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Salicylic acid and NAA mitigate the adverse effect of high temperature stress on growth and yield of tomato (*Solanum lycopersicum* L.)

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ABSTRACT

The aim of this study was to evaluate the effect of salicylic acid and NAA application on pre flowering initiation. Salicylic acid (SA) and Auxin (NAA) are the growth regulator that modified plant growth and development by inducing changes in cell processes, physiology and morphology. An investigation "Salicylic acid (SA) and NAA induced thermo-tolerance responses on physiology, growth and productivity in tomato (*Solanum lycopersicum* L.) under changing environment" was conducted at Horticulture Complex, Department of Horticulture, College of Agriculture JNKVV, Jabalpur (M.P.) during pooled data over both 2019-20 & 2020-21 years. The experiment consists of thirty-six treatments comprising plant growth regulators was laid out in randomized complete block design having three replications. There were two plant growth regulators Salicylic acid (0ppm, 50ppm, 75ppm and 100ppm) and NAA (0pmm, 25ppm and 50ppm) were use with different combinations. The experiment consisted of three dates of sowing on 30th November (D1: Normal transplanting), 30th December (D2: Late transplanting) and 30th January (D3: Very late transplanting). Salicylic acid and NAA were sprayed at pre-flowering stages. Under this experiment determine the effect of high temperature, SA and NAA on various morphology, growth and yield parameters like plant height (cm) at 45, 60 and 90 DAT, number of leaves per plant at 45 and 60 DAT, number of branches per plant at 45, days to flower initiation, days to 50% flowering, days to first harvest, leaf area index at 45 and 60 DAT, leaf area duration (cm2 days), specific leaf area (cm^2 g^{-1}) at 45 and 60 DAT, Yield per plant (kg) and Yield (q/ha) these parameters were recorded at fruiting stages and yield parameters after harvesting . May be improved that the recorded by treatment combinations of SA (50ppm) + NAA (50ppm) T5 (D1S2N1) under normal, late and very late sown conditions. SA and NAA spray treatment mitigates the effect of high temperature on yield and yield attributes traits in tomato with a better result in yield. The findings of this study will not only help in getting economical yield under high-temperature conditions but will also play its role in ensuring food security under a global warming scenario.

Keywords: Heat stress, SA, NAA and morphological, growth and yield parameters, tomato

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INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is widely grown all over the world for fresh markets as well as for the processing industry. It is universally treated as "Protective food" and a good source of minerals, antioxidants, vitamin A & C. It is a very good appetizer and is a good remedy for patients suffering from constipation. It is a very good source of income for small and marginal farmers and contributes to the nutrition of the consumers. Tomato is mostly grown in India it is grown in an area of 814 thousand ha. the area with the production of 20515 thousand MT and productivity is 25.2 MT per ha [3]. High temperature can induce substantial oxidative damage due to the production of reactive oxygen species like superoxide and hydrogen peroxide [16, 18]. Resistance to heat stress involves various complex tolerance and avoidance mechanisms, the membrane is thought to be a site of primary physiological injury by heat [21].

The effect of different planting dates on growth, flowering and fruit yield of tomato during November 2013 to April 2014. Three transplanting were done at an interval of 10 days. The different transplanting dates were; December 10, December 20 and December 30. The experimental results showed that different planting dates showed significant influence on growth and reproductive characters of tomato including fruit yield. The first transplanting date, December 10th resulted in improvement of all the attributes including increased plant height (70.22 cm at 60 DAT), leaf number (62.3), branch number (9.07), cluster number (17.43), number of flowers plant-1 (148.7), fruit number (86.38), number of fruit plant-1 (86.08), fruit diameter (5.51 cm), fruit length (6.29 cm) and yield per hectare (66.46 t) compared to 2nd transplanting date, December 20 and 3rd transplanting date, December 30. Therefore, it is suggesting that earlier transplanting produced higher fruit yield of tomato [2].

Salicylic acid has recently been recognized as a plant hormone [9]. Salicylic acid belongs to a group of chemicals known as phenolics and is considered as a plant "Aspirin" in acetylated form. Salicylic acid plays diverse physiological roles in plants including thermo-genesis, flower induction, nutrient uptake, ethylene biosynthesis, stomata movement, photosynthesis and enzyme activities [9]. Exogenous application of Salicylic acid or its synthetic functional analogs results in the activation of gene expression and enhanced resistance to pathogens [25, 6]. Further evidence comes from the analysis of plants in which endogenous Salicylic acid levels are altered.

Studies the ten treatments comprised following levels of NAA 50ppm, 100ppm, 10ppm, 25ppm, 150ppm and GA3 concentrations *viz.*10ppm, 25ppm, 50ppm, 100ppm and control. Among all the treatments it was concluded that for growth as well as yield attributes, NAA @50 ppm gave maximum plant height (34.6 cm), number of branches (51.6), number of leaves (56.3), days to 50% flowering (46.10), flowers per plant (3.6) and fruits per plant (51.6), fruit yield per plant (400 g), yield per plot (10.56 kg), yield per hectare (146.10 q), fruit length (17.6 cm) and fruit breadth (3.9 cm). From this experiment, it was concluded that 50 ppm of NAA can be recommended in chilli for its better growth and yield [20].

MATERIAL AND METHODS

The experiment was conducted at the Horticulture complex, Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) during Rabi season over both 2019-20 & 2020-21 years. The Jabalpur has situated in the "Kymore Plateau and Satpura Hills" agro-climatic region of Madhya Pradesh. It falls on 23.9° North latitude and 79.58° East longitudes with an altitude of 411.8 meters above sea level. The climate is semi-arid and subtropical, with hot summer and moderately cool winter. with a relative humidity of 80-90%, temperature low to high (6.3°C to 40.1°C) having annual rainfall varies from 1200-1500 mm, with an average of 1350 mm and R.H of 80-90%%. The soil of the experimental plot was categorized as have medium to deep depth and black colour with sandy clay-loam texture with neutral soil reaction and well-drained. The soil of the experimental field was medium black and good a drainage uniform texture. The experiment was laid out in Randomized Complete Block Design (RCBD- Asymmetrical factorial) with three replications. The field experiment consisted of 36 treatments involving the combination of Salicylic acid and NAA. There were two plant growth regulators Salicylic acid (0ppm, 50ppm, 75ppm and 100ppm) and NAA (0pmm, 25ppm and 50ppm) were use with different combinations as a foliar spray at pre-flowering. The experiment consisted of three dates of sowing at 30th November, 30th December and 30th January with the spacing of 60 cm × 50 cm and NPK @120:50:50 kg per ha was applied as per recommended dose. The recorded physiological parameters were plant height (cm) at 45, 60 and 90 DAT, number of leaves per plant at 45 and 60 DAT, number of branches per plant at 45, days to flower initiation, days to 50% flowering, days to first harvest, leaf area index at 45 and 60 DAT, leaf area duration (cm^2 days), specific leaf area (cm^2 g^{-1}) at 45 and 60 DAT, Yield per plant (kg) and Yield (q/ha).

Table 1: Details of treatment

Treatment combinations	Treatment details	Treatment combinations	Treatment details
D1T1 Control	Without application	D1T7	75 ppm SA + 0 ppm NAA
D1T2	0 ppm SA + 25 ppm NAA	D1T8	75 ppm SA + 25 ppm NAA
D1T3	0 ppm SA + 50 ppm NAA	D1T9	75 ppm SA + 50 ppm NAA
D1T4	50 ppm SA + 0 ppm NAA	D1T10	100 ppm SA + 0 ppm NAA
D1T5	50 ppm SA + 25 ppm NAA	D1T11	100 ppm SA + 25 ppm NAA
D1T6	50 ppm SA + 50 ppm NAA	D1T12	100 ppm SA + 50 ppm NAA
D2T1 Control	Without application	D2T7	75 ppm SA + 0 ppm NAA
D2T2	0 ppm SA + 25 ppm NAA	D2T8	75 ppm SA + 25 ppm NAA
D2T3	0 ppm SA + 50 ppm NAA	D2T9	75 ppm SA + 50 ppm NAA
D2T4	50 ppm SA + 0 ppm NAA	D2T10	100 ppm SA + 0 ppm NAA
D2T5	50 ppm SA + 25 ppm NAA	D2T11	100 ppm SA + 25 ppm NAA
D2T6	50 ppm SA + 50 ppm NAA	D2T12	100 ppm SA + 50 ppm NAA
D3T1 Control	Without application	D3T7	75 ppm SA + 0 ppm NAA
D3T2	0 ppm SA + 25 ppm NAA	D3T8	75 ppm SA + 25 ppm NAA
D3T3	0 ppm SA + 50 ppm NAA	D3T9	75 ppm SA + 50 ppm NAA
D3T4	50 ppm SA + 0 ppm NAA	D3T10	100 ppm SA + 0 ppm NAA
D3T5	50 ppm SA + 25 ppm NAA	D3T11	100 ppm SA + 25 ppm NAA
D3T6	50 ppm SA + 50 ppm NAA	D3T12	100 ppm SA + 50 ppm NAA

D1 : 30th Nov. date of sowing (Normal)
D2 : 30th Dec. date of sowing (Let)
D3 : 30th Jan. date of sowing(Very let)
SA : Salicylic acid
NAA : Naphthalene acetic acid

RESULTS AND DISCUSSION

Effect of date of transplanting and foliar spray of plant growth regulator consortium on morphological traits of tomato

Due to the date of transplanting significant difference was observed for plant height at 45, 60 and 90 DAT, number of leaves per plant at 45 and 60 DAT and number of branches per plant at 45 DAT ($p < 0.001$). The highest plant height, number of leaves per plant and number of branches per plant at all stages were observed for the first date of transplanting (D1: 30th November). Results revealed that D1 date of transplanting recorded in the pooled data over both 2019-20 & 2020-21 years. Due to significantly higher plant height at 45, 60 and 90 DAT (47.33 cm, 54.60 cm and 66.33 cm), number of leaves per plant at 45 and 60 DAT (29.23 and 37.35) and number of branches per plant (5.70) respectively. Similar research trends were observed by Agrawal and Nath [2] and Islam *et al.* [11] were significantly affected by different transplanting dates, it is suggesting that earlier transplanting produced higher fruit yield of tomato. In contrast, the lowest plant height, number of leaves per plant and number of branches per plant was observed for the third date of transplanting (D3: 30th January). In contrast, lowest plant height at 45, 60 and 90 DAT (34.94 cm, 38.36 cm and 43.42 cm), number of leaves per plant at 45 and 60 DAT (17.02 and 23.54) and number of branches per plant (4.18) (Table no. 2) dates of transplanting were also reported by Afsana *et al.* [1] as the same finding. With respect to foliar spray of plant growth regulator consortium, a significant difference was observed for maximum plant height at all the three stages, number of leaves per plant and number of branches per plant ($p < 0.001$) in the year. The highest plant height, leaves and branches ware observed for T5 (50 ppm SA and 25 ppm NAA) due to plant height at 45, 60 and 90 DAT (45.36 cm, 52.88 cm and 62.37 cm), number of leaves per plant at 45 and 60 DAT (30.34 and 37.45) and number of branches per plant (6.57). The minimum plant height, leaves and branches being observed for T1 (Control Without application), in all stages uniformly over the year, plant height at 45, 60 and 90 DAT (34.47 cm, 39.04 cm and 47.01 cm), number of leaves per plant at 45 and 60 DAT (17.49 and 24.09) and number of branches per plant (3.49) (Table no. 2). This is similar reported by Bertila *et al.* [4], Kaur *et al.* [15], Pundir *et al.* [20] and Gupta *et al.* (2019) highest tomato growth under normal sown conditions, the tomato transplanting on normal time vegetative growth is good because the temperature remains optimum due to which the plant height, leaves and branches increases positively influenced the use of plant growth regulators of application.

Effect of date of transplanting and foliar spray of plant growth regulator consortium on phenological traits of tomato

Due to the date of transplanting significant difference was observed for days to flower initiation, days to 50% flowering and days to first harvest in pooled data ($p < 0.001$). Due to significantly (Table no. 2) observed for the second date of transplanting (D2) higher days to flower initiation 43.20 days and days to 50% flowering were the date of transplanting 52.44, while significantly observed for the first date of transplanting (D1) higher days to first harvest 109.51 days. In contrast, lower days to flower initiation 32.83 days, days to 50% flowering 40.38 days and days to first harvest 92.66 days were observed for the third date of transplanting (D3). This is according Cheena *et al.* [5] the analysed data revealed that days taken to first flowering by tomato different dates transplanting were significant and Hossain *et al.* [10], who reported that days to flower initiation decreases under late transplanting conditions in tomato. Due to the prevalence of high temperature at the time of vegetative and reproductive stage, there occurs a reduction in days to harvesting and flower due to rapid phonological development to escape high-temperature stress during fruit formation. With reported to a foliar spray of PGR consortium, a significant difference (Table no. 2) was observed on days to flower initiation, days to 50% flowering and days to first harvest ($p < 0.001$) in the over both 2019-20 & 2020-21 years. The highest reduction in days to flower initiation, days to 50% flowering and days to the first harvest was observed due to treatment T5 (50 ppm SA and 25 ppm NAA) in uniformly over the year, days to flower initiation (34.91 days), days to 50% flowering (42.92 days) and days to first harvest (97.15 days). Similar results were also found by Gupta *et al.* [8] and Mohamed *et al.* [19] it was observed that the days to first flowering was significantly differed by application of different plant growth regulators and another finding the plant growth regulators might have influenced the physiological regulation of flower formation of the plants possibly influencing the timing of anthesis mechanism [15]. T1 (Control Without application) longer time to achieve days to flower initiation, days to 50% flowering and days to harvest being observed in uniformly over pooled data, days to flower initiation (40.41 days), days to 50% flowering (51.26 days) and days to first harvest (106.81 days) Pundir *et al.* [20].

Effect of date of transplanting and foliar spray of plant growth regulator consortium on growth analysis of tomato

Due to the date of transplanting significant difference was observed (Table no. 3) for leaf area index at 45 and 60 DAT, leaf area duration (cm2 days) and specific leaf area (cm2 g-1) at 45 and 60 DAT ($p < 0.001$). The maximum leaf area index, leaf area duration and specific leaf area at all stages was observed for the first date of transplanting (D1: 30th November). Results revealed that D1 date of transplanting recorded in the pooled data. It was observed for higher leaf area index at 45 and 60 DAT (0.43 and 0.49), leaf area duration (cm2 days) (20795.02) and specific leaf area (cm2 g-1) at 45 and 60 DAT (130.57 and 136.98). Similar research was observed by Gupta *et al.* [8] and Kamrozzaman *et al.* [14] were significantly affected leaf area index was significantly influenced by different dates of sowing. Maximum leaf area index was reported for the crop sown on 1st December at all growth stages in both years. Delay in sowing significantly reduced the LAI at all stages, probably because of a reduction in the rate of photosynthesis and poor development of leaves. In contrast, the minimum leaf area index, leaf area duration and specific leaf area were observed for the third date of transplanting (D3: 30th January). Due to significantly minimum leaf area index at 45 and 60 DAT (0.22 and 0.27), leaf area duration (cm2 days) (11251.84) and specific leaf area (cm2 g-1) at 45 and 60 DAT (81.51 and 105.50) (Table no. 3). With respect to foliar spray of plant growth regulator consortium, a significant difference was observed for the highest leaf area index at 45 and 60 DAT, leaf area duration (cm2 days) and specific leaf area (cm2 g-1) at 45 and 60 DAT ($p < 0.001$) in the both years. The highest leaf area index, leaf area duration and specific leaf area were observed (Table no. 3) for T5 (50 ppm SA and 25 ppm NAA) due to leaf area index at 45 and 60 DAT (0.39 and 0.55), leaf area duration (cm2 days) (23114.37) and specific leaf area (cm2 g-1) at 45 and 60 DAT (134.52 and 156.31). The minimum leaf area index, leaf area duration and specific leaf area being observed for T1 (Control Without application), in all stages uniformly over in the over both 2019-20 & 2020-21 years, leaf area index at 45 and 60 DAT (0.21 and 0.23), leaf area duration (cm2 days) (9900.84) and specific leaf area (cm2 g-1) at 45 and 60 DAT (78.35 and 94.68), respectively. This is similarly reported by Siri *et al.* [23] and Yadav *et al.* [26] are reported that increases positively influenced the use of plant growth regulators of application.

Effect of date of transplanting and foliar spray of plant growth regulator consortium on yield of tomato

Significant difference was observed for yield per plant (kg) and yield (q/ha) in 2019-20 ($p < 0.001$). Significantly observed for the first date of transplanting (D1) maximum yield per plant (1.28 kg) and yield (428.55 q/ha) in pooled data, respectively. In conflict, minimum yield per plant (0.44 kg) and yield (148.05 q/ha) were observed for the third date of transplanting (D3) in (Table no. 3), respectively. That reported the earlier transplanting produced higher fruit yield of tomato Islam *et al.* [11]. As morphological characters the yield of tomato is also significantly reduced by late transplanting. With reported to a foliar spray of PGR consortium, a significant difference was observed on yield per plant (kg) and yield (q/ha) ($p < 0.001$) in the both years. The maximum yield per plant and yield were observed due to treatment T5 (50 ppm SA and 25 ppm NAA) uniformly over the years, yield per plant (1.08 kg) and yield (353.32 q/ha), respectively. T1 (Control Without application) minimum yield per plant and yield being observed in uniformly over the year, yield per plant (0.61 kg) and yield (205.50 q/ha) (Table no. 3), respectively. Similar results were also found by, Jakhar *et al.* [13], Shinwari *et al.* [22] and Siwna *et al.* [24] are an application of different plant growth regulators to increase the yield per plant and total yield of tomato. On the basis of research to say that the use of plant growth regulators increases the total yield of tomato and develops the ability to tolerate high temperature.

Table 2. Effect of date of transplanting and plant growth regulator consortium on morphological and phenological traits of tomato

Effect of DAT	Plant height (cm)			No. of leaves per plant		No. of branches per plant	Days to flower initiation	Days to 50% flowering	Days to first harvest
	45 DAT	60DAT	90DAT	45 DAT	60DAT				
Factor A									
D1 (Normal date of transplanting)	47.33	54.60	66.33	29.23	37.35	5.70	35.89	46.49	109.51
D2 (Late date of transplanting)	39.26	43.53	54.78	27.90	33.50	5.21	43.20	52.44	103.82
D3 (Very late date of transplanting)	34.94	38.36	43.42	17.02	23.54	4.18	32.83	40.38	92.66
SEm±	0.22	0.19	0.18	0.09	0.11	0.055	0.11	0.14	0.29
C.D. (P=0.05)	0.62	0.55	0.53	0.25	0.32	0.15	0.32	0.403	0.82
Factor B									
T1 (Control Without application)	34.47	39.04	47.01	17.49	24.09	3.49	40.41	51.26	106.81
T2 (25 ppm NAA)	37.30	41.21	48.67	19.78	26.62	4.22	39.53	49.29	105.06
T3 (50 ppm NAA)	37.76	42.54	49.79	22.04	28.11	4.35	39.23	47.23	104.44
T4 (50 ppm SA)	39.66	44.53	51.56	23.67	29.24	4.50	38.34	48.06	103.74
T5 (50 ppm SA + 25 ppm NAA)	45.36	52.88	62.37	30.34	37.45	6.57	34.91	42.92	97.15
T6 (50 ppm SA + 50 ppm NAA)	43.51	46.89	59.19	27.07	33.46	5.38	35.88	45.33	99.65
T7 (75 ppm SA)	40.70	44.97	56.29	24.42	29.72	5.07	37.82	46.83	102.55
T8 (75 ppm SA + 25 ppm NAA)	42.93	47.16	57.92	25.56	32.37	5.39	36.74	45.35	101.14
T9 (75 ppm	40.76	45.56	57.32	26.08	33.17	5.23	36.30	45.20	101.92

SA + 50 ppm NAA)									
T10 (100 ppm SA)	39.66	46.24	54.95	24.89	32.46	5.20	37.08	45.67	101.72
T11 (100 ppm SA + 25 ppm NAA)	41.24	46.81	56.21	27.15	35.65	5.47	35.91	44.87	100.26
T12 (100 ppm SA + 50 ppm NAA)	42.76	48.18	56.86	28.14	35.26	5.49	35.53	45.22	99.52
SEm±	0.44	0.39	0.37	0.18	0.23	0.11	0.23	0.28	0.58
C.D. (P=0.05)	1.24	1.10	1.07	0.51	0.65	0.31	0.65	0.806	1.64

DAT: Days after transplanting

Table 3. Effect of date of transplanting and plant growth regulator consortium on growth analysis and yield of tomato

Effect of DAT	Leaf area index		Leaf area duration (cm^2 days)	Specific leaf area ($cm^2 g^{-1}$)		Yield per plant (kg)	Yield (q/ha)
	45 DAT	60 DAT		45 DAT	60 DAT		
Factor A							
D1 (Normal date of transplanting)	0.43	0.49	20,795.02	130.57	136.98	1.28	428.55
D2 (Late date of transplanting)	0.29	0.40	17,266.95	110.93	126.52	0.76	254.53
D3 (Very late date of transplanting)	0.22	0.27	11,251.84	81.51	105.50	0.44	148.05
SEm±	0.001	0.001	131.93	0.46	0.43	0.003	1.03
C.D. (P=0.05)	0.003	0.004	372.93	1.32	1.23	0.009	2.92
Factor B							
T1 (Control Without application)	0.21	0.23	9,900.84	78.35	94.68	0.61	205.50
T2 (25 ppm NAA)	0.23	0.26	11,543.78	84.12	99.76	0.63	211.18
T3 (50 ppm NAA)	0.25	0.31	13,298.00	91.30	102.87	0.65	217.51
T4 (50 ppm SA)	0.27	0.32	13,427.11	97.82	114.20	0.70	233.50
T5 (50 ppm SA + 25 ppm NAA)	0.39	0.55	23,114.37	134.52	156.31	1.08	353.32
T6 (50 ppm SA + 50 ppm NAA)	0.35	0.43	18,340.62	115.97	130.28	0.95	329.64
T7 (75 ppm SA)	0.32	0.39	16,429.63	106.82	122.52	0.80	268.49
T8 (75 ppm SA + 25 ppm NAA)	0.35	0.42	18,057.20	118.58	132.72	0.91	303.74
T9 (75 ppm SA + 50 ppm NAA)	0.35	0.43	18,368.72	111.34	131.04	0.94	313.96
T10 (100 ppm SA)	0.32	0.40	16,717.90	105.95	115.83	0.86	289.64
T11 (100 ppm SA + 25 ppm NAA)	0.36	0.45	19,158.58	123.07	140.06	0.94	315.15
T12 (100 ppm SA + 50 ppm NAA)	0.37	0.43	18,898.46	124.17	135.73	0.94	315.53
SEm±	0.002	0.003	263.87	0.93	0.87	0.006	2.07
C.D. (P=0.05)	0.006	0.007	745.87	2.64	2.46	0.018	5.85

CONCLUSION

The results concluded that yield of tomato was significantly affected by different transplanting dates and plant growth regulators. PGR play important role on physiology and yield attributes of tomato. The finding revealed that treatment T5 (50 ppm SA and 25 ppm NAA) recorded the maximum yield (q/ha).

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