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Effect of NAA and GA_3 on quality and fruit yield of Tomato (*Solanum lycopersicum* Mill.)

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Abstract
The field experiment was carried to check effect of NAA and GA_3 on quality and fruit yield of tomato (*Solanum lycopersicum* Mill.) during the agricultural year 2023-24 at the Research Farm, Department of Horticulture, Suresh Gyan Vihar University, Jaipur (Rajasthan). The experimental design used was a factorial randomized block design (FRBD) consisting of 16 treatment combinations. These treatments involved four different levels of NAA (0, 10, 15 and 20 ppm) and four levels of GA_3 (0, 30, 60 and 90 ppm), each replicated three times. The key parameters observed during the study included fruit yield and quality parameters such as ascorbic acid content, reducing and non-reducing sugars. The results clearly demonstrated that the combination of NAA at 20 ppm and GA_3 at 90 ppm (N_3G_3) was significantly superior in enhancing all the studied parameters. The fruit yield per hectare also reached its peak at 99.62 tons, significantly higher than the control and other treatments. Furthermore, the fruit quality parameters were also notably improved, with this treatment yielding fruits with the highest total soluble solids (6.45°B), ascorbic acid content (35.48 mg/ 100 g), reducing sugar content (3.35%) and non-reducing sugar content (3.63%). In contrast, lower levels of NAA and GA_3 or their absence led to comparatively lower yield. In conclusion, the study establishes that the combined application of NAA at 20 ppm and GA_3 at 90 ppm maximizes the fruit yield and quality of tomato. This combination also proves to be the most economically viable, ensuring optimal returns for growers under the agro-climatic conditions of Jaipur, Rajasthan.

Keywords: GA_3, fruit yield, NAA and quality

Introduction
Tomato (*Solanum lycopersicum* L.) (2n=2x=24) is one of the most important solanaceous vegetable crop cultivated across the world due to higher adaptability, yield and suitability for variety of uses in fresh as well as processed food industries. The crop is native to Central and South America (Vavilov 1951) [1], It is popularly known as 'Love Apple', which is grown under kitchen garden (Dhyani *et al*. 2018) [2]. Tomato is regarded as nutritional vegetable crop and good source of Vitamin A (1000 IU), Vitamin C_{22} mg), minerals like potassium, iron, calcium, soluble and insoluble dietary fibers, organic acids (malic and citric acid) and serve as a cheapest source to meet daily nutritional requirements (Gupta *et al*. 2019) [3]. Lycopene, phenolics and ascorbic acid is the predominant antioxidant present in tomato fruits that reduces the risk of prostate cancer (Rai *et al*. 2012) [4]. According to Dhillon *et al*. (2019) [5], abiotic factors such as rainfall, temperature, relative humidity, and light intensity, as well as crop factors like flower and fruit drop, all have an impact on the growth, yield, and quality of tomato crops. It has been reported that under unfavourable climatic circumstances, plant growth regulators are crucial. Chemical substances with low concentrations that stimulate and control the physiological functions of plants are known as plant growth regulators (Siwna *et al*. 2018) [6]. Several growth regulators are used extensively worldwide, including 2, 4-D, 4-CPA, naphthalene acetic acid (NAA), and gibberellic acid (GA). PGRs have an impact on fruit set, size, growth, yield, and quality in both high and low temperatures. In order to improve growth and yield, the use of plant growth regulators also helps to increase tomato and other vegetable production (Saha, 2009) [7].
In horticultural crops, NAA is frequently used. It aids in the stimulation of several physiological

processes in plants, such as water absorption, photosynthesis, RNA synthesis, cell division, and shoot elongation. According to Razzak *et al*. (2011) [8], it increases yield by preventing pre-harvest fruit drop, increasing fruit set, flower induction, leaf chlorophyll content, delayed senescence, and bud sprouting. In addition, it influences physiological functions, speeds up fruit maturity, yields higher-quality fruits, and increases branch count, fresh weight, and yield, among other things (Pramanik *et al*. 2018) [9]. There are many different plant growth regulators on the market, but the concentrations of these regulators can differ depending on the crop, the season, and the climate. In order to improve tomato yield and quality parameters under protected conditions, it is necessary to determine the most appropriate plant growth regulators and their concentration. It is crucial to find potential ways to boost production in response to the world's growing population, keeping in mind the limitations of the tomato crop and the significance of a change in humankind's attitude towards increased crop production worldwide. Thus, the purpose of the current study was to determine how various plant growth regulators at varying concentrations affected tomato yield and quality attributes.

Martials and Methods

There are 15 treatments combinations were laid out in Factorial Randomized Block Design and Treatments details of experiment are presented under following heads.

Table 1: Treatment combination details

S. No.	Treatments	Symbol
1	Control	T_0
2	NAA @ 10 PPM	T_1
3	NAA @ 15 PPM	T_2
4	NAA @ 20 PPM	T_3
5	GA3 @ 30 PPM	T_4
6	GA3 @ 60 PPM	T_5
7	GA3 @ 90 PPM	T_6
8	NAA @ 10 ppm + GA3 @ 30 ppm	T_7
9	NAA @10 ppm + GA3 @ 60 ppm	T_8
10	NAA @ 10 ppm + GA3 @ 90 ppm	T_9
11	NAA @ 15 ppm + GA3 @ 30 ppm	T_{10}
12	NAA @ 15 ppm + GA3 @ 60 ppm	T_{11}
13	NAA @ 15 ppm + GA3 @ 90 ppm	T_{12}
14	NAA @ 20 ppm + GA3 @ 30 ppm	T_{13}
15	NAA @ 20 ppm + GA3 @ 60 ppm	T_{14}
16	NAA @ 20 ppm + GA3 @ 90 ppm	T_{15}

Manures and fertilizers application

Before the transplanting of plants, Farm yard manure at amount of 25 tons per hectare, applied in the plots as per their respective treatment at the time of land preparation. Nitrogen, phosphorus and potassium were applied to the respective treatment in the form of urea, single super phosphate and murate of potash, appropriately at amount of 100:50:50 kg NPK per hectare as per the recommendation. At the time of seedlings transplanting, half dose of nitrogen and full dose of phosphorus and potassium were applied as basal dose and mixed thoroughly in the soil to the respective treatment. The remaining half dose of nitrogen was top dressed, 45 days after transplanting. Transplanting: Transplanting was done on 12th August 2023, as 30 days old healthy seedlings were transplanted at the spacing of 45 cm X 70 cm, in the experiment.

Statistical analysis

The recorded data on various parameters were statistically analyzed using OPSTAT. The mean for all the treatments was calculated and analysis of variance for all the characters was performed by Gomez and Gomez (1984) [10] using Factorial RBD. The calculated F values were compared with the tabulated F- values at 5% level of significance. When the calculated F-values were higher than the tabulated, it was considered to be significant.

Results and Discussion

Quality traits: The different levels of NAA and GA_3 application significantly influenced the reducing sugars during investigation. The application of N_3 treatment shows significantly maximum reducing sugars (2.82%) followed by N_2 treatment (2.63%) and minimum was recorded with N_0-Control (2.20%). In case of GA_3, highest reducing sugars recorded with treatment G_3 (2.84%) followed by G_2 (2.67%) and minimum was recorded with the application of G_0-Control (2.15%) (Table 2 and Fig.1). The levels of NAA showed that the application of N_3 treatment shows significantly maximum non reducing sugars (3.03%) followed by N_2 (2.76%) and minimum non- reducing sugars (2.41%) was observed with N_0-Control. With respect to GA_3 treatments, maximum non reducing sugars was recorded in treatment G_3 (3.04%) followed by G_2 treatment (2.83%) and minimum (2.32%) was observed with the G_0-Control. Comparison among the levels of NAA showed that the application of N_3 treatment shows maximum ascorbic acid (30.44 mg/100g) followed by N_2 (28.233 mg/100 g) and minimum (24.66 mg/100 g) with the N_0-Control. With respect to GA_3 application, higher ascorbic acid was recorded with treatment G_3 (30.47 mg/100 g) followed by G_2 treatment (28.80 mg/100g) and lowest (24.06 mg/100 g) with the G_0-Control. It is evident from the data (Table 2) that the plant growth regulators had significant influence on total soluble solids, ascorbic acid, reducing and non-reducing sugars percent. The highest TSS, ascorbic acid content, reducing sugars and non-reducing sugars were recorded by the application of treatment N_3G_3- NAA @ 20 ppm + GA_3 @ 90 ppm. The significant influence of quality characters like TSS, ascorbic acid, reducing sugars and non-reducing sugars, could partially be explained by less dense canopy cover of crops under limited nitrogen rates, which resulted in increased light transmittance and exposure of tomato to solar radiation, thus affecting the biosynthetic rate of sugars and accumulation of lycopene content in fruits. GA_3 influences several quality attributes, such as color, firmness, and sweetness. It can delay the degradation of chlorophyll, which helps maintain the green colour of certain fruits, and it also enhances the synthesis of sugars, leading to improved sweetness (Tuteja *et al.*, 2010) [11]. These results are in agreement with those of Prasad *et al.* (2013) [12] and Kumar *et al.* (2023) [13] in tomato.

Fruit yield: Data regarding the fruit yield per plant are presented in Table 3 and depicted in Fig. 2. Comparison among the levels of NAA showed that the application of N_3-NAA @ 20 PPM treatment shows significantly maximum fruit yield per plant (2.47 kg) and it was followed with N_2-NAA @ 15 PPM treatment (2.03 kg). However, minimum fruit yield per plant (1.57 kg) was recorded with the application of N_0- Control. With respect to GA_3 application, significantly maximum fruit yield per plant was recorded with the application of treatment G_3-GA_3 @ 90 PPM (2.47 kg), while, G_3-GA_3 @ 90 PPM treatment followed with G_2-GA_3 @ 60 PPM treatment (2.24 kg). However, minimum fruit yield per plant (1.35 kg) was observed with the application of G_0- Control. The effect of interaction between NAA and GA_3 application were showed significant on fruit yield per plant and data are presented in Table 2. Whereas, the application of N_3G_3-NAA @ 20 PPM+GA_3 @ 90 PPM showed the maximum fruit yield per plant (3.36 kg), whereas it was found at par with N_3G_2-NAA @ 20 PPM+GA_3 @ 60 PPM (2.96

kg). However, the minimum fruit yield per plant (1.18 kg) was recorded with the application of N_0G_0-Control.

Yield can be considered to be the final expression of the physiological and metabolic activities of plants and is governed by the various factors like favorable physical, chemical and biological properties of soil as well as effective plant growth promoters making morpho-physiological and biochemical changes in the plants (Rajashree, 2022) [14]. The significant variations in yield attributes due to treatments having applied PGR's might be change the metabolic process in the plant. Similar findings have been reported by Khaled *et al.* (2015) [15], Gurjar *et al.* (2018) [16], Singh *et al.* (2019) [17], Kumar *et al.* (2023) [13] in tomato.

Table 2: Interaction effects between NAA and GA_3 on quality attributes of tomato cv. Abhilash

Total Soluble Solids (°B)					
Treatments	**NAA**				
GA_3	**N_0**	**N_1**	**N_2**	**N_3**	**Mean**
G_0	4.17	5.15	5.24	5.30	4.96
G_1	5.26	5.37	5.40	5.49	5.38
G_2	5.32	5.44	5.70	6.18	5.66
G_3	5.35	5.53	5.77	6.45	5.77
Mean	5.02	5.37	5.53	5.86	
S.Em. ±	0.15				
C.D. at 5%	0.45				
Reducing sugar (%)					
Treatments	**NAA**				
GA_3	**N_0**	**N_1**	**N_2**	**N_3**	**Mean**
G_0	1.78	2.23	2.27	2.30	2.15
G_1	2.28	2.44	2.51	2.59	2.46
G_2	2.34	2.54	2.74	3.05	2.67
G_3	2.39	2.61	3.00	3.35	2.84
Mean	2.20	2.46	2.63	2.82	
S.Em. ±	0.09				
C.D. at 5%	0.26				
Non reducing sugar (%)					
Treatments	**NAA**				
GA_3	**N_0**	**N_1**	**N_2**	**N_3**	**Mean**
G_0	2.01	2.37	2.42	2.50	2.32
G_1	2.45	2.64	2.66	2.75	2.62
G_2	2.56	2.68	2.84	3.24	2.83
G_3	2.63	2.79	3.11	3.63	3.04
Mean	2.41	2.62	2.76	3.03	
S.Em. ±	0.10				
C.D. at 5%	0.30				
Ascorbic Acid (mg /100 g)					
Treatments	**NAA**				
GA_3	**N_0**	**N_1**	**N_2**	**N_3**	**Mean**
G_0	20.87	24.78	25.01	25.59	24.06
G_1	25.33	26.73	26.98	27.46	26.63
G_2	25.98	27.23	28.76	33.23	28.80
G_3	26.46	27.74	32.19	35.48	30.47
Mean	24.66	26.62	28.23	30.44	
S.Em. ±	0.97				
C.D. at 5%	2.80				

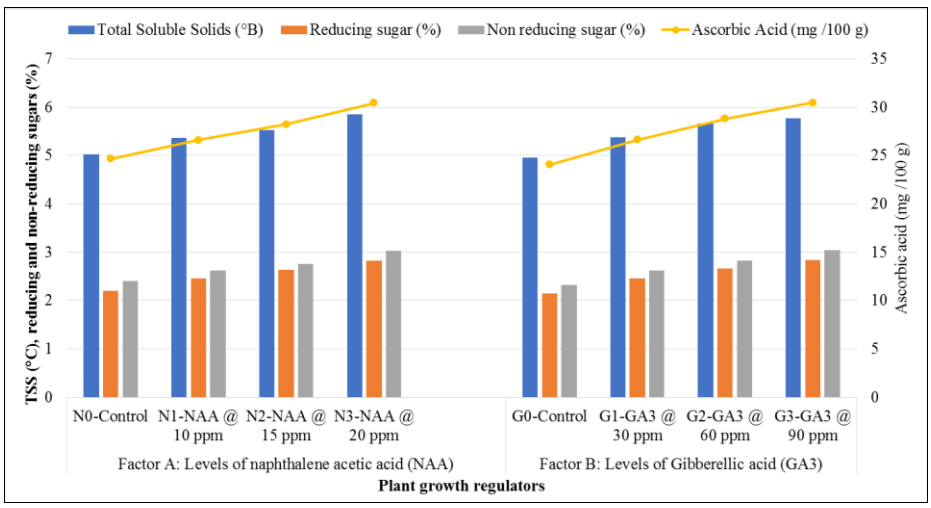

Fig 1: Effect of plant growth regulators on quality attributes of tomato cv. Abhilas

Table 3: Interaction effects between NAA and GA_3 on fruit yield of tomato cv. Abhilash

Fruit yield per plant (kg)					
Treatments	**NAA**				
GA_3	**N_0**	**N_1**	**N_2**	**N_3**	**Mean**
G_0	1.18	1.31	1.39	1.50	1.35
G_1	1.48	1.89	1.92	2.04	1.83
G_2	1.73	1.97	2.32	2.96	2.24
G_3	1.90	2.16	2.48	3.36	2.47
Mean	1.57	1.83	2.03	2.47	
S.Em. ±	0.11				
C.D. at 5%	0.31				
Fruit yield per plot (kg)					
GA_3	**N_0**	**N_1**	**N_2**	**N_3**	**Mean**
G_0	28.27	31.52	33.41	36.00	32.30
G_1	35.53	45.38	46.06	49.06	44.01
G_2	41.54	47.17	55.58	71.07	53.84
G_3	45.64	51.73	59.54	80.67	59.39
Mean	37.74	43.95	48.65	59.20	
S.Em. ±	2.55				
C.D. at 5%	7.37				
Fruit yield per hectare (t)					
GA_3	**N_0**	**N_1**	**N_2**	**N_3**	**Mean**
G_0	34.91	38.93	41.26	44.46	39.89
G_1	43.88	56.05	56.88	60.59	54.35
G_2	51.30	58.25	68.64	87.77	66.49
G_3	56.36	63.89	73.53	99.62	73.35
Mean	46.61	54.28	60.08	73.11	
S.Em. ±	3.15				
C.D. at 5%	9.11				

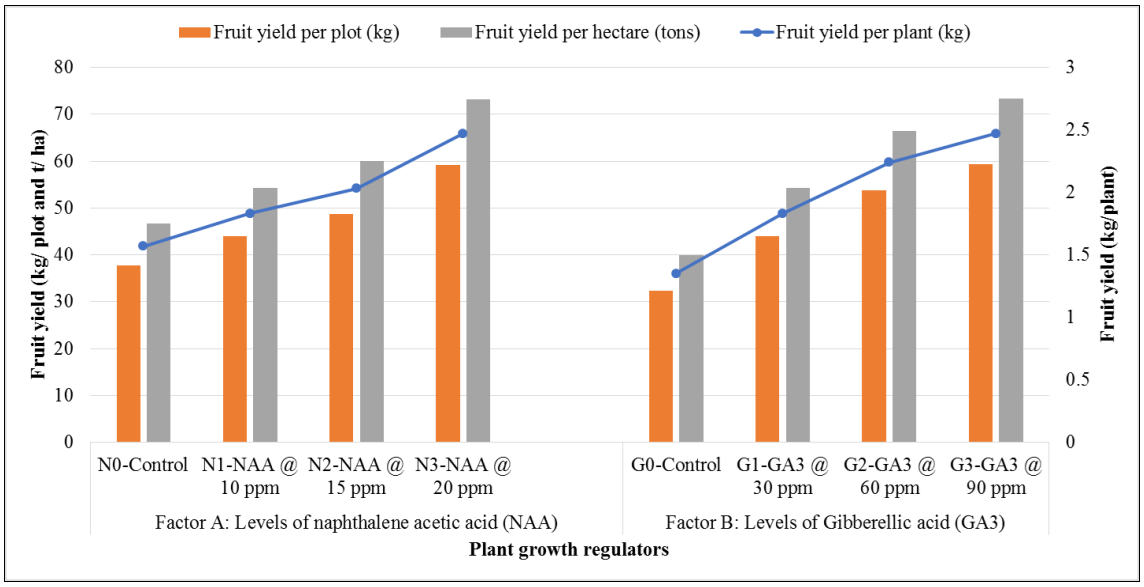

Fig 2: Effect of plant growth regulators on fruit yield of tomato cv. Abhilash

Conclusion

combined application of NAA at 20 ppm (N_3) and GA_3 at 90 ppm (G_3) showed superior results across total soluble solids, reducing sugar, non-reducing sugar and fruit yield indicating their potential for enhancing tomato production under experimental conditions at Suresh Gyan Vihar University, Jaipur. These findings provide valuable insights for optimizing tomato cultivation practices aimed at maximizing both productivity and profitability.

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