Influence of Gibberellic Acid and Naphthalene Acetic Acid on Tomato Production Under Protected Cultivation in Kaski, Nepal

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Abstract

An experiment was carried out under naturally ventilated greenhouse to assess the performance of tomato cv. Srijana as influenced by GA3 and NAA during the summer season of 2018-2019 at Pokhara, Kaski, Nepal. Treatments comprised of four levels of GA3 (i.e. 0 ppm, 25 ppm, 50ppm and 75 ppm) each combined at four different levels of NAA (i.e. 0ppm, 25ppm, 50ppm and 75 ppm). The result revealed that the fruit yield was significantly influenced by the levels of GA3, NAA and their interactions. Among four levels of NAA, the highest yield (109.91metric ton ha-1) of tomato was recorded with NAA at 25 ppm which was 10.37%, 17.47% and 24.78% higher over NAA at 0ppm, NAA at 50ppm and NAA at 75ppm respectively. Similarly, a significantly higher yield (103.46metric ton ha-1) of tomato was attained with GA3 at 50 ppm and it was 13.91 %, 10.31% and 6.74 % higher over GA3 at 0ppm, GA3 at 25 ppm and GA3 at 75 ppm respectively. Interactions between GA3 and NAA levels were significant for all yield attributes. Regression analysis on the effect of GA3 and NAA on the yield of tomato showed polynomial regression equation, while the physical maximum dose of GA3 was 52.65 ppm and NAA was 20.29 ppm respectively. It can be concluded that the production of tomato could be improved by the combined application of GA3 at 50 ppm and NAA at 25 ppm under the protected condition of Pokhara, Nepal.

Keywords: *GA3, Greenhouse, NAA, Tomato, Yield*

INTRODUCTION

Tomato (Lycopersicon esculentum Mill.) is one of the most important vegetables of Solanaceae family grown widely all over the world. It is a self-pollinated crop with 2n=24 chromosomes. It originated in the western coastal plain of South America (Thompson & Kelly, 1957). Tomato has a wide range of uses, fruits are commonly eaten as raw or salad, also used for ketchup or pickle making. In terms of human health, tomato is considered as protective food as it constitutes an important source of minerals, vitamins, and antioxidant compounds (Bose & Som, 1990). In Nepal, it is grown under an area of 21,389 ha, with a total production of 400,674

metric tons. The average yield of tomato is 19 metric ton ha-1. In Kaski, the area under tomato cultivation is about 395 ha with a production of 6123 metric tons and the average yield is 16 metric ton ha-1 (MoAD, 2018). Tomato can be grown year-round as it is photo-periodically insensitive but the average yield per hectare for tomato is very low in summer season (Ghimire et al. 2007). Higher temperature interferes with fruit set and results in flower drop due to an impaired complex of the physiological process in the pistil. Increased temperature above optimal lead to failure of tomato fruit set due to the disruption of sugar metabolism and proline translocation during the narrow window of male reproductive development (Sato et al. 2006). Disturbed sugar metabolism affects anther development by reducing the length of the stamen resulting stigma elongation. Reproductive developments in tomato including stamen and pollen differentiation and fruit set are important to fruit yield and quality (Kinet & Peet, 1997). The period of non-availability of fruits in the summer months can be reduced by the application of plant growth regulators which enhance the source-sink relationship and stimulate the translocation of photoassimilates thereby helping in better retention of flowers and fruits (Kishan-Swaroop et al., 2001). Among various PGRs (Plant Growth Regulators), GA3 (Gibberellic acid) and NAA (Naphthalene acetic acid) have been reported to show the promising effect on tomato crop (Meena, 2008). NAA is known to stimulate cell division, cell elongation, shoot elongation, photosynthesis, RNA synthesis, membrane permeability and water uptake (Maurya et al., 2013). Along with NAA, GA3 stimulate cell elongation and cause plants to grow taller (Khan, et al., 2006). GA3 is also involved in other plant processes, such as flowering and fruit ripening (Wittwer et al., 1957). In addition to this, the protected horticulture can make smallholdings viable by producing maximum from limited land. Realizing the above-mentioned significance, the present investigation has been undertaken to assess the influence of GA3 and NAA on the performance of tomato under naturally ventilated greenhouse and to explore the suitable combination of GA3 and NAA for ensuring the maximum growth and higher yield of tomato.

Materials And Methods

2.1 Experimental detail

The experiment was conducted in the Kham Ghale Krishi Farm, Chauthe, in Kaski district. The site is situated in western Nepal of sub-tropical climate. The altitude of the site is 763 meters above mean sea level. Geographically, it is located at the longitude of 84° 01' 41" E and latitude of 28° 11' 23" N (PMAMP, 2018). Analysis of soil available nitrogen, phosphorous and potassium were done using Kjeldhal distillation unit (Bremner, 1965), modified Olsen method (Watanabe & Olsen, 1965) using sphectrophotometer and Neutral Ammonium Acetate method using Flame Photometer respectively. Similarly, soil pH and organic matter were analyzed through Beckman Glass Electrode pH meter (1:2.5 soil water suspension) and Walkley and Blacks' titration method respectively. The pH of the soil was neutral (6.9) in nature. The available phosphorus (939.2 kg/ha) and potassium (978.5 kg/ha) were found to be higher. In contrast, the total nitrogen (0.03 %) and the average organic carbon content (0.67%) were found to be of low status. Hygrothermometer inside the greenhouse recorded the maximum temperature as 23.25 °C during the first week of January to 35.29 °C during the second week of May, 2019. Similarly, the minimum temperature was ranged from 8 °C during the first week of January to 21.3 °C during the second week of May, 2019.

2.2 Experimental design

The experiment was laid out in RCBD with 3 replications and the combination of 16 treatments consisting of four levels of GA3 and four levels of NAA.

A. GA3 Levels

i) GA3 at 0 ppm (G0)
ii) GA3 at 25 ppm (G1)
iii) GA3 at 50 ppm (G2)
iv) GA3 at 75 ppm (G3)

B. NAA Levels

i) NAA at 0 ppm (N0)
ii) NAA at 25 ppm (N1)
iii) NAA at 50 ppm (N2)
iv) NAA at 75 ppm (N3)

Table 1. Detail of treatments and their symbols for tomato experimentation

S.N.	Treatments with symbol	Treatment combination
1.	T1 - G0N0	GA3 @ 0 ppm + NAA @ 0 ppm
2.	T2 - G0N1	GA3 @ 0 ppm + NAA @ 25 ppm
3.	T3 – G0N2	GA3 @ 0 ppm + NAA @ 50 ppm
4.	T4 - G0N3	GA3 @ 0 ppm + NAA @ 75 ppm
5.	T5 - G1N0	GA3 @ 25 ppm + NAA @ 0 ppm
6.	T6 - G1N1	GA3 @ 25 ppm + NAA @ 25 ppm
7.	T7 - G1N2	GA3 @ 25 ppm + NAA @ 50 ppm
8.	T8 -G1N3	GA3 @ 25 ppm + NAA @ 75 ppm
9.	T9- G2N0	GA3 @ 50 ppm + NAA @ 0 ppm
10.	T10 - G2N1	GA3 @ 50 ppm + NAA @ 25 ppm
11.	T11 - G2N2	GA3 @ 50 ppm + NAA @ 50 ppm
12.	T12 - G2N3	GA3 @ 50 ppm + NAA @ 75 ppm
13.	T13 - G3N0	GA3 @ 75 ppm + NAA @ 0 ppm
14.	T14 - G3N1	GA3 @ 75 ppm + NAA @ 25 ppm
15.	T15 - G3N2	GA3 @ 75 ppm + NAA @ 50 ppm
16.	T16- G3N3	GA3 @ 75 ppm + NAA @ 75 ppm

2.3.1 Preparation of GA3 and NAA

The stock solution was first prepared by dissolving the weighed amount of each chemical separately in a small quantity of absolute alcohol and then adding the required quantity of distilled water. The solution of various concentrations of GA3 and NAA were prepared at the time of foliar application at various growth stages.

2.3.2 Spray of GA3 and NAA

Only the freshly prepared solutions having teepol at the rate of 0.1% of the spray solution as a wetting agent were sprayed on the foliage with a hand pump sprayer fitted with a fine nozzle at an interval of 15 days starting from 15th DAT (Days after transplanting) till 45 day . To avoid drift of NAA and GA3 solution from one plot to another, spraying was done stretching the polythene sheet between the plants of two adjacent plots.

2.4 Observation and measurement

Five randomly selected plants in each plot were tagged for observations and the following characters were studied in the successive stages of crop growth.

2.4.1Phenological observations

2.4.1.1 Days to 50% flowering

Days to 50% flowering were observed in each treatment and the mean data was calculated.

2.4.1.2 Number of flower cluster per plant

The number of flower cluster was counted from the sample plants at 60 and 75 DAT, and the average number of flower clusters produced per plant was calculated.

2.4.1.3 Number of flowers per cluster

The number of flowers per cluster was taken from the sample plant at 60 and 75 DAT, and was calculated as follows:

Number of flowers per cluster=(Total number of flowers in sample plants)/(Total number of flowers cluster in sample plants)

2.4.1.4 Number of flowers per plant

The total number of flower was counted from the sample plants at 60 and 75 DAT, and the average number of flower produced per plant was calculated.

2.4.2 Yield attributing characters

2.4.2.1 Number of fruits per plant

Fruits from all the picking were counted for each selected plants.

2.4.2.2 Individual fruit weight (g)

Fruit from the tagged plants was selected randomly. The total weight was noted at the time of harvesting and the average weight per fruit was calculated.

2.4.2.3 Fruit yield (kg/plant)

The yield was recorded by weighing the fruits harvested in different pickings. The total weight of all picked fruits during the season from a single plant gave the yield per plant.

2.4.2.4 Fruit yield (metric ton ha-1)

The fruit yield was recorded by weighing the fruits harvested in different pickings. The total weight of all picked fruits during the season per plot gave the fruit yield per plot. The fruit yield per plot was converted into metric tons per hectare.

2.5 Statistical analysis

The data obtained for different characteristics in respect of growth, yield contributing characters of tomato and yield were statistically analyzed to find out the statistical significance. The means for all the treatments were calculated and the analysis of variance for all the characters was performed by “F” (variance ratio) test. The significance of the difference among the means was evaluated by Duncan’s Multiple Range Test (DMRT) according to Gomez and Gomez (1984) for interpretation of the result at a 5% level of probability.

RESULTS

3.1 Phenological observations

3.1.1 Days to 50 % flowering

The days to 50 % flowering of tomato was significantly influenced by both hormones i.e. GA3 and NAA levels. The average day to 50% flowering was 47.83 in the experiment (Table 2).

The earliest days to 50 % flowering (44.33 days) was recorded at GA3 at 50 ppm. GA3 at 75 ppm resulted in delayed 50 % flowering. The other levels of GA3 except the above-mentioned

levels were intermediate in range for days to 50 % flowering. Similarly, the days to 50 % flowering was also influenced by NAA levels where NAA at 25 ppm resulted in earliest days to 50 % flowering while NAA at 75 ppm resulted in delayed 50 % flowering. The other levels of NAA except the above-mentioned level were intermediate in range for days to 50 % flowering.

Table 2 Days to 50 % flowering of tomato plant as influenced by the GA3 and NAA

Treatments	Days to 50 % Flowering
GA3 Levels	
0 ppm	48.42b
25 ppm	48.08b
50 ppm	44.33c
75 ppm	50.5a
LSD	1.42***
NAA levels	
0ppm	47.33b
25ppm	40.83c
50 ppm	48.5b
75 ppm	54.67a
LSD	1.42***
SEM(±)	0.49
CV (%)	3.56
Grand mean	47.83

Note: Treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

There was significant interaction of GA3 and NAA on the days to 50 % flowering of tomato. The days to 50 % flowering due to the interaction of GA3 and NAA levels ranged from 37.33 days to 57.67 days (Figure 1).

Among the different combinations of GA3 and NAA, the 50 % flowering was the earliest (37.33) due to the interaction of GA3 at 50 ppm with NAA at 25 ppm which was statistically similar to GA3 at 0 ppm with NAA at 25 ppm. GA3 at 0 ppm with NAA at 75 ppm resulted in delayed days to 50 % flowering (57.67).

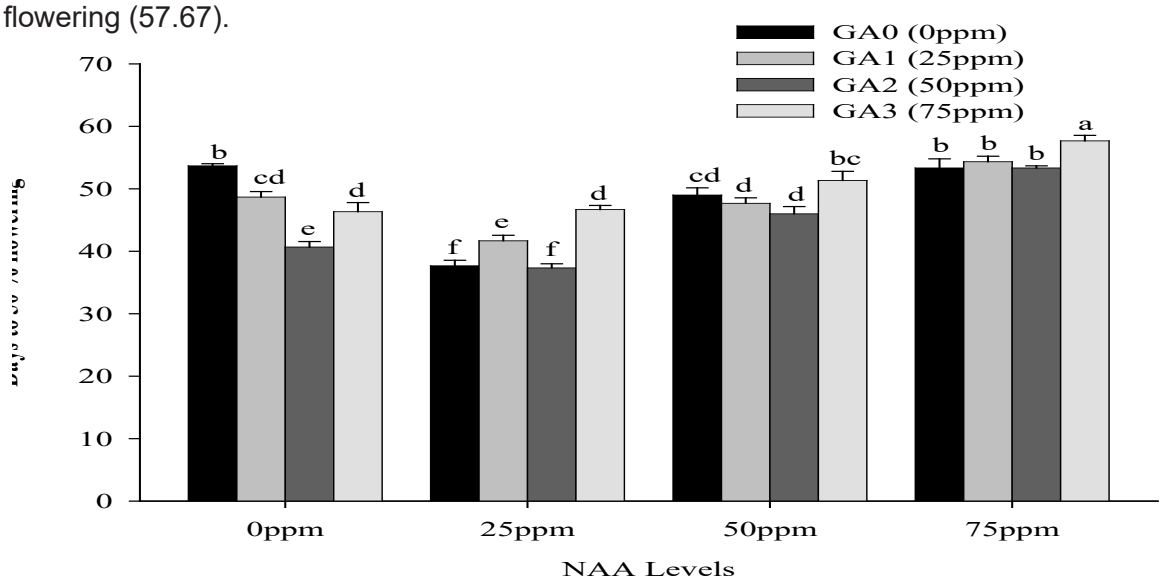

Figure 1 Days to 50 % flowering of tomato plant at 60 DAT as influenced

by the interaction of GA3 and NAA 3.1.2 Flowering behavior of tomato

The number of flower clusters, number of flowers per cluster as well as flowers per plant of tomato was significantly influenced by both hormones i.e. GA3 and NAA levels at all dates of observation. The average number of flower cluster per plant was noted as 4.99 at 60 DAT which increased to 6.46 at 75 DAT. The average flower per cluster was noted as 4.08 at 60 DAT which increased to 5.33 at 75 DAT and the average flower per plant was 20.93 at 60 DAT which increased to 34.7 at 75 DAT (Table 3).

The number of flower clusters increased with increasing levels of GA3 at 60 DAT but at 75 DAT, the number of flower clusters increased from GA3 at 0 ppm to GA3 at 50 ppm and thereafter decreased at GA3 at 75 ppm. Similarly, the number of flower clusters per plant of tomato was also influenced by NAA levels where the highest number of flower clusters per plant was recorded at NAA at 25 ppm and the lowest at NAA at 75 ppm. More or less similar trend was observed at all dates of observation.

The number of flowers per cluster as well as per plant increased with increasing levels of GA3 at all dates of observation. Similarly, the number of flowers per cluster as well as per plant of tomato was also influenced by NAA levels where the highest number of flowers per cluster, as well as flowers per plant, was recorded at NAA at 25 ppm. The lowest number of flowers per cluster, as well as flowers per plant, was obtained at NAA at 75ppm. The number of flowers per cluster, as well as flowers per plant at other levels of NAA except for the above-mentioned levels was intermediate in range. More or less similar trend was observed at all dates of observation.

Table 3 Flowering behavior of tomato as influenced by the application of GA3 and NAA

Treatments	Number of flower clusters per plant		Number of flowers per cluster		Number of flowers per plant	
	60 DAT	75 DAT	60 DAT	75 DAT	60 DAT	75 DAT
GA3 Levels						
0 ppm	4.68b	5.93c	3.87b	5.30ab	18.97b	31.93b
25 ppm	5.03a	6.55ab	3.94b	5.05b	19.96b	33.12b
50 ppm	5.20a	6.94a	4.34a	5.49a	22.98a	38.31a
75 ppm	5.05a	6.41b	4.16a	5.46a	21.82a	35.45ab
LSD	0.306*	0.407***	0.186***	0.279*	1.6***	3.36**
NAA levels						
0ppm	5.02b	6.50b	3.98b	5.08b	20.13b	33.23b
25ppm	5.98a	7.38a	5.09a	5.95a	30.54a	44.03a
50 ppm	4.83b	6.37b	3.92b	5.16b	19.17b	32.96b
75 ppm	4.13c	5.58c	3.32c	5.11b	13.89c	28.60c
LSD	0.306***	0.407***	0.186***	0.279 ***	1.6***	3.36 ***
SEM(±)	0.106	0.14	0.06	0.09	0.55	1.16
CV (%)	7.37	7.56	5.49	6.28	9.19	11.6
Grand mean	4.99	6.46	4.08	5.33	20.93	34.7

Note: Treatments means followed by common letter (s) are not significantly different among each other based on DMRT at 5% level of significance

There was significant interaction of GA3 and NAA on the number of flower clusters per plant, number of flowers per cluster as well as the number of flowers per plant at all dates of observation (Figure 2, Figure 3, Figure 4 and Figure 5)

The number of flower clusters per plant of tomato was the highest (6.61) at GA3 at 0 ppm with NAA at 25 ppm at 60 DAT (Figure 2). This number of flower clusters was statistically similar to GA3 at 50 ppm with NAA at 25 ppm. The number of flower clusters was the lowest (3.44) due to the interaction of GA3 at 75 ppm with NAA at 75 ppm which was statistically similar to GA3 at 0 ppm with NAA at 75 ppm. The other number of flower clusters at different combinations of GA3 and NAA except the above-mentioned combinations were intermediate at 60 DAT.

The number of flower clusters per plant of tomato was the highest (7.72) due to the interaction of GA3 at 50 ppm with NAA at 25 ppm at 75 DAT (Figure 3). This number was statistically similar to GA3 at 50 ppm with NAA at 0 ppm, GA3 at 25 ppm with NAA at 50 ppm and all levels of GA3 with NAA at 25 ppm. The number of flower clusters was the lowest (4.72) due to the interaction of GA3 at 75 ppm with NAA at 75 ppm which was statistically similar to GA3 at 0 ppm with NAA at 75 ppm and GA3 at 0 ppm with NAA at 50 ppm. The other number of flower clusters at different combinations of GA3 and NAA except the above-mentioned combinations were intermediate at 75 DAT.

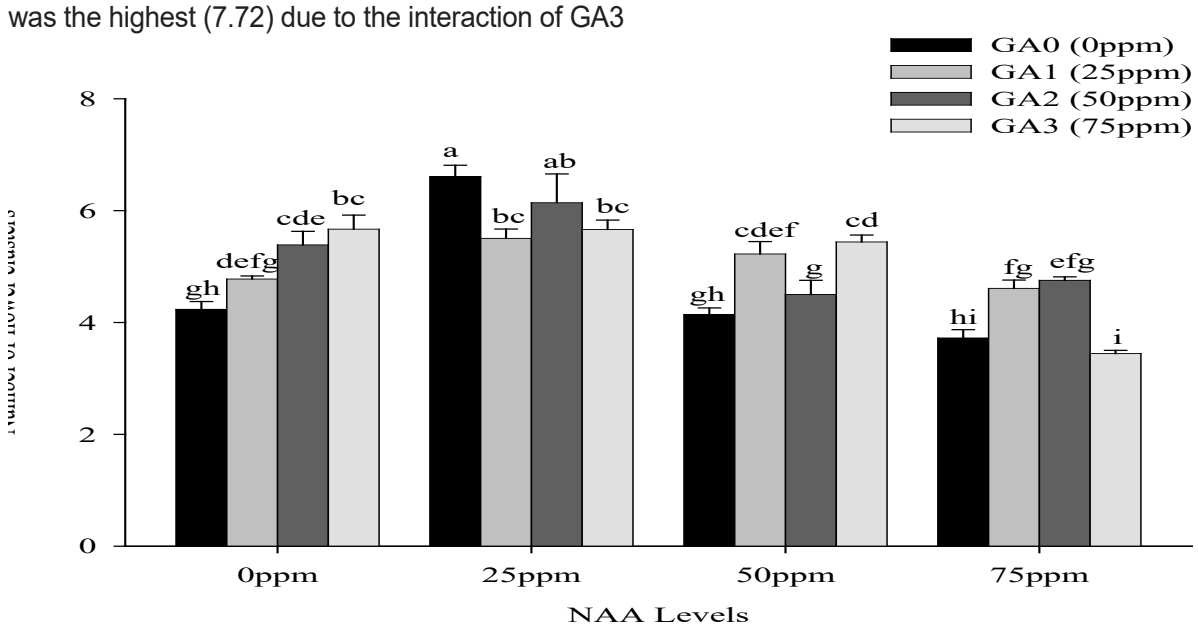

Figure 2 Flower clusters per plant of tomato at 60 DAT as influenced by the interaction of GA3 and NAA

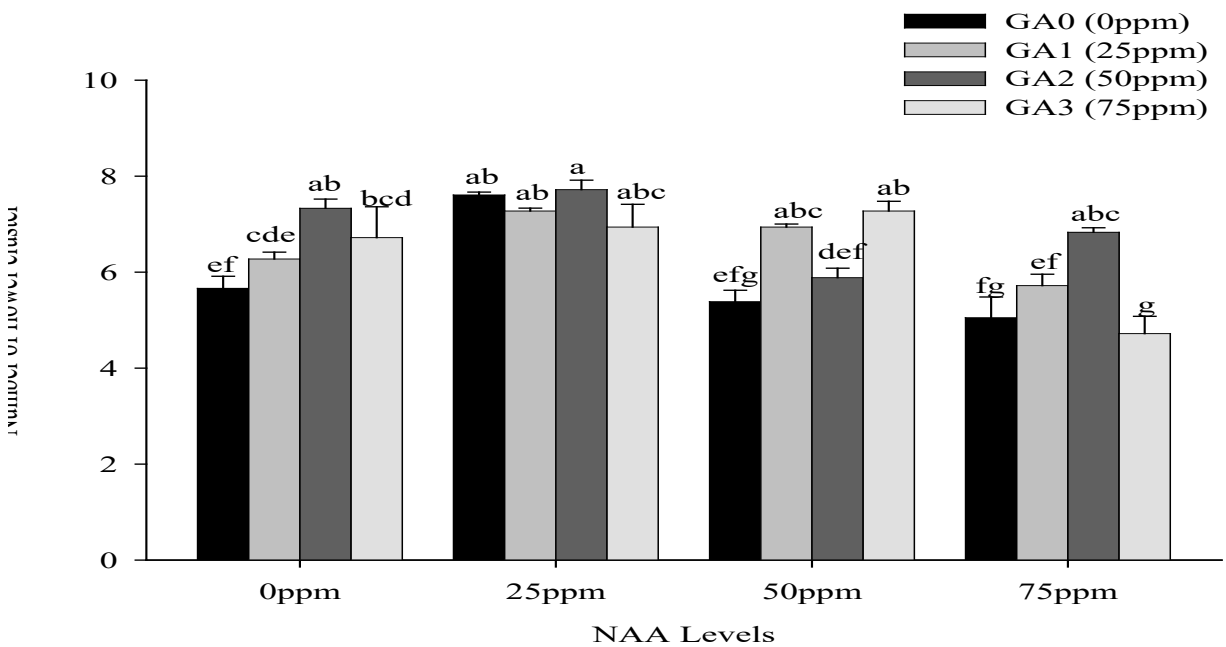

Figure 3 Flower clusters per plant of tomato at 75 DAT as influenced by the interaction of GA3 and NAA

The number of flowers per cluster was the highest (5.53) due to the interaction of GA3 at 50 ppm with NAA at 25 ppm at 60 DAT (Figure 4). This number of flowers per cluster was statistically similar among GA3 at 75 ppm with NAA at 25 ppm, GA3 at 0 ppm with NAA at 25 ppm. The number of flower per clusters was the lowest (2.69) due to the interaction between GA3 at 75 ppm with NAA 75 ppm. The other number of flowers per cluster at different combinations of GA3 and NAA except the above-mentioned combinations was intermediate.

The number of flowers per cluster was again the highest (6.41) due to the interaction of GA3 at 50 ppm with NAA at 25 ppm at 75 DAT (Figure 5) which was statistically similar among GA3 at 75 ppm with NAA at 25 ppm and GA3 at 0 ppm with NAA at 25 ppm. The number of flowers per cluster was the lowest (4.57) at control (i.e. GA 0 ppm and NAA 0 ppm). The other number of flowers per cluster at different combinations of GA and NAA except the above-mentioned combinations was intermediate.

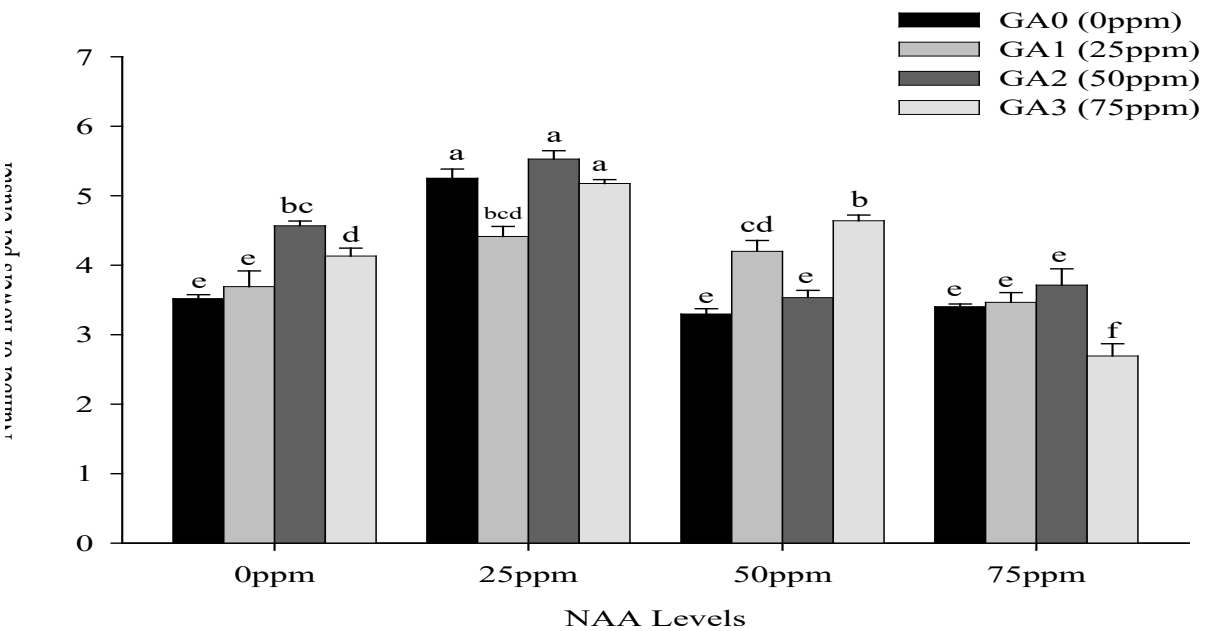

Figure 4 Flowers per cluster of tomato at 60 DAT as influenced by the interaction of GA3 and NAA

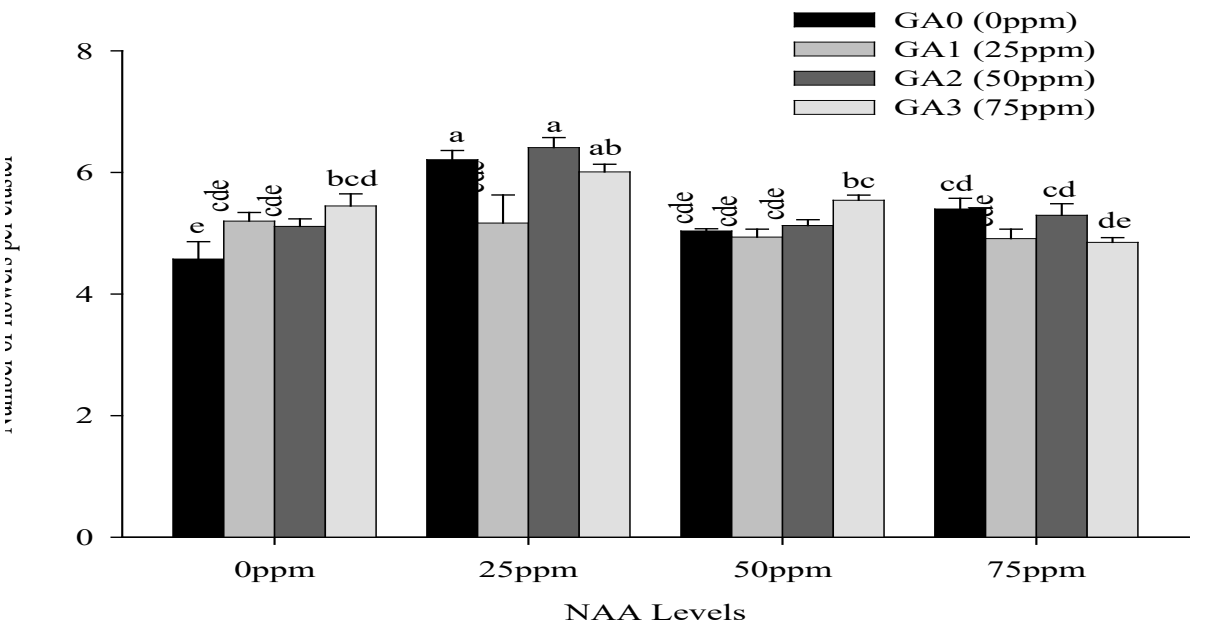

Figure 5 Flowers per cluster of tomato at 75 DAT as influenced by the interaction of GA3 and NAA

3.2 Yield attributes

3.2.1 Fruit number

The number of fruit per plant of tomato was significantly influenced by both hormones i.e. GA3 levels and NAA levels. The average fruit number was noted as 40.37/plant (Table 4).

The highest fruit number (43.47/plant) was obtained with GA3 at 50 ppm. The fruit number was the lowest (38.78) with GA3 at 0ppm which was statistically similar to GA3 at 25 ppm and GA3 at 75 ppm. Similarly, the fruit number of tomato was also influenced by NAA levels where the highest fruit number (45.09/plant) was obtained with NAA at 25 ppm. The lowest fruit number (36.06/plant) was recorded with NAA at 75ppm. The fruit number at other levels of NAA except the above-mentioned level was intermediate in range.

There was significant interaction of GA3 and NAA on the fruit number of tomato (Figure 6). The fruit number due to the interaction of GA3 and NAA levels ranged from 35.01/plant to 47.99/plant. The highest fruit number (47.99/plant) was obtained due to the interaction of GA3 at 50 ppm with NAA at 25 ppm. This fruit number was statistically similar among GA3 at 50 ppm with NAA at 0 ppm, GA3 at 50 ppm with NAA at 50 ppm, GA3 at 75 ppm with NAA at 25 ppm, GA3 at 0 ppm with NAA at 25 ppm. The lowest fruit numbers (35.01/plant) was recorded due to the interaction between GA3 at 75 ppm with NAA at 50 ppm. This fruit number was statistically similar among interaction of all levels of GA3 with NAA at 75 ppm, GA3 at 25 ppm with NAA at 50 ppm, GA3 at 0 ppm with NAA at 50 ppm and control (i.e. GA3 at 0 ppm with NAA at 0ppm). The fruit number due to the interaction of GA3 and NAA levels other than mentioned above was intermediate in range.

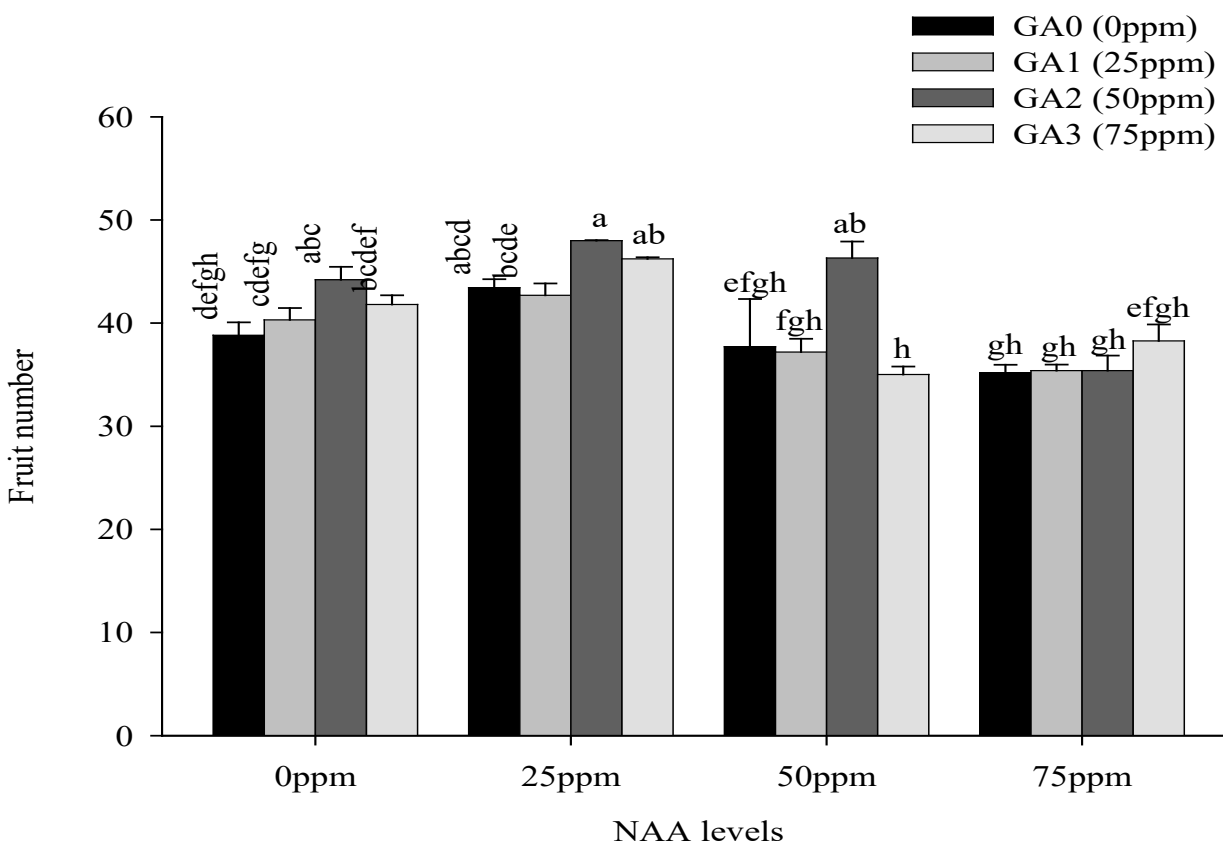

Figure 6 Fruit number per plant of tomato as influenced by the interaction of GA3 and NAA

3.2.2 Individual fruit weight

The fruit weight of tomato was significantly influenced by both hormones i.e. GA3 levels and NAA levels. The average fruit weight was 63.76g (Table 4).

The highest fruit weight (64.49 g) was obtained with GA3 at 25 ppm which was statistically similar to all higher levels of GA3. The lowest fruit weight (62.01 g) was recorded without GA3 application. Similarly, the fruit weight of tomato was also influenced by NAA levels where the maximum fruit weight (65.69 g) was recorded with NAA at 25 ppm which was statistically similar to NAA at 0 ppm. The minimum fruit weight (62.00 g) was recorded with NAA at 75 ppm which was statistically similar to NAA at 50ppm. The data revealed that average fruit weight decreased as the levels of NAA was increased.

There was significant interaction of GA3 and NAA on the individual fruit weight of tomato (Figure 7). The average fruit weight of tomato due to the interaction of GA3 and NAA levels ranged from 57.75 g to 69.57 g. The highest yield (69.57 g) was obtained due to the interaction of GA3 at 50 ppm with NAA at 25 ppm. This fruit weight was statistically similar among GA3 at 75 ppm with NAA at 25 ppm and GA3 at 75 ppm with NAA at 0 ppm. The lowest fruit weight (57.75 g) was obtained due to the interaction of GA3 at 75 ppm with NAA at 75 ppm which was statistically similar among GA3 at 50 ppm with NAA at 50 ppm, GA3 at 0 ppm with NAA at 50 ppm. The individual fruit weight due to the interaction between GA3 and NAA levels other than mentioned above was intermediate in range.

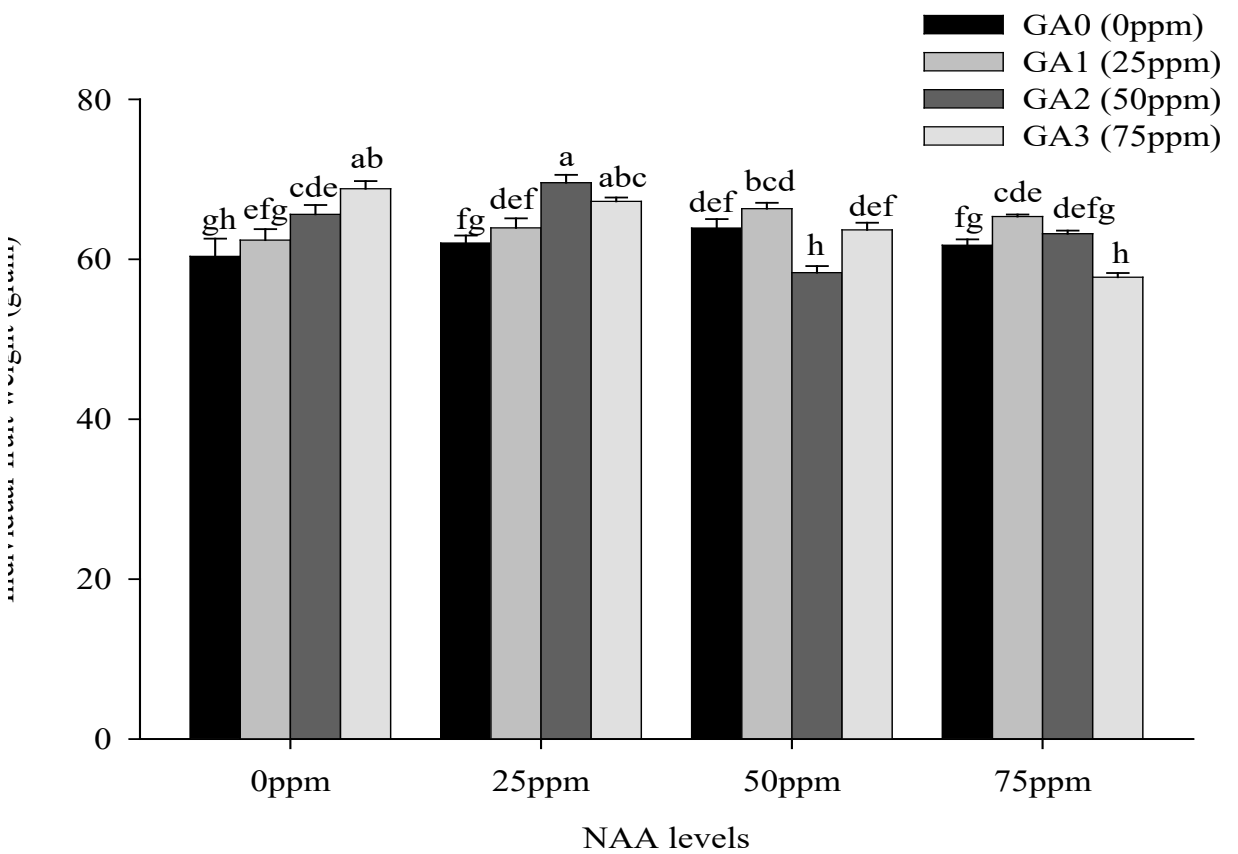

Figure 7 Individual fruit weight of tomato as influenced by the interaction of GA3 and NAA

3.2.3 Fruit yield (metric ton ha-1)

The fruit yield of tomato was significantly influenced by both hormones i.e. GA3 levels and NAA levels. The average fruit yield of tomato was 95.45metric ton ha-1 (Table 4).

The highest fruit yield (103.46 metric ton ha-1) was recorded with GA3 at 50 ppm. The lowest fruit yield (89.06 metric ton ha-1) was obtained without GA3 application which was statistically similar to GA3 at 25 ppm. The fruit yield at other levels of GA3 except the above-mentioned level was intermediate in range. Similarly, the fruit yield of tomato was also influenced by NAA levels where the highest fruit yield (109.91 metric ton ha-1) was obtained with NAA at 25 ppm. The lowest fruit yield (82.67 metric ton ha-1) was produced with NAA at 75ppm. The fruit yield at other levels of NAA except the above-mentioned level was intermediate in range.

There was significant interaction of GA3 and NAA on the yield of tomato (Figure 8). The yield due to the interaction of GA3 and NAA levels ranged from 80.50 metric ton ha-1 to 123.66 metric ton ha-1. The yield was the highest (123.66 metric ton ha-1) due to the interaction of GA3 at 50 ppm with NAA at 25 ppm. This yield was statistically similar among GA3 at 75 ppm with NAA at 0 ppm. The lowest yield (80.50 metric ton ha-1) was recorded due to the interaction of GA3 at 0 ppm with NAA at 75 ppm which was statistically similar among control (i.e. GA3 at 0 ppm with NAA at 0 ppm), GA3 at 0 ppm with NAA at 50 ppm and all levels of GA3 with NAA at 75 ppm. The fruit yield due to the interaction of GA3 and NAA levels other than mentioned above was intermediate in range.

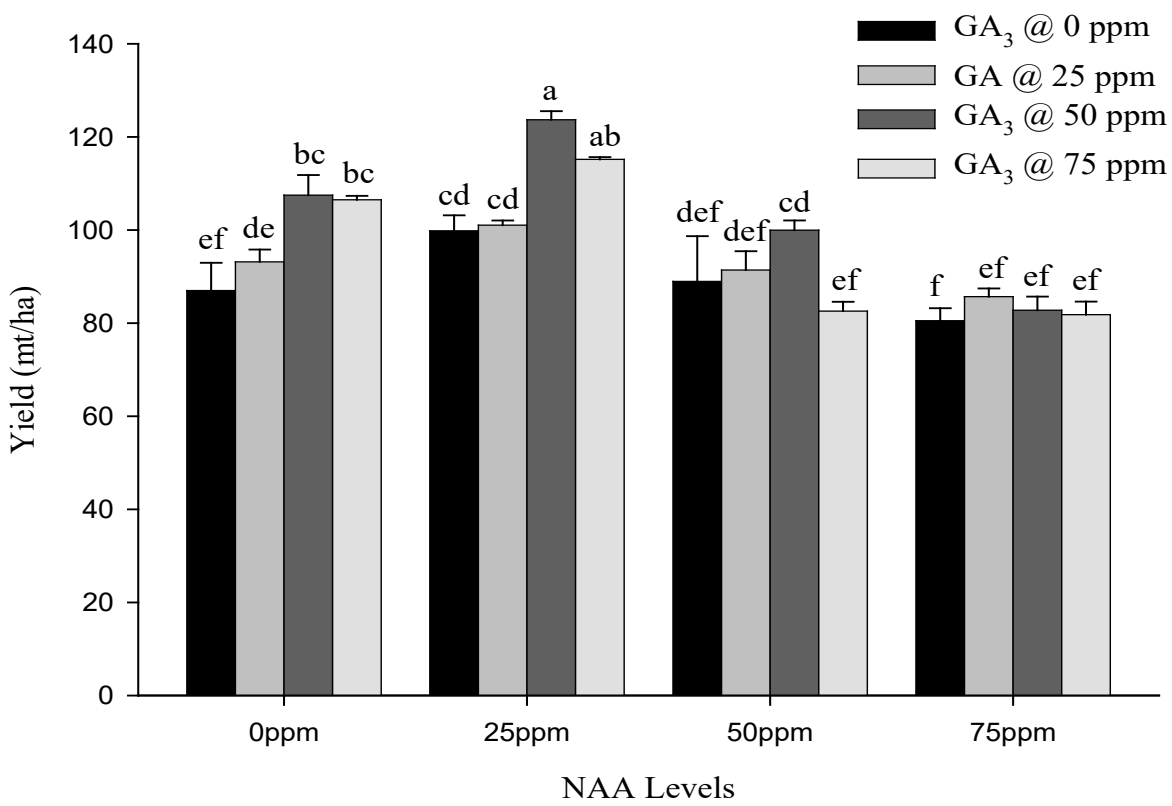

Figure 8 Fruit yield of the tomato plant as influenced by the interaction of GA3 and NAA

Table 4 Fruit number, individual fruit weight and yield of tomato plant as influenced by the GA3 and NAA				
Treatments	**Fruit number**	**Individual fruit weight (gram)**	**Yield (Kg/ plant)**	**Yield (metric ton ha-1)**
GA3 Levels				
0 ppm	38.78b	62.01b	2.40c	89.06c
25 ppm	38.90b	64.49a	2.51bc	92.79bc
50 ppm	43.47a	64.17a	2.79a	103.46a
75 ppm	40.33b	64.36a	2.61b	96.48b
LSD	2.26***	1.42**	0.147***	5.43***
NAA levels				
0ppm	41.28b	64.29ab	2.66b	98.51b
25ppm	45.09a	65.69a	2.97a	109.91a
50ppm	39.05b	63.05bc	2.45c	90.71c
75ppm	36.06c	62.00c	2.23d	82.67d
LSD	2.26***	1.42***	0.147***	5.43***
SEM(±)	0.78	0.49	0.05	1.87
CV (%)	6.71	2.68	6.82	6.82
Grand mean	40.37	63.76	2.58	95.45

Note: Mean separated by DMRT and columns represented with same letter (s) are non-significant at 5% level of significance; non-significant.

3.3 Response of GA3 and NAA

The influence of GA3 and NAA on the yield of tomato was significant and the polynomial regression equation was obtained. In statistics, polynomial regression is a form of linear regression in which the relationship between the independent variable x and the dependent variable y is modeled as an nth degree polynomial (Gomez & Gomez, 1984).

GA3 response equation, NAA response equation and physical maximum dose (PMD) of GA3 and NAA with their regression equation and fruit yield are shown in (Table 5).

Table 5 GA3 response equation, NAA response equation, physical maximum dose (PMD) of GA3 and NAA			
Treatments	**PMD ppm**	**Regression equation**	**Yield (metric ton ha-1) of PMD**
GA3	52.65	y = -0.0043x2 + 0.4528x + 87.833	99.75
NAA	20.29	y = -0.0078x2 + 0.3165x + 100.59	103.80

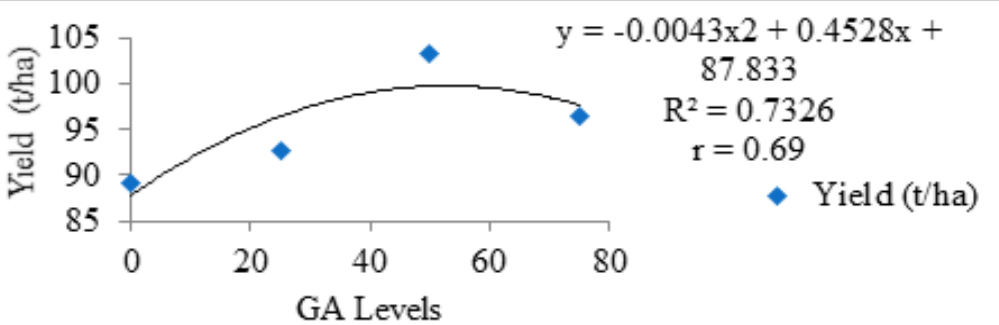

Figure 9 Relationship between levels of GA3 and yield of tomato

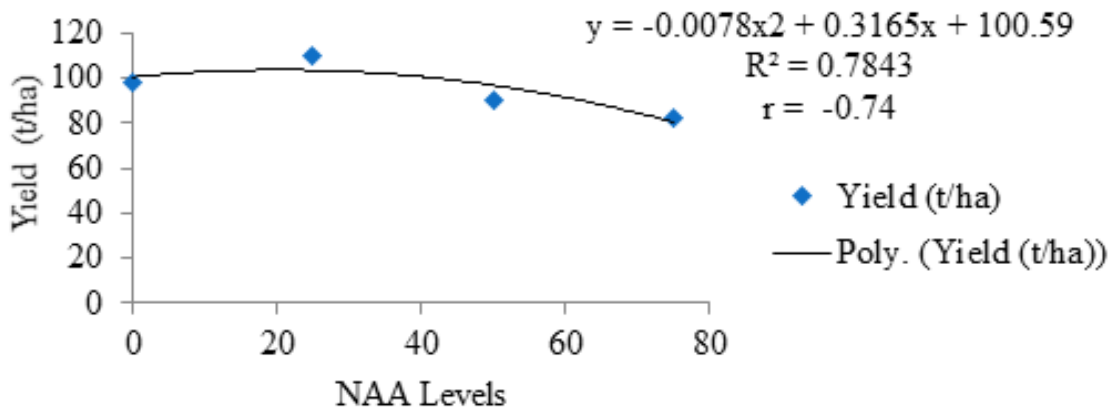

Figure 10 Relationship between levels of NAA and yield of tomato.

4 DISCUSSION

In the present investigation, GA3 at 0 to 50ppm shortened the days to 50% flowering. This result is in line with the findings of Bokade et al. (2006) in tomato and Dixit et al. (2001) in watermelon. Kuo (1991) also reported that the potential uses of gibberellin affect flowering. This might be due to the rapid increase in respiration, photosynthesis and transpiration. Due to the rapid increase in the physiological process, there may be a greater accumulation of carbohydrate, owing to greater photosynthesis which caused early flowering (Coulombe & Rogers, 1959). On further increasing the concentration of GA3 beyond 50 ppm, there was delayed 50 % flowering which might be due to unwanted vegetative growth at the higher concentration of GA3. The results explain that earliness due to a positive influence on the physiological activity of plants. Furthermore, the present study showed that the maximum number of flower clusters, flowers per cluster as well as flowers per plant at 50 ppm which was more or less statistically similar with GA3 at 75 ppm. This result is in line with the finding of Kuo (1991). This might be due to an increase in respiration and photosynthesis and better vegetative growth which hastens the flowering. Flower primodia were promoted by GA3 which resulted in a higher number of flowers per cluster as well as flowers per plant. The result is also in harmony with the finding reported by Auerswald (1991).

In the case of NAA, NAA at 25 ppm resulted in earliest days to 50 % flowering as compared to other levels of NAA. This might be due to the increased synthesis of cytokinin and auxin in the root tissue by their enhanced activity due to the application of NAA. Their simultaneous transport to the axillary buds would have resulted in a better sink for the mobilization of photo-assimilates at a faster rate. This has helped in the early transformation from the vegetative phase to the reproductive phase. This result is in line with the finding of Jayram (2015) who reported that NAA at 25 ppm had resulted in early flowering. The higher levels of NAA delayed flowering. This might be due to some malformations in tomato which is supported by the idea that intensity of leaf curling, reduced stem growth and increased flower bud abscission were greater at especially high concentration of NAA spray compared to GA3. NAA at 25 ppm resulted in the higher number of flower clusters, flowers per cluster as well as flowers per plant as compared to other levels of NAA. Higher concentration showed less percentage of flower clusters as well as flower numbers as it induces ethylene biosynthesis that causes the reduction in polar auxin transport resulting in the formation of the abscission layer. The antagonistic effect of NAA at the higher concentration on the number of flower has also been reported by Singh and Rai (2011).

In the case of interaction of GA3 and NAA, NAA at 25 ppm without any GA3 application or in combination with GA3 at 50 ppm was more effective in terms of days to 50 % flowering as compared with the combination of all different levels of GA3 and NAA except the above-mentioned combination. This result is in line with the finding of Saha et al. (2009). NAA at 25 ppm in combination with GA3 at 50 ppm was more effective in terms of phenological parameters (i.e. flower clusters per plant, flowers per cluster and flowers per plant) as compared with the combination of higher levels of NAA with any levels of GA3. This might be due to proper regulation of the physiological and biochemical process at this combination in plants in such a way which tended to reduce the vegetative growth and the photosynthates transmitted from vegetative parts towards the reproductive organ.

In the case of yield parameters, the average fruit weight of tomato revealed statistically significant variation due to the application of GA3. Application of GA3 at 25 ppm at vegetative stage increased fruit size with an increase in polar and equatorial diameter of fruit which ultimately increased individual fruit weight. The result is in harmony with the finding of Kaushik et al. (1974). Furthermore, GA3 at 50 ppm lead to higher fruit number and yield as compared to other GA3 levels. This might be due to the better vegetative growth and increased rate of photosynthesis (Alvin, 1960). A similar trend in the result was also revealed by Adlakha and Verma (1965).

In the case of NAA, NAA at 25 ppm resulted in higher average fruit weight, fruit number and yield as compared to other levels of NAA. This might be due to the building up of suitable carbohydrate reserves in the plant. There is considerable evidence that the lower concentration of auxin primarily in a catalytic or regulatory capacity in some phase of carbohydrate metabolism in plant. The findings of the current experiment contradict with the findings reported by Prasad, Singh et al. (2013) where NAA at 100ppm enhanced the productivity of tomato. The possible reason for the decline in yield beyond NAA at 25 ppm in this experiment is due to decreased leaf size, induced epinastic and intensity of leaf curling which lead to the lower number of fruits per plant, average fruit weight and fruit yield per plant. Furthermore, higher concentration showed fewer fruit numbers as it induces the formation of abscission layer resulting in the antagonistic effect of NAA at the higher concentration on the number of fruits as reported by Rao (2011).

In the case of interaction of GA3 and NAA, lower levels of NAA up to 25 ppm in combination with higher levels of GA3 were more effective in terms of yield. This might be due to the growth of treated plant remain physiologically more active to build up sufficient food reserve for the developing fruits. Greater number of fruit ultimately leads to higher yield as witnessed in the present experiment. This result is in line with the findings of Saha et al. (2009). Lesser fruit yield in the combination of higher levels of GA3 and NAA may be due to the lesser vegetative growth which proved to be toxic for reproductive development.v

CONCLUSION

Regression analysis on the effect of GA3 and NAA levels on yield of tomato showed polynomial regression equation, while the physical doses of GA3 and NAA were 52.65 ppm and 20.29 ppm respectively. Hence, it can be concluded that the productivity of tomato cv. Srijana could be improved by the combined application of GA3 at 50 ppm and NAA at 25 ppm under the protected condition of Pokhara, Kaski, Nepal.

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