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Effect of plant growth regulators under high temperature stress conditions on quality and yield of tomato (*Solanum lycopersicum* L.)

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Abstract
The study was to reduce the impact of high-temperature stress by using the growth regulators salicylic acid (SA) and auxin (NAA), which altered plant growth and development by triggering changes in cell processes, physiology, and morphology. A randomized complete block design with three replications was used to set up the experiment, which included 36 treatments that included plant growth regulators and three transplantation dates. In this experiment, TSS, pH, yield per plant (kg), and yield (q/ha) were recorded at various phases to assess the effects of high temperature, SA, and NAA on quality and yield parameters. Spraying SA and NAA on tomatoes improves yield by reducing the impact of high temperatures on yield and yield attributes.

Keywords: Heat stress, SA, NAA, growth and yield of tomato

1. Introduction
Tomato (*Lycopersicon esculentum* L.) belongs to the genus Lycopersicon under Solanaceae family and chromosome number 2n=24. Tomato is one of the most important vegetables worldwide. Tomato is an originated to Peruvian and Mexican region. Portuguese probably introduced it to India. Most tomato cultivars produce red fruits when ripe, the attractive red colour of fruit is due to lycopene and yellow colour is due to carotenes.
Tomato is one of the most important "protective foods" because they are rich source of trace elements, vitamins, essential amino acids and healthy organic acids like citric, formic and acetic acids. Tomato is used for soup, sauces, salad, ketchup, pickles, puree and in many other ways.

2. Material and Methods
The experiment was conducted at the Horticulture complex, Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) during in both 2019-20. The temperature ranges from low to high (6.3 °C to 40.1 °C), and the climate is semi-arid and subtropical, with hot summers and somewhat chilly winters. The annual rainfall ranges from 1200 to 1500 mm, with an average of 1350 mm and a R.H. of 80–90%. Salicylic acid and NAA were used in varied combinations as foliar sprays at pre-flowering in the 36 treatments that made up the field trial. Salicylic acid was used at concentrations of 0 ppm, 50 ppm, 75 ppm, and 100 ppm, while NAA was used at concentrations of 0 ppm, 25 ppm, and 50 ppm. The experiment had three transplanting dates: 30 November (normal transplanting), 30 December (late transplanting), and 30 January (very late transplanting).

Table 1: Details of treatment

D_1: 30th November (Normal date of transplanting)					
D_2: 30th December (Late date of transplanting)					
D_3: 30th January (Very late date of transplanting)					
T_1:	Control	T_5:	50 ppm SA+ 25 ppm NAA	T_9:	75 ppm SA+ 50 ppm NAA
T_2:	25 ppm NAA	T_6:	50 ppm SA+ 50 ppm NAA	T_{10}:	100 ppm SA
T_3:	50 ppm NAA	T_7:	75 ppm SA	T_{11}:	100 ppm SA+ 25 ppm NAA
T_4:	50 ppm SA	T_8:	75 ppm SA+ 25 ppm NAA	T_{12}:	100 m SA+ 50 ppm NAA

3. Results and Discussion

3.1 Effect of dates of transplanting and foliar spray of PGRs on quality of tomato

3.1.1 Total soluble solids (^{0}Brix): Significant differences were seen because of the transplanting dates (Table 2). The highest total soluble solids were found in transplanting date D3 (very late, or 30th January), at 4.26 0Brix, and in transplanting date D2 (late, or 30th December), at 4.14 0Brix. D1 (Normal Date of Planting, or the 30th of November) had the lowest total soluble solids, 4.09 0Brix. This could be a result of the late and very late transplanting period's high-temperature stress, which leads to an increase in total soluble solids. Shivashankara *et al.* (2015) [11] and Lokesha *et al.* (2019) [7] both supported the findings. According to Table No. 2, treatment T5 (50 ppm SA + 25 ppm NAA) showed the considerably highest total soluble solids (4.79 0Brix), while control (T1) showed the lowest total soluble solids (3.46 0Brix). Similar results showed that NAA considerably enhanced total soluble solids and pH (Oaliya *et al.*, 2010; Patel *et al.*, 2012; and Ujjwal *et al.*, 2018) [8, 9, 14]. By improving the yield and quality-influencing parameters, exogenous applications of salicylic acid (0.5 mM) led to considerable increases in tomato fruit yield (Kazemi, 2014; Singh and Singh, 2016) [6, 16].

3.1.2 pH: The minimum pH was observed in D_3 (Very late date of transplanting *i.e.*30th January) *i.e.* 4.11 followed by D_2 (Late date of transplanting *i.e.* 30th December) 4.13. The maximum pH 4.44 was noted in D_1 (Normal Date of planting *i.e.*30th November).High temperature stress leads to an increase significantly in pH decreased during late and very late dates of transplanting period (Lokesha *et al.*, 2019) [7].
With respect to treatment T_5 (50 ppm SA +25 ppm NAA) exhibited (Table no. 2) the significantly minimum pH 3.71, while the maximum pH 4.67 was noted with control (T_1).

3.2 Effect of dates of transplanting and foliar spray of PGRs on yield of tomato

Yield per plant (kg) and overall yield (q/ha) were found to differ significantly in 2019–20 (Table no. 2). Maximum yield per plant (1.22 kg) and total yield (407.49 q/ha) were significantly recorded on the first transplantation date (30 November), whereas minimal yield per plant (0.45 kg) and total yield (150.63 q/ha) were observed on the third transplanting day (30 January). According to Islam *et al.* (2017) [4], early tomato transplanting increased fruit yield. Ali *et al.* (2020) [1] reported having seen similar studies. Tomato production is dramatically decreased by late transplanting as well as other physical characteristics.
A significant difference in yield per plant (kg) and overall yield (q/ha) was seen when PGR's consortium reported a foliar spray. The treatment T5 (50 ppm SA and 25 ppm NAA) uniformly produced a maximum yield per plant and total yield of 343.32 q/ha and a minimum yield per plant of 0.60 kg. The control (T1) produced a minimum yield per plant and a total yield of 202.11 q/ha. They may be caused by the stimulating effect SA, whereby improvements in nutrient absorption, nitrate reductase, photosynthesis, enhanced flow assimilates translocation, cytoplasmic streaming, and increased cell integrity finally resulted in an increase in yield (Amin *et al.*, 2007) [2], Due to less flower and fruit drop and higher fruit setting on plant^{-1}, the application of NAA increases fruit yield (Baliyan *et al.*, 2013) [3]. This eventually increases yield per hectare. In order to enhance the yield per plant and overall production of tomatoes, several plant growth regulators were applied by Jakhar *et al.* (2018) [5], Shinwari *et al.* (2018) [10], and Siwna *et al.* (2019) [13], with similar results.

Table 2: Effect of dates of transplanting and foliar spray of PGRs on quality and yield of tomato

Treatments	Total soluble solids (^{0}Brix)	pH	Yield per plant (kg)	Total yield (q/ha)
Factor A				
D1 (Normal date of transplanting)	4.09	4.44	1.22	407.49
D2 (Late date of transplanting)	4.14	4.13	0.68	228.86
D3 (Very late date of transplanting)	4.26	4.11	0.45	150.63
S.Em±	0.04	0.06	0.004	1.33
C.D. (P=0.05)	0.11	0.19	0.01	3.78
Factor B				
T1 (Control Without application)	3.46	4.67	0.60	202.11
T2 (25 ppm NAA)	4.12	4.51	0.62	209.59
T3 (50 ppm NAA)	4.25	4.32	0.63	211.37
T4 (50 ppm SA)	4.28	4.18	0.71	237.85
T5 (50 ppm SA + 25 ppm NAA)	4.79	3.71	1.03	343.32
T6 (50 ppm SA + 50 ppm NAA)	4.47	3.71	0.91	305.59
T7 (75 ppm SA)	3.92	4.27	0.81	271.49
T8 (75 ppm SA + 25 ppm NAA)	4.13	4.17	0.86	288.59
T9 (75 ppm SA + 50 ppm NAA)	4.10	4.24	0.82	275.87
T10 (100 ppm SA)	3.93	4.62	0.80	268.14
T11 (100 ppm SA + 25 ppm NAA)	4.31	4.31	0.84	281.16
T12 (100 ppm SA + 50 ppm NAA)	4.21	4.02	0.83	279.47
S.Em±	0.08	0.13	0.007	2.67
C.D. (P=0.05)	0.22	0.38	0.02	7.56

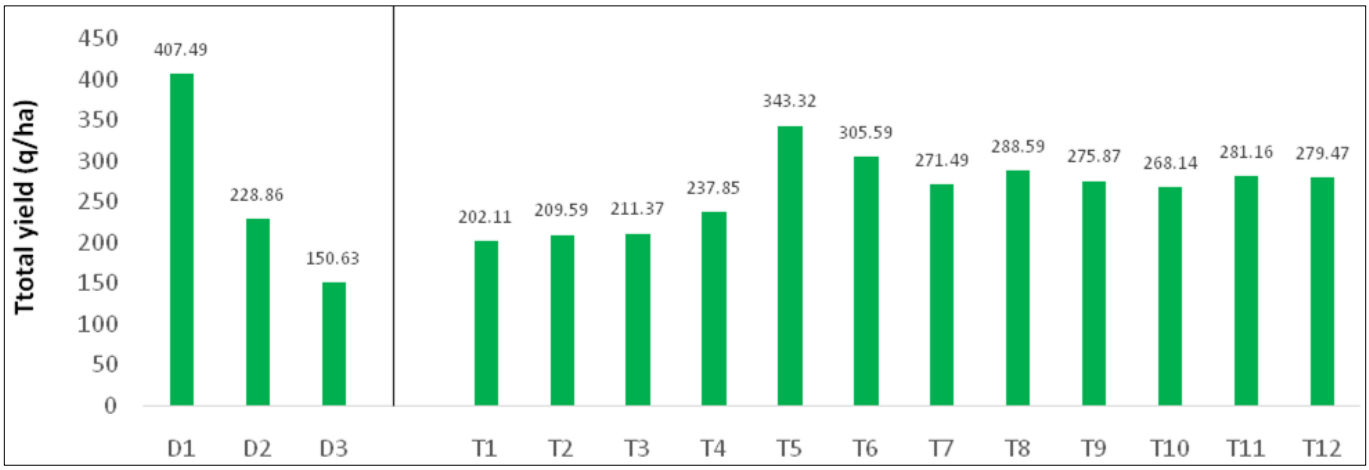

Fig 2: Effect of dates of transplanting and foliar spray of PGRs on total (q/ha) yield of tomato

4. Conclusion

The findings of this study showed that the tomato variety Kashi Amrit had a substantial impact on vegetative growth, flowering, fruit setting, quality, and yield on the day of transplanting. Due to the higher production of the tomato variety Kashi Amrit, the majority of the attributes were found to be best with foliar sprays of the bioregulators consortium (salicylic acid at 50 mg/L and naphthalene acetic acid at 25 mg/L) in late and very late transplanting conditions. The best time to plant was on November 30.

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