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Influence of Plant Growth Regulators on Morphological, Floral and Yield Traits of Cucumber (*Cucumis sativus* L.)

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ABSTRACT

The possibility was examined of altering the plant frame and inducing femaleness at early stages in the development of cucumber for productivity enhancement and early development using various plant growth regulators at the Vegetable Experimental Farm, Division of Vegetable Science and Floriculture, S.K. University of Agricultural Sciences and Technology of Jammu, India during the spring-summer season of 2009. Three plant growth regulators were sprayed onto plants at the two-, four- and six-leaf and full-bloom stage using the cucumber variety Cucumber Long Green. Two of the growth regulators, maleic hydrazide and ethephon, were each applied at two different concentrations of 100 and 200 ppm and the third, naphthalene acetic acid, was applied at 50 and 100 ppm, and some combined applications of growth regulators were also tested. The experiment comprised 15 treatments and was laid out in a randomized block design with three replications. The results revealed that the influence of the plant growth regulators was variable on the morphological traits of cucumber but the floral and yield traits were significantly affected by a combined application of 100 ppm maleic hydrazide and 100 ppm ethephon. This treatment induced early development, maximized the sex ratio with regard to yield and was comparatively helpful in reducing plant expansion. This treatment also produced the best economic results for the production of cucumber.

Keywords: cucumber, morphology, flowering, yield, maleic hydrazide, ethephon, NAA

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a widely cultivated plant, belonging to the family Cucurbitaceae and having a chromosome number, 2n =14. It is an endemic vegetable of India (De Candole, 1967). Cucumber is commonly a monoecious, annual, trailing or climbing vine (Bailey, 1969) having hirsute or scabrous stems with triangular ovate leaves with shallow and acute sinuses. Cucumber exhibits a fascinating range of floral morphology, including staminate, pistillate and hermaphrodite flowers occurring in various arrangements and yielding several types of sexual expression. Furthermore, these types are affected greatly by environmental factors as well as hormonal levels in the plant system. Growth regulators have tremendous effects on sex expression and flowering in various cucurbits leading to either suppression of male flowers or an increase in the number of female flowers (Al-Masoum and Al-Masri, 1999) without imposing any deleterious effect on the environment and human health. Exogenous application of plant

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growth regulators can alter the sex ratio and sequence if applied at the two- or four-leaf stage, which is the critical stage at which the suppression or promotion of either sex is possible (Hossain *et al.,* 2006). Plant growth regulators are also used to control the vegetative growth of plants, thereby increasing the plant population per unit area with regard to yield (Latimer, 1991).

Therefore, this study aimed to obtain the ideal plant type of cucumber having bushy growth with maximum and early yield using various plant growth regulators under Jammu agro-climatic conditions. Chatha (Jammu) lies in the state of Jammu and Kashmir, the northwestern state of India, situated at latitude 33° 55 N and longitude 74° 58 E with an altitude of 332 m above mean sea level. The region has a subtropical climate with a hot dry summer, a warm and humid rainy season and cold winter months. The maximum temperature reaches 46 °C during summer (May to June) and the minimum temperature falls below 10 °C during winter (December to January). The mean annual rainfall is in the range 1,000˘1,200 mm. Cucumber is an important crop of the region and to increase the productivity of the crop, both the yield and plant population per unit area are considered important and thus research work was initiated using plant growth regulators. Moreover, this type of research was lacking and was considered necessary by the farming community of the region in order to maximize farm income.

MATERIALS AND METHODS

The present investigation was carried out on the cucumber variety, Cucumber Long Green, at the Vegetable Experimental Farm, Division of Vegetable Science and Floriculture, SKUAST-J, Chatha during the spring˘summer season of 2009. The soil in the field plots was sandy loam in texture (sand, silt and clay content was 59, 33 and 8%, respectively), slightly alkaline in reaction (pH = 7.40), low to medium in electrical conductivity (0.41 dsm^{-1}), with low levels of organic carbon (0.45%) and available nitrogen (226 kg/ha), but medium levels of phosphorus (17.40 kg/ha) and potassium (161.37 kg/ha). The experiment was carried out in a randomized block design, with three replicates, using three growth regulators at two different concentrations namely , maleic hydrazide (100 and 200 ppm), ethephon (100 and 200 ppm) and napthalene acetic acid (50 and 100 ppm) alone and in some different combinations, sprayed at the two-, four- and six-leaf and the full-bloom stage. The stock solutions were prepared fresh at the time of each spraying and dilutions to the required concentrations were made using stock solution. All the growth regulators were procured from SD Fine-Chemicals Limited, Mumbai (400030). All the chemicals used were laboratory reagents and not commercial formulations.

The seeds were sown on 20 January 2009 under protected conditions in poly-bags of size 15 × 8 cm. The growing medium in the poly-bags was prepared by mixing farmyard manure, sand and clay in the ratio of 1:1:1. Two seeds per poly-bag were sown and kept inside the poly-house. Regular watering was carried out as required. After complete germination of the seeds at 18 d after sowing, the poly-bags were separated, keeping eight plants per treatment tagged to document various observations. Two sprays, one each at the two-leaf and four-leaf stage at 19 d and 35 d after sowing, were applied using a hand-operated sprayer. The field was ploughed twice followed by planking to attain good condition. The area for the experiment was set out using a measuring tape and pits of size 0.5 × 0.5 × 0.5 m were dug at a spacing of 1.5 × 1 m. Transplanting was carried out 1.5 mth after sowing. About 5˘6 kg of farmyard manure was thoroughly mixed with soil in each pit. Nitrogen, phosphorous and potassium at 100:50:50 kg/ha was applied in the form of urea (46% N; 197.5 kg), di-ammonium phosphate (48% P and 18% N; 108.5 kg) and muriate of potash (60% K; 83.3 kg). A full dose of phosphorus and potassium and a half dose of nitrogen were applied as the basal dose. The remaining dose of nitrogen was applied as top dressing during the first and second hoeing and earthing-up operations. The remaining two sprays of growth regulators, one each at the six-leaf and the full-bloom stage at 52 and 85 d after sowing, respectively, were applied according to the treatment schedule, using a foot operated sprayer. The plants were irrigated when required depending on the soil moisture regime. Plants were protected from insect pests and diseases using appropriate plant protection measures from the initial stages of crop growth until crop senescence. Straw mulching was carried out to avoid direct contact of fruit with the soil and to prevent fruit rotting. Fruit was ready for marketing 1.5 mth after transplanting and was field-picked at intervals of 3 to 4 d. Fruits having a weight less than or equal to 200 g were picked for marketing purposes. The data obtained during the experiment were subjected to statistical analysis for a randomized block design according to the procedure of Gomez and Gomez (1984). The test to determine a significant difference between treatments was set at the $P < 0.05$ level.

Morphological, floral and metrical measurements in the study

Eight plants were randomly selected in each plot and properly tagged to record the following observations.

Morphological measurements

Length of main stem

The length of the primary stem was measured from ground level (the point of emergence of the plant) to the top of the vine on each tagged plant with the help of a meter scale and the average length was calculated.

Number of primary branches per vine

The total number of branches arising from the main stem was counted from each tagged plant and the average was calculated.

Length of primary branches per vine

The average length of primary branches was calculated by dividing the total length of the primary branches by the number of primary branches per vine on all tagged plants.

Number of nodes on main stem

All the nodes appearing on the main stem were counted on each tagged plant and the average was calculated.

Number of nodes per unit length of vine

Nodes per unit length were calculated by dividing the total number of nodes appearing on the main stem by the total length of the main stem of the vine.

Inter-nodal distance

The distance between the nodes of each tagged plant was measured from the middle of the vine using a scale and the average was calculated.

Floral measurements

Node at which first female flower appeared on the main stem

The node at which the first female flower appeared on the main stem was recorded on each tagged plant and the average was calculated.

Days to first female flower appearance after sowing

The number of days to the appearance after sowing of the first female flower was recorded on each tagged plant and the average was calculated.

Days to 50% flowering from the date of sowing

The total number of days taken for 50% of the plants to bear flowers in each treatment plot from the date of sowing was counted and the average was calculated.

Sex ratio

The sex ratio was recorded as the ratio of pistillate to staminate flowers at the flowering stage, counted from the appearance of the first flower until the last flower on each tagged plant.

Metrical measurements

Days to marketable fruit formation from flower bud initiation.

The number of days taken by a bud to reach a marketable fruit size (less than or equal to 200 g) was calculated with at least three buds from each tagged plant being selected at the time of bud initiation stage.

Number of fruit per plant

The number of fruit per plant was recorded as the average of the cumulative number of fruit in all pickings of selected plants at a marketable stage.

Fruit weight per vine

Fruits harvested from the selected plants were weighted separately at each picking and the cumulative yield per vine was calculated.

Fruit yield per hectare

The fruit yield per hectare was calculated by multiplying the fruit yield per plant by the total number of plants on one hectare.

RESULTS

Morphological traits

All the morphological traits, such as length of main stem, number of primary branches per vine, length of primary branches, number of nodes on vine and inter nodal distance, were variably affected by the application of various plant growth regulators (Table 1). The results revealed that all the treatments were effective in

Table 1 Influence of plant growth regulators on morphological traits of cucumber.

Notation	Treatments	Length of main stem (cm)	Number of primary branches per vine	Length of primary branches (cm)	Number of nodes on main stem	Number of nodes per unit length of vine (nodes/m)	Inter-nodal distance (cm)
T_1	Maleic hydrazide @ 100 ppm	180.24*	5.75*	108.41*	29.06*	16.13*	6.20*
T_2	Maleic hydrazide @ 200 ppm	178.91*	5.50*	138.04	27.55	15.43*	6.49*
T_3	Ethephon @ 100 ppm	184.92*	5.00	121.78	30.18*	16.63*	6.13*
T_4	Ethephon @ 200 ppm	141.30*	5.08	151.34	26.94	19.08*	5.29*
T_5	NAA @ 50 ppm	199.58*	4.58	134.30	32.45*	16.28*	6.15*
T_6	NAA @ 100 ppm	186.42*	4.50	121.43	25.98	15.02*	6.70*
T_7	Maleic hydrazide @ 100 ppm + Ethephon @ 100 ppm	175.85*	5.50*	90.26*	37.90*	19.97*	5.02*
T_8	Maleic hydrazide @ 200 ppm + Ethephon @ 100 ppm	181.93*	4.33	148.34	30.09*	14.02	7.14*
T_9	Maleic hydrazide @ 100 ppm + Ethephon @ 200 ppm	156.27*	4.50	149.02	29.00*	18.49*	5.48*
T_{10}	Maleic hydrazide @ 200 ppm + Ethephon @ 200 ppm	115.31*	5.00	94.86*	24.40	19.75*	5.18*
T_{11}	Maleic hydrazide @ 100 ppm + NAA @ 50 ppm	174.04*	5.17	116.60*	27.65	15.99*	6.28*
T_{12}	Maleic hydrazide@200 ppm + NAA @ 50 ppm	147.25*	5.17	101.10*	25.59	17.38*	5.76*
T_{13}	Maleic hydrazide @ 100 ppm + NAA @ 100 ppm	164.22*	5.25	113.56*	26.03	15.85*	6.31*
T_{14}	Maleic hydrazide @ 200 ppm + NAA @ 100 ppm	186.45*	4.50	63.40*	25.75	13.88	7.24*
T_{15}	Control (Distilled water spray)	231.47	4.42	161.21	24.25	11.93	8.61
	SE ±	8.47	0.31	14.71	1.19	1.01	0.40
	CD at 5%	24.65	0.91	42.84	3.45	2.93	1.17

* = Significant difference compared to the control value in the column at the 5% level of significance ($P < 0.05$).

CD at 5% = Critical difference for the 5% level of significance.

reducing the length of the main stem ranging from 13 to 50%. A maximum reduction was observed in T_{10} (200 ppm maleic hydrazide + 200 ppm ethephon), where a vine length of 115.31cm was observed which was significantly different from other treatments, including the control (T_{15}) which recorded a vine length of 231.47 cm.

The maximum number of primary branches (5.75) was recorded with 100 ppm maleic hydrazide which was significantly different from T_5 (50 ppm maleic hydrazide), T_6 (100 ppm NAA), T_8 (200 ppm maleic hydrazide + 100 ppm ethephon), T_9 (100 ppm maleic hydrazide + 200 ppm ethephon), T_{14} (200 ppm maleic hydrazide + 100 ppm NAA) and T_{15} (control), but not significantly different from the other treatments. The lowest number of primary branches (4.33) was recorded in T_8 (200 ppm maleic hydrazide + 100 ppm ethephon). All treatments including plant growth regulators were found effective in decreasing the average length of primary branches per vine (Table 1). The maximum reduction of 97.81 cm was recorded in T_{14} (200 ppm maleic hydrazide + 100 ppm NAA). This treatment produced plants with primary branches only 63.40 cm in length, which was significantly different from the control with primary branches that were 161.21 cm in length.

Foliar sprays of various growth regulators maximized the number of nodes compared with the control, but a significant increase was observed in T_3 (100 ppm ethephon), T_5 (50 ppm NAA), T_7 (100 ppm maleic hydrazide + 100 ppm ethephon), T_8 (200 ppm maleic hydrazide + 100 ppm ethephon) and T_9 (100 ppm maleic hydrazide + 200 ppm ethephon) with 30.18, 32.45, 37.90, 30.09 and 29.00 nodes on the main stem, respectively. However, the lowest number of nodes on the main stem (24.25) was recorded in the control (T_{15}). The application of growth regulators tended to increase the number of nodes per unit vine length compared with the control (Table 1). However, the maximum nodes (19.97) per unit length of vine was recorded in T_7 (100 ppm maleic hydrazide + 100 ppm ethephon). The internodal distance in all treatments was significantly less than the control. However, the minimum internodal distance (5.02 cm) was observed in T_7 (100 ppm maleic hydrazide + 100 ppm ethephon), which was significantly different from the control (T_{15}) with an internodal distance of 8.61 cm (Table 1).

Floral traits

Maleic hydrazide either alone or in combination with ethephon had a significant effect on floral characters (Table 2). It was clear that the foliar application of growth regulators either alone or in combination had a significant role in promoting earliness in the crop compared with the control. Thus, 100 ppm maleic hydrazide (T_1), which recorded the first female flower at the 4.17 node was significantly different to the rest of the treatments except T_7 (100 ppm maleic hydrazide + 100 ppm ethephon), T_{10} (200 ppm maleic hydrazide + 200 ppm ethephon) and T_{11} (100 ppm maleic hydrazide + 50 ppm NAA). The minimum number of days (65.00) to the appearance of the first female flower was recorded in T_1 (100 ppm maleic hydrazide) and T_7 (100 ppm maleic hydrazide + 100 ppm ethephon). Among the treatments, the minimum number of days to 50 percent flowering (63.67 d) was recorded in T_1 (100 ppm maleic hydrazide) which was significantly different to the control (69.67 d). It was also observed that treatments with NAA applied either alone or in combination delayed flowering compared with the control. The maximum number of pistillate flowers per staminate flower (1.26) was recorded in T_7 (100 ppm maleic hydrazide + 100 ppm ethephon) which was similar to T_{10} (200 ppm maleic hydrazide + 200 ppm ethephon) with a sex ratio of 1.23, but was significantly different from the rest of the treatments. The control recorded the lowest number of pistillate flowers (0.22) per staminate flower.

Table 2 Influence of plant growth regulators on floral traits of cucumber.

Notation	Treatment	Node at which first female flower appears on main stem	Days to first female flower appearance	Days to 50% flowering	Sex Ratio	Days to marketable fruit formation after flower bud initiation
T_1	Maleic hydrazide @ 100 ppm	4.2*	65.0*	63.7*	0.4*	10.2*
T_2	Maleic hydrazide @ 200 ppm	7.5*	70.7*	66.3*	0.2*	10.2*
T_3	Ethephon @ 100 ppm	5.8*	67.0*	65.0*	0.8*	11.2*
T_4	Ethephon @ 200 ppm	6.5*	68.3*	68.3	1.1*	9.5*
T_5	NAA @ 50 ppm	7.0*	70.0*	71.0	0.4*	12.5
T_6	NAA @ 100 ppm	6.0*	75.0*	72.0	0.3	12.2
T_7	Maleic hydrazide @ 100 ppm + Ethephon @ 100 ppm	4.7*	65.0*	64.3*	1.3*	9.2*
T_8	Maleic hydrazide @ 200 ppm + Ethephon @ 100 ppm	6.5*	66.3*	65.0*	0.9*	11.2*
T_9	Maleic hydrazide @ 100 ppm + Ethephon @ 200 ppm	6.7*	66.0*	68.0	1.0*	9.2*
T_{10}	Maleic hydrazide @ 200 ppm + Ethephon @ 200 ppm	5.7*	68.7*	64.3*	1.2*	10.0*
T_{11}	Maleic hydrazide @ 100 ppm + NAA @ 50 ppm	5.5*	73.3*	73.7	0.4*	11.0*
T_{12}	Maleic hydrazide@200 ppm + NAA @ 50 ppm	6.5*	76.3	71.7	0.3	11.2*
T_{13}	Maleic hydrazide @ 100 ppm + NAA @ 100 ppm	6.0*	77.3	74.3	0.3	12.0*
T_{14}	Maleic hydrazide @ 200 ppm + NAA @ 100 ppm	6.0*	75.3*	74.0	0.2	12.4
T_{15}	Control (Distilled water spray)	9.0	79.7	69.7	0.2	13.7
	SE ±	0.59	1.40	1.12	0.05	0.5
	CD at 5%	1.71	4.08	3.25	0.15	1.5

* = Significant difference compared to the control value in the column at the 5% level of significance ($P < 0.05$).
CD at 5% = Critical difference for the 5% level of significance.

Yield traits

The application of growth regulators significantly hastened fruit development compared with the control. However, the application of 100 ppm maleic hydrazide in conjunction with 100 ppm ethephon (T_7) or 200 ppm ethephon (T_9) produced the minimum number of days (9.25) for marketable fruit formation from flower bud initiation. The maximum number of fruit (11.58) was also recorded with 100 ppm maleic hydrazide + 100 ppm ethephon (T_7), which was significantly different from the rest of the treatments including the control (T_{15}) which had 5.75 fruit per vine. The maximum fruit weight per vine (2.19 kg) was recorded in T_7 (100 ppm maleic hydrazide + 100 ppm ethephon), followed by T_1 (100 ppm maleic hydrazide) with an average fruit weight of 1.96 kg per vine; these treatments were significantly different to the rest of the treatments, including the control which had a fruit weight of 1.20 kg per vine. The results also indicated that napthalene acetic acid either alone or in combination with other plant growth regulators did not cause any significant increase in fruit weight per vine. The maximum yield (13.13 tonne/ha) was recorded in T_7 (100 ppm maleic hydrazide + 100 ppm ethephon) which was similar to T_1 (100 ppm maleic hydrazide) and T_9 (100 ppm maleic hydrazide + 200 ppm ethephon) with yields of 11.72 and 11.11 tonne/ha, respectively. However, the control plot produced a yield of 7.23 tonne/ha, which was about 45% less than the best treatment.

Economics of the treatments

The economics analysis of fruit production of cucumber indicated that T_7 (100 ppm maleic hydrazide + 100 ppm ethephon) provided the maximum return followed by T_1 (100 ppm maleic hydrazide) with a benefit cost (B:C) ratio of 1.48 and 1.26, respectively. The lowest B:C ratio (0.49) was recorded for the control (Table 3).The cost of plant growth regulators and spraying expenses are presented in Tables 4 and 5.

DISCUSSION

Morphological traits

The results revealed that the influence of plant growth regulators was variable on the morphological parameters of cucumber. Both maleic hydrazide and ethephon were effective in reducing the length of the main stem and increasing the number of primary branches. The inhibition of apical growth may have been due to the effect of maleic hydrazide on cell division (Graulach and Atchinson, 1953) and plant polar auxin transport (Arora *et al.,* 1982). At higher concentrations, maleic hydrazide and ethephon showed more severe and lasting inhibition on vegetative growth (Abdel-Rahman and Thompson, 1969). Similar findings were reported by Arora *et al*. (1994) in longmelon and by Murthy *et al*. (2007) in gherkin. Miller *et al*. (1969) attributed the increased number of branches in eggplant and pepper to forced lateral bud development and injury to the terminal bud by the use of growth regulators, which endorsed the present findings. T_{14} (maleic hydrazide at 200 ppm in combination with napthalene acetic acid at 100 ppm) was most effective in reducing the length of primary branches of the vines to 63.40 cm compared with

Table 3 Influence of plant growth regulators on yield traits of cucumber.

Notation	Treatment	Number of fruits per vine	Fruit weight per vine (kg)	Fruit yield (tonnes/ha) (T)
T_1	Maleic hydrazide @ 100 ppm	9.70*	1.96*	11.77*
T_2	Maleic hydrazide @ 200 ppm	6.67	1.24	7.42
T_3	Ethephon @ 100 ppm	8.50*	1.68*	10.05*
T_4	Ethephon @ 200 ppm	8.58*	1.61*	9.63*
T_5	NAA @ 50 ppm	6.33	1.22	7.33
T_6	NAA @ 100 ppm	5.58	1.34	8.02
T_7	Maleic hydrazide @ 100 ppm + Ethephon @ 100 ppm	11.58*	2.19*	13.12*
T_8	Maleic hydrazide @ 200 ppm + Ethephon @ 100 ppm	7.42	1.43	8.56
T_9	Maleic hydrazide @ 100 ppm + Ethephon @ 200 ppm	8.50*	1.85*	11.10*
T_{10}	Maleic hydrazide @ 200 ppm + Ethephon @ 200 ppm	7.00	1.23	7.36
T_{11}	Maleic hydrazide @ 100 ppm + NAA @ 50 ppm	5.75	1.23	7.39
T_{12}	Maleic hydrazide@200 ppm + NAA @ 50 ppm	6.25	1.27	7.64
T_{13}	Maleic hydrazide @ 100 ppm + NAA @ 100 ppm	6.17	1.41	8.43
T_{14}	Maleic hydrazide @ 200 ppm + NAA @ 100 ppm	5.93	1.50	9.00
T_{15}	Control (Distilled water spray)	5.75	1.20	7.22
	S.E Ø	0.45	0.12	0.7
	CD at 5%	1.30	0.34	2.04

* = Significant difference compared to the control value in the column at the 5% level of significance ($P < 0.05$).
CD at 5% = Critical difference for the 5% level of significance.

the control (161.21cm). The reduction in the length of primary branches might have been due to suppression in the apical growth of the plant (Singh and Choudhary, 1989) and also due to the effect of plant polar auxin transport (Arora *et al*., 1982). Such inhibitory effects of maleic hydrazide and napthalene acetic acid at higher concentrations have also been reported in other cucurbits (Sadhu and Das, 1978). The number of nodes on the main stem, based on per unit length and internodal distance was found to be significantly enhanced by the combined application of maleic hydrazide at 100 ppm and ethephon at 100 ppm compared with the control. A possible reason might be that ethylene acts as an anti-gibberellin and causes cessation of the mitotic processes in the meristem of root and shoot, thereby affecting the length of the plant (Hayashi *et al*., 2001). Inhibition of both cell division and cell elongation has been found with the application of growth retardants, resulting in production of shorter shoots and leaves in melon (Rajala and Peltonen-Saino, 2001). Similar reports have been published by Ouzounidou *et al*. (2008) in *Cucumis melo* L.

Table 4 Cost of plant growth regulators (PGRs) including spraying using various treatments of cucumber.

Notation	Treatment	Quantity of PGR used			Individual cost (INR)			Total cost of PGRs (INR)	Cost of PGRs including cost of spraying (INR)
		MH (g)	Ethephon (mL)	NAA (g)	MH (g)	Ethephon (mL)	NAA (g)		
T_1	MH @ 100 ppm	100	Nil	Nil	110	-	-	110.0	3410.0
T_2	MH @ 200 ppm	200	Nil	Nil	220	-	-	220.0	3520.0
T_3	Ethephon @ 100 ppm	100	Nil	Nil	820	-	-	820.0	4120.0
T_4	Ethephon @ 200 ppm	200	Nil	Nil	1640	-	-	1640.0	4940.0
T_5	NAA @ 50 ppm	50	Nil	Nil	262.5	-	-	262.5	3562.5
T_6	NAA @ 100 ppm	100	Nil	Nil	525	-	-	525.0	3825.0
T_7	MH @ 100 ppm + Ethephon @ 100 ppm	100	100	Nil	110	820	-	930.0	4230.0
T_8	MH @ 200 ppm + Ethephon @ 100 ppm	200	100	Nil	220	820	-	1040.0	4340.0
T_9	MH @ 100 ppm + Ethephon @ 200 ppm	100	200	Nil	110	1640	-	1750.0	5050.0
T_{10}	MH @ 200 ppm + Ethephon @ 200 ppm	200	200	Nil	220	1640	-	1860.0	5160.0
T_{11}	MH @ 100 ppm + NAA @ 50 ppm	100	Nil	50	110	-	262.5	372.5	3672.5
T_{12}	MH@200 ppm + NAA @ 50 ppm	200	Nil	50	220	-	262.5	482.5	3782.5
T_{13}	MH @ 100 ppm + NAA @ 100 ppm	100	Nil	100	110	-	525	635.0	3935.0
T_{14}	MH @ 200 ppm + NAA @ 100 ppm	200	Nil	100	220	-	525	745.0	4045.0
T_{15}	Control (Distilled water spray)	Nil	Nil	Nil	0	-	-	0.0	0.0

INR = Indian rupees.

Floral traits

The results of the present study indicated that maleic hydrazide either alone or in combination with ethephon had a significant effect on floral characters, which agreed with other research workers (Kooner *et al.*, 2000; Sulochanamma, 2001; Bhat *et al.*, 2004), who also found that spraying plants with maleic hydrazide and ethephon shifted sex expression towards femaleness. Such effects could be attributed to the fact that a lower concentration of maleic hydrazide and ethephon slightly inhibited vegetative growth, increased lateral development, reduced respiration (thus increasing carbohydrate levels) and enhanced the development of early pistillate flowers. Such synergistic effects not only increased early fruit setting, but also accelerated the fruit development processes (Abdel-Rahman and Thompson, 1969). Yamasaki *et al.* (2000) reported that higher levels of endogenous ethylene production caused greater accumulation of CS-ETR2 and CS-ERS mRNA, which play a role in the development of female flowers in cucumber. Moreover, maleic hydrazide at low concentrations increased cell length, cell size and early cell enlargement in algae (Gupta and Kumar, 1970) and increased the cell carbohydrate content (Currier *et al.*, 1951; Derridj *et al.*, 1986) which in turn promoted pistillate flower production in the vine. It was also noticed that application of maleic hydrazide reduced inter-nodal distance, thus increasing the source-sink relationship and helped in the early accumulation of photosynthates necessary for the flowering and fruit setting processes of the plant.

Yield traits and economics

Fruit yield and its contributing traits such as days to marketable fruit formation, number of fruits per vine, yield per plant and yield per hectare were influenced by the application of lower concentrations of maleic hydrazide, either alone or in combination with ethephon. A probable

Table 5 Economic cost of fruit production for various treatments of cucumber.

Treatment	Cost (INR) of PGRs including cost of spraying	Cost (INR) of treatment (Cost of cultivation+ PGRs)	Yield (tonnes/ha)	Gross Income (INR)	Net Returns (INR)	Additional returns over control (INR)	B:C Ratio
T_1	3410.0	52060.0	11.77	117720	65660.0	42050.0	1.26[2]
T_2	3520.0	52170.0	7.42	74240	22070.0	-1540.0	0.42[12]
T_3	4120.0	52770.0	10.05	96340	43570.0	19960.0	0.88[4]
T_4	4940.0	53590.0	9.63	100500	46910.0	23300.0	0.83[5]
T_5	3562.5	52212.5	7.33	73350	21137.5	-2472.5	0.40[14]
T_6	3825.0	52475.0	8.02	80220	27745.0	4135.0	0.53[9]
T_7	4230.0	52880.0	13.12	131260	78380.0	54770.0	1.48[1]
T_8	4340.0	52990.0	8.56	85690	32700.0	9090.0	0.62[7]
T_9	5050.0	53700.0	11.10	111080	57380.0	33770.0	1.07[3]
T_{10}	5160.0	53810.0	7.36	73600	19790.0	-3820.0	0.37[15]
T_{11}	3672.5	52322.5	7.39	73910	21587.5	-2022.5	0.41[13]
T_{12}	3782.5	52432.5	7.64	76490	24057.5	447.5	0.46[11]
T_{13}	3935.0	52585.0	8.43	84310	31725.0	8115.0	0.60[8]
T_{14}	4045.0	52695.0	9.00	90070	37375.0	13765.0	0.71[6]
T_{15}	0.0	48650.0	7.22	72260	23610.0	0.0	0.49[10]

INR = Indian rupees.

Sale price of fresh cucumber = INR 10 per kilogram.

[1,2,3,…,15] = Ranking in descending order.

reason suggested by Ries (1985), which endorsed the present results, was that the application of growth retardants like maleic hydrazide increased the endogenous ethylene level which triggered metabolic processes and affected the C:N ratio in plants, in turn stimulating flowering, fruit set, sex ratio and thereby yield. It was also found that napthalene acetic acid at all concentrations showed nonsignificant results which might have been due to the fact that during the two- and four-leaf stages, spraying of this chemical inhibited leaf expansion and caused downward curling of seedlings (showing epinasty) which caused improper growth in the early stages, thereby making the plants less competitive and poor performers for developing yield and its contributing traits (personal assessment).The plants performed poorly (retarded growth) after early spraying and some plants even died. However, with later spraying, plants receiving NAA sprays either alone or in combination with maleic hydrazide, performed in the same way as the plants under the other treatments. The results conformed to the findings of Bhat *et al*. (2004) who reported maximum fruit yield in watermelon with an application of maleic hydrazide at 100 ppm. The economic studies (with all costs in the present paper shown in Indian rupees, INR) determined that the cost of cultivation of cucumber was INR 48,650.00 in the control. Application of plant growth regulators (including the cost of sprays) raised the growing cost by INR 3,400.00 to 5,200.00 under various treatments in the study. The yield increased from 7.22 tonne/ha in the control to 13.13 tonne/ha in the treatment with 100 ppm maleic hydrazide and 100 ppm ethephon, resulting in an additional return of INR 54,770.00 leading to the maximum benefit cost ratio of 1.48 in comparison with the control (0.49). The high return was clearly due to the maximum fruit yield per hectare in the treatment. Similar results of plant growth regulators have also been detailed for cucumber by Singh and Singh (1984).

CONCLUSION

The influence of the plant growth regulators at the two-, four- and six-leaf and full-bloom stages of the cucumber variety, Cucumber Long Green, on the morphological, floral and fruit yield traits was significant. The plant growth regulators used were maleic hydrazide and ethephon each at 100 or 200 ppm and napthalene acetic acid at 50 and 100 ppm sprayed either alone or in different combinations. However, among different treatments, a foliar application of maleic hydrazide with ethephon each at 100 ppm, proved best for increasing fruit yield and its contributing parameters. This treatment not only brought earliness, increased the sex ratio and reduced plant expansion (that is, accommodation of more plants per unit area) but also gave the best economic result.

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