control (1.46 %) respectively. The CCC has the ability to block the biosynthesis of gibberellins thereby improved the oil content. This is in agreement with the findings of Ravisankar (1983); Jayachandran and Sethumadhavan (1988) [2]; Maruthi *et al*. (2003b) [4] and Velayutham *et al*. (2013) [13] in ginger. The observations on oleoresin content showed highest with CCC at 500 ppm (5.15 %) and it was followed by CCC at 100 ppm

(4.67 %) and Ethrel at 50 ppm (4.43 %). The lowest oleoresin content was found with GA_3 at 100 ppm (4.11 %) and GA_3 at 50 ppm (4.14 %) as compared to control (4.39 %) respectively. This results were found similarity with the findings of Jayachandran and Sethumadhavan (1988) [2] in ginger. Whereas, the dry recovery content was noticed highest with CCC at 500 ppm (20.87 %) followed by CCC at 100 ppm (20.28 %) and Ethrel at 50 ppm (20.11 %). The lowest oleoresin content was found with GA_3 at 100 ppm (18.11 %) and GA_3 at 50 ppm (18.28 %) as compared to control (18.84 %) respectively. The mode of action behind the treatment is thickening of fibre cells with advancing maturity that would have resulted in more crude fibre content. The earlier works of Jayachandran and Sethumadhavan (1988) [2]; Maruthi *et al*. (2003b) and Velayutham *et al*. (2013) [13] in ginger supported the findings of present study.

From this experiment it can be concluded that for obtaining maximum yield and good quality of ginger *var*. Nadia rhizomes, foliar application of GA_3 at 150 ppm and Cycocel (CCC) at 500 ppm could be recommended to the farmers of alluvial plains of West Bengal for commercial cultivation.

Table 1: Influence of different plant growth regulators on growth parameters

Treatments	Plant Height (cm)	Number of Leaves/Tiller	Leaf Length (cm)	Leaf Breadth (cm)	Number of Tillers/Clump
GA_3 50 ppm	61.93	16.85	22.47	2.18	15.79
GA_3 100 ppm	72.37	13.78	23.62	2.20	15.63
GA_3 150 ppm	77.16	15.09	23.96	2.14	15.15
Ethrel 50 ppm	59.72	21.14	20.23	2.11	17.18
Ethrel 100 ppm	67.91	23.48	19.77	2.12	17.63
Ethrel 150 ppm	70.25	22.77	19.61	2.10	18.26
Cycocel 100 ppm	52.06	18.75	22.18	2.20	17.94
Cycocel 200 ppm	53.84	19.26	22.43	2.22	18.12
Cycocel 500 ppm	59.66	22.52	23.05	2.17	18.53
Control	53.34	16.57	20.82	2.14	13.21
S.Em±	1.92	0.93	0.96	0.21	1.24
CD(P=0.05)	5.31	2.77	2.85	0.65	3.68

Table 2: Influence of different plant growth regulators on yield parameters

Treatments	Number of Fingers/Clump	Length of Fingers (cm)	Girth of Fingers (cm)	Length of Clump (cm)	Breadth of Clump (cm)	Yield/Plant (gm)	Yield/Plot (kg)	Yield/hectare (t/ha)
GA_3 50 ppm	19.88	9.57	2.50	17.85	8.95	172.40	8.27	19.85
GA_3 100 ppm	20.04	9.96	3.21	18.11	9.14	184.23	8.84	21.21
GA_3 150 ppm	20.79	10.89	4.20	20.54	10.62	235.55	11.30	27.15
Ethrel 50 ppm	20.26	10.44	4.06	19.85	10.03	205.21	9.85	23.64
Ethrel 100 ppm	19.70	9.62	3.52	19.24	9.54	191.06	9.17	22.00
Ethrel 150 ppm	20.16	10.11	3.85	19.49	9.76	197.83	9.49	22.79
Cycocel 100 ppm	19.08	9.71	3.57	19.11	9.27	195.10	9.36	22.47
Cycocel 200 ppm	19.77	10.21	3.72	19.62	9.88	203.14	9.75	23.40
Cycocel 500 ppm	20.83	10.96	4.26	20.03	10.27	223.95	10.74	25.81
Control	13.87	8.98	2.31	16.36	8.59	148.93	7.14	17.13
S.Em±	2.60	0.85	0.42	1.26	0.50	6.86	0.46	0.86
CD(P=0.05)	7.73	2.53	1.26	3.74	1.50	20.39	1.37	2.58

Table 3: Influence of different plant growth regulators on quality parameters

Treatments	Essential oil (%)	Oleoresin (%)	Dry Recovery (%)
GA_3 50 ppm	1.38	4.14	18.28
GA_3 100 ppm	1.31	4.11	18.11
GA_3 150 ppm	1.43	4.21	18.33
Ethrel 50 ppm	1.53	4.43	20.11
Ethrel 100 ppm	1.52	4.34	19.69
Ethrel 150 ppm	1.45	4.19	19.35
Cycocel 100 ppm	1.58	4.67	20.28
Cycocel 200 ppm	1.48	4.27	19.42
Cycocel 500 ppm	1.74	5.15	20.87
Control	1.46	4.39	18.84
S.Em±	0.01	0.16	0.27
CD(P=0.05)	NS	0.48	0.82

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