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Deciphering the Inheritance Mechanisms of Fruit Color in Tomato

Sandeep Kumar[1], Aditi Sharma[1*], Bhupinder S. Thakur[2], Devinder K. Mehta[1], Sandeep Kansal[1] and R. K. Dogra[3]

[1]Dept. of Vegetable Science, [3]Dept. of Fruit Science, Dr YS Parmar University of Horticulture and Forestry, Himachal Pradesh (173 230), India

[2]Regional Horticulture Research & Training Station, Bajaura, Kullu, Himachal Pradesh (175 125), India

Corresponding Author

Aditi Sharma

e-mail: aditibhrdwj796@gmail.com

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Abstract

The experiment was conducted during *kharif,* 2020–21 at Regional Horticultural Research and Training Station, Bajaura, Kullu, Himachal Pradesh (175 121) a breeding program was initiated using two distinct tomato genotypes: Solan lalima and BN-7 to explore the development of novel colour development. These parent varieties were strategically chosen for their complementary traits, with the goal of combining and enhancing desirable characteristics, including unique color expressions, in their progeny. The initial step involved crossbreeding these genotypes to produce F_1 hybrid plants. Following this hybridization, we embarked on a process of repeated self-pollination (selfing) and backcrossing. This technique, employed over six successive generations, allowed us to carefully select and propagate plants exhibiting the most promising combinations of traits, particularly focusing on fruit color. Chi-square analysis further revealed that Solan Lalima (red)×BN-7 (yellow) showed dominance of red colour over yellow colour.

Keywords: Colour, gene, inheritance, tomato, antioxidants, carotenoid

1. Introduction

The tomato (*Solanum lycopersicum* L.), a cornerstone of global agriculture within the Solanaceae family, is celebrated for its remarkable adaptability, diverse culinary applications, and significant nutritional contributions. Originating in the tropical regions of Central and South America (Vavilov, 1951), the modern tomato was domesticated from its wild ancestor, *Solanum lycopersicum* var. *cerasiforme* (Cox, 2000). Its introduction to India, facilitated by Portuguese explorers, catalyzed its widespread cultivation across the subcontinent. Beyond its culinary prominence, the tomato serves as a pivotal model organism for plant biology research, particularly in the study of fruit ripening. Researchers delve into the intricate mechanisms of ethylene and carotenoid biosynthesis, cell wall degradation, and metabolic shifts (Kinet and Peet, 1997), thereby enriching our comprehension of fruit development (Giovannoni et al., 2017). Recent strides in genomics have provided deeper insights into the genetic regulation of these processes (Munoz-Blanco et al., 2023), allowing for precise manipulation of key traits. The commercial significance of tomato fruit color has experienced a dramatic surge in recent years, driven by escalating consumer demand for visually diverse produce. This demand is fueled by the aesthetic appeal of varied colors, perceived flavor nuances, and heightened awareness of the health benefits associated with specific pigments. The vibrant hues of tomato fruits arise from a complex interplay of pigments, including lycopene, beta-carotene, lutein, anthocyanins, and betalains (Liu et al., 2020; Zhang et al., 2021). Contemporary research has elucidated the intricate genetic pathways governing pigment accumulation and the influence of environmental factors and breeding strategies (Fernandez-Moreno et al., 2022; Sun et al., 2023). Targeted manipulation of regulatory genes and metabolic pathways is underway to enhance color variations and produce novel phenotypes (Li et al., 2021). Furthermore, the exploitation of advanced breeding methodologies is expanding the market for specialty tomatoes with unique color profiles (Panthee et al., 2020).

Tomato fruits are not only visually captivating but also serve as potent sources of antioxidants, including lycopene, carotenoids, and flavonoids, which play a crucial role in mitigating cellular damage caused by free radicals (Raffo et

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al., 2019; Perez-Gallegos et al., 2023). These antioxidants contribute to a spectrum of health benefits, including anti-inflammatory, anti-allergenic, and anti-thrombotic effects, underscoring their nutritional significance. Contemporary research emphasizes the correlation between specific pigment profiles and enhanced antioxidant capacity (Chaturvedi et al., 2020; Rodriguez-Concepcion et al., 2021). Moreover, studies are investigating the influence of diverse cultivation techniques on the antioxidant profiles of various tomato cultivars (Kumar et al., 2022). The commercialization of diverse colored tomatoes with varying pigment profiles and antioxidant levels holds significant promise for enhancing public health. Breeding programs employing marker-assisted and genomic selection techniques are instrumental in enhancing antioxidant levels (Foolad et al., 2022; Causse et al., 2022; Sim et al., 2023). This dual focus on color and antioxidant content aligns with the burgeoning emphasis on functional foods, where nutritional and health benefits are prioritized alongside traditional traits (Butt et al., 2023; Raiola et al., 2020; Schwalfenberg et al., 2020). The integration of modern phenotyping and genotyping technologies is pivotal in the development of tomato lines with superior nutritional value (Tripodi et al., 2019). Ultimately, the development of novel cultivars with enhanced nutritional attributes and appealing visual characteristics is essential for the sustainable future of tomato production.

2. Materials and Methods

The study was carried out at the Regional Horticultural Research and Training Station, Bajaura, Kullu, Himachal Pradesh (175 121) during *kharif*, 2020–21. The materials used in studying the inheritance of fruit color consisted of six genotypes including two recipient parents (P_1s) one F_1, one F_2, one B_1 and one B_2. During *kharif,* 2020, both the genotypes (Solan Lalima and BN-7) were crossed with each other without reciprocal crosses to develop F_1 for the study of inheritance of fruit color. The seeds were extracted from fully matured fruits and kept in shade. The following F_1 was obtained during *kharif,* 2020. During *rabi* 2021, both the parents (P_1 and P_2), F_1, F_2 and back crosses (B_1 and B_2) were evaluated in the protected condition to study the pattern of inheritance for fruit color. The crop was transplanted in the protected field during first week of August, 2021. The population for parents and F_1 comprises of twenty plants each, seventy for F_2 and 20 for B_1 and B_2. All recommended cultural practices were followed to ensure a healthy crop. Analysis was done as per chi square test given by Panse and Sukhatme (1967).

3. Results and Discussion

The cross between Solan lalima (RR) and BN-7 (yy) showed Red (Ry) i.e. Red fruit colour in F_1 generation whereas, in F_2 generation 3 Red (RR): 1 yellow (yy) (Table 1) fruits were observed. Dominant allele can dominate the recessive allele, as a result of which, the resulting phenotype becomes a red. F_2 plants showed a 3:1 (red:yellow) segregation of fruit color, and 100% red when backcrossed with red type or 1:1 (red:yellow) segregation in backcrosses with the yellow; hence, yellow fruit color was determined by a recessive allele (Figure-1). The red color in the tomato fruit is the result of a single completely dominant gene for red color; yellow color in tomato fruit is the result of a homozygous recessive allele (Rego et al., 1999). Thompson (1955), working with a yellow cv. Snowball tomato mutant, found similar results for red and yellow color segregation.

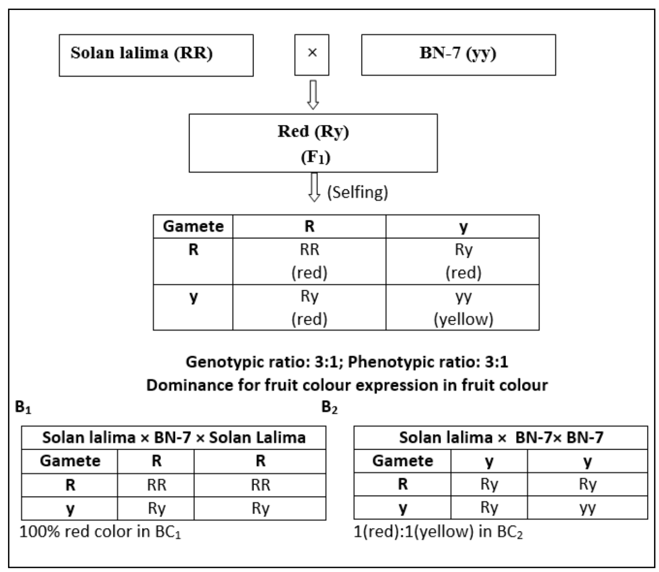

Table 1: Observed and expected frequencies of Solan lalima (P_1) × BN-7 (P_2) tomato fruits in F_1 (P_1×P_2), F_2 (F_1×F_1), backcrosses BC_1 (F_1×P_1) and BC_2 (F_2×P_2)

Generations	No. of plants (Observed frequency)			Expected frequency			Ratio	Chi-sqaure (cal)	Chi-square (tab)
	Red	Intermediate	Yellow	Red	Intermediate	Yellow			
P_1	25	-	-	-	-	-			
P_2	-	-	20	-	-	-			
F_1	16	-	-	-	-	-			
F_2	55	-	17	54	-	18	3:1	0.07	3.84
B_1	52	-	-	52	-	-	1:0	-	-
B_2	22	-	15	18.5	-	18.5	1:1	1.32	3.84

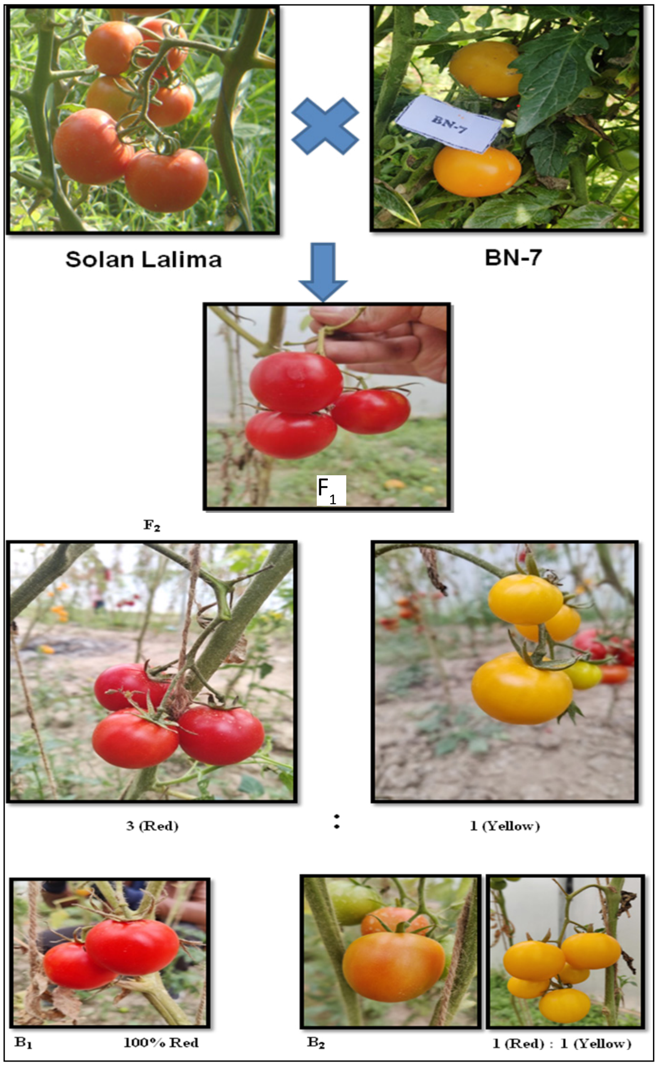

Figure 1: Inheritance of fruit colour of Solan lalima (Red)× BN-7

4. Conclusion

This research aims to contribute to the growing field of tomato color diversification, ultimately providing consumers with a wider selection of visually appealing and potentially nutritionally enhanced produce. The development of new, diverse-colored tomato varieties has the potential to not only satisfy consumer preferences but also to open up new market opportunities for growers and seed companies.

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