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Identification of suitable genotype of tomato for middle Gangetic plains of India

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Abstract

Twenty one elite lines of tomato were evaluated in Varanasi during 2010-11 to 2014-15 for important yield traits. Pooled analysis of variance revealed highly significant genotypic and environmental effects for all the traits. Variances due to genotype × environment revealed significant differences for number of fruits/plant and fruit yield/plant. Variance due to environment (linear) component was highly significant for all the traits. Variance due to genotype × environment (linear) was significant. The genotypes Kashi Amrit and Azad T 5 revealed stability for average fruit weight and the genotype H 24 for number of fruits/plant. The genotypes H 86, Kashi Amrit, Pusa Sadabahar were the stable genotypes for fruit yield/plant. The genotypes BT 120, NDTVR 60, Punjab Upma, Pusa Sadabahar were responsive genotypes for average fruit weight and the genotype GT was responsive for number of fruits/plant. The genotypes FLA 7171, Punjab Upma, Selection 7 were responsive genotypes for fruit yield/plant.

Keywords: Tomato, Stability, Regression coefficient, Fruit weight, Fruit Yield

Introduction

The interplay of genotypes and environments yield a range of phenotypes mostly in an unpredictable manner. The unparallel behaviour of two or more genotypes to different environments indicates the presence of genotype-environment interaction. The statement of Gauch and Zobel (1996) '*Were there no interaction……, one replicate at one location would indentify that one best variety that flourishes worldwide*" signifies the existence and importance of genotype-environment interaction. The ubiquitous nature of genotype-environment interaction necessitates evaluation of test genotypes across different environments. However, in general practice, genotypes are generally selected or rejected based on their performance under one environment only, leading to the loss of potential genotypes due to limited testing. Multi-environment trials are conducted to evaluate yield stability of genetic materials under varying environmental conditions (Yan and Rajcan 2002), to assess genotype-environment interaction and to identify genotypes with specific- or broad- adaptation (Kang 2001). Stability analysis is a good technique for measuring the adaptability of different crop varieties to varying environments (Morales et al. 1991). Among different models of stability analysis, Eberhart and Russell model (1966) is the most preferred model for analysis of genotype-environment interaction. In addition to the two parameters (mean and regression coefficient) as suggested by Finlay and Wilkinson (1963), this model takes into consideration 'deviation from regression (s^2d)' as one more parameter which provides for testing of phenotypic stability of individual genotypes (Singh and Pawar, 2010)

Tomato is 2nd most important among vegetable crops and 7th most important crop among all the crops. Although, domesticated very recently in the 18th century, its popularity has surpassed almost all other crops among customers by virtue of excellent organoleptic properties and exceptional nutritional values. It is popular among farmers on account of its short duration, high yield potential, high profitability and economic viability (Bhandari et al. 2017). Further, its amenability to grow under diverse conditions has made its cultivation widespread across the world. It is the 'darling of processing industries' being suitable as a raw material for a variety of processed foods. On account of its economic profitability, its cultivation has spread far and wide in the country. Different improved genotypes have been developed and proposed for cultivation from time to time. However, due to genotype-environment

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interaction, all the genotypes are not suitable for all the regions and locale-specific recommendation needs to be made. In this context, the present investigation was undertaken to evaluate different elite lines representing indigenous and exotic collection and to identify stable and responsive genotypes for the middle Gangetic Plains zone of India.

Materials and Methods

Experimental site and environment: The present investigation was carried out at Vegetable Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The experimental site is located in the middle Gangetic plains in the Eastern part of the state of Uttar Pradesh at 25°192 593 N latitude, 83°002 003 E longitude and at elevation of 77 m above mean sea level. The climate of the location is characterized as humid subtropical climate with large variations between summer and winter temperatures. The average annual rainfall is 1,110 mm.

Experimental material and experimentation: The experimental material comprised of 21 elite genotypes of tomato collected from different institutes and agricultural universities across India and abroad and maintained at Department of Genetics & Plant Breeding, Institute of Agricultural Sciences, BHU, Varanasi, UP. The nursery was raised in 1st week of August every year. Due care was taken to get the healthy seedlings. The 25-day-old crop was transplanted in the main field. The experiment was laid out in Randomized Complete Block design (RCBD) with three replications. An inter-row spacing of 60 cm and inter-plant distance of 45 cm was maintained. Each genotype was accommodated in three rows of 5m length to ensure sufficient plants for observation. All the recommended package of practices was followed to get a healthy crop. Data were recorded from five randomly selected plants for three important yield traits *viz*., average fruit weight, number of fruits per plant and fruit yield/plant.

Statistical analyses: Data were analyzed across all the environments (years) using pooled data according to Sharma (2006) by Indostat statistical package software and stability analysis was performed according to the model of Eberhart and Russell (1966) as it was shown to be the most reliable one (Westcott, 1986). The model is as follows:

$$Y_{ij} = \mu + \beta_i I_j + \delta_{ij}$$

Where Y_{ij} is mean of ith variety in jth environment; is mean of all varieties over all environments; $\hat{a}_i$ is regression coefficient of ith variety on environmental index that measures the response of this variety to varying environments; I_j is environmental index, *i.e.* the deviation of the mean of all the varieties at a given environment from the overall mean; and äij is the deviation from regression of ith variety at jth environment.

Results

The pooled analysis of variance (ANOVA) revealed highly significant genotypic and environmental effects for all the traits (Table 1). This indicated differences in the mean performance of genotypes across the environments and variation in the environmental means over test genotypes. Variances due to genotype × environment revealed significance for number of fruits/plant and fruit yield/plant indicating substantial variation in the mean performance of all the 21 genotypes under different environments. Non-significant variance due to genotype × environment for average fruit weight refers to non-substantial variation in the genotypes for average fruit weight under diverse environments. Variances due to environment (linear) component were highly significant for all the traits. This is suggestive of non-linear response of environmental index for unit change in environmental conditions. Significance of variance due to genotype × environment (linear) component implies differential yield performances of genotypes under diverse environments but with considerable varying reaction norms.

Stability parameters: An ideal (stable) variety is one with higher yield, having regression coefficient ($\hat{a}_i$) of unity and having deviation from linearity (S^2d_i) non-significantly different from zero These genotypes perform more or less consistently over all environments. Regression coefficient of unity ($\hat{a}_i$=1) refers to the responsiveness of genotypes to varying environmental conditions. The genotypes with lower value of $\hat{a}_i$ and low S^2d_i are less sensitive to the varying environmental conditions. These genotypes are generally not able to

Table 1: ANOVA for stability for different yield traits

SV	df	Average Fruit wt	No. of fruits/ plant	Fruit Yield/ plant
Rep. within Env.	10	5.69	0.91	0.01
Genotypes	20	894.24***	129.37**	0.67***
Env. + (Gen.× Env.)	84	333.83***	140.21***	0.19***
Environments	4	3352.60***	1312.40***	1.71***
Gen.× Env.	80	182.89	81.60*	0.11*
Environments (Lin.)	1	13410.38***	5249.60***	6.84***
Gen.× Env. (Lin.)	20	272.0*	172.38***	0.23***
Pooled Deviation	63	145.90***	48.89***	0.07***
Pooled Error	200	2.21	0.83	0.01

df: Degree of freedom, Rep.: Replication, Env.: Environment, Gen.: Genotype, Lin.: Linear

*: Significant at p=0.05, **: significant at p=0.01, ***: significant at P <0.01

capitalize on favourbale environments and hence, are specifically suitable for poor environments. The genotypes with $\hat{a}_i$>1 and high S^2d_i are highly sensitive to environments and are suitable for intensive agriculture. But they fail miserably under poor environments.

Average Fruit weight: As evident from Table 2, none of the genotypes except Kashi Amrit fulfilled the criteria of an ideal genotype in terms of regression coefficient ($\hat{a}_i$) and deviation from linearity (s^2d_i). The genotype Kashi Amrit recorded higher mean performance (81.57), near-to-unit regression coefficient (1.33) and very low degree of deviation from linearity (2.68). Similarly, the genotype Azad T-5 recorded near to unity regression coefficient and very low amount of deviation from linearity. Although it was not a good performer, but its mean was very near to the population mean. Nine genotypes (BT 120, FLA 7171, GT, H 86, Kashi Amrit, Kashi Sharad, NDTVR 60, Punjab Upma and Selection7) were good performers as they recorded higher values when compared to the population mean. Among the good performers (Nine genotypes), only five genotypes (*viz*., GT, Kashi Amrit, Kashi Sharad, Punjab Upma and Selection-7) possessed $\hat{a}_i$ H”1.0 (Figure1.1). This indicates that these genotypes responded consistently well to the varying environmental conditions. Among these five genotypes, four (GT, Kashi Amrit, Kashi Sharad and Selection-7) were highly stable as these possessed relatively lower value of S^2d_i.

Seven genotypes were grouped as low-responsive or adapted to low performance environments and 14 were grouped as adapted to high performance environments based on $\hat{a}_i$. Based on S^2d_i value, 12 genotypes were grouped as high-stable and eight genotypes were grouped as low-stable (Figure 2.2). The genotype Columbia revealed average stability as it fell exactly in between the high-stable and low-stable zone.

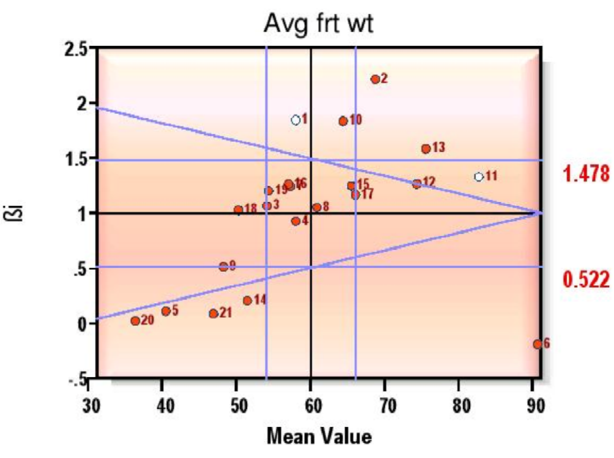

Fig 1.1: Mean performance of genotypes and their regression value ($\hat{a}_i$) for average fruit weight

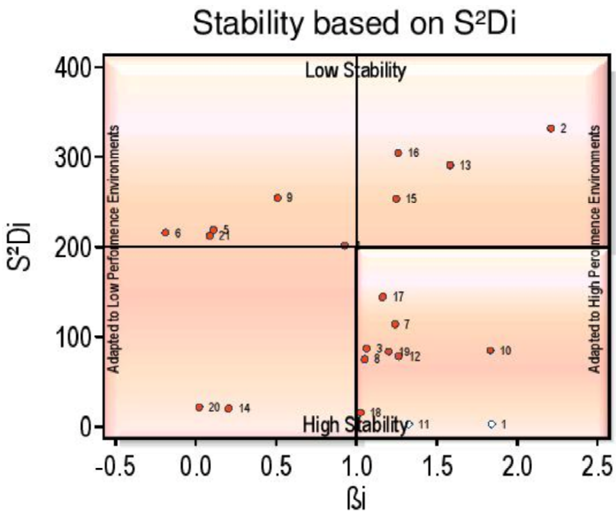

Fig 1.2: Stability of different genotypes based on S^2d_i for average fruit weight

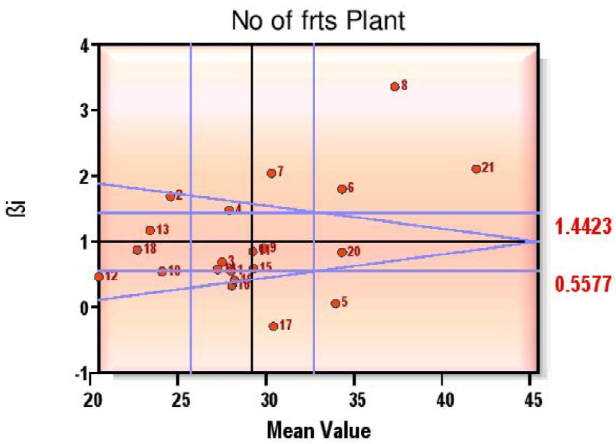

Fig 2.1: Mean performance of genotypes and their regression value ($\hat{a}_i$) for no of fruits/plant

Number of Fruits/plant: Ten genotypes (DT 10, FLA 7171, Flawery, GT, H 24, Kashi Amrit, Punjab Upma, Selection 7, Swarna Naveen and VR 20) recorded more number of fruits/plant compared to the population mean (Table 2). Among these 10 genotypes, three genotypes namely H 24, Kashi Amrit and Swarna Naveen recorded $\hat{a}_i$H”1 (Figure 2.1). The genotype H 24 appeared to be the most stable genotype among all the genotypes although S^2d_i value was relatively higher than zero but was still smaller when compared to that of others. Fourteen genotypes were grouped as low-responsive or adapted to low performance environments and seven were grouped as adapted to high performance environments based on $\hat{a}_i$ (Figure 2.2). Based on S^2d_i value, 20 genotypes were grouped as high-stable. The genotype GT was grouped as low-stable as its S^2d_i value was highest among all the genotypes. The genotype GT was recognized as also the high-responsive genotype as it recorded highest value of regression coefficient ($\hat{a}_i$=3.36).

Table 2: Estimation of Mean and Stability Parameters

		Average fruit weight			Number of fruits/plant			Fruit Yield/Plant		
S. No.	Genotype	μ (Mean)	β_i	S^2d_i	μ (Mean)	β_i	S^2d_i	μ (Mean)	β_i	S^2d_i
1.	Azad T 5	56.88	1.84	3.08	27.54	0.56	16.39	1.60	1.58	0.09
2.	BT 120	67.63	2.21	331.63	24.10	1.69	12.87	1.18	1.36	0.04
3.	CO 3	52.98	1.06	87.20	27.03	0.69	6.79	1.45	1.06	0.10
4.	Columbia	56.89	0.93	201.49	27.43	1.47	39.37	1.36	1.35	0.06
5.	DT 10	39.33	0.11	218.49	33.47	0.06	105.76	1.28	0.46	0.04
6.	FLA 7171	89.51	0.19	215.58	33.83	1.80	92.86	1.96	2.72	0.15
7.	Flawery	56.15	1.24	114.20	29.83	2.04	17.80	1.18	1.07	0.00
8.	GT	59.74	1.05	74.95	36.83	3.36	262.94	1.34	0.85	0.01
9.	H 24	47.13	0.51	254.45	29.37	0.90	12.73	1.20	0.34	0.05
10.	H 86	63.26	1.83	84.94	23.61	0.54	30.51	1.70	0.96	0.07
11.	Kashi Amrit	81.57	1.33	2.68	28.76	0.85	46.44	2.50	1.32	0.00
12.	Kashi Sharad	73.21	1.26	78.58	20.01	0.46	31.54	1.68	-0.34	0.07
13.	NDTVR 60	74.43	1.58	290.92	22.92	1.17	9.28	1.41	1.35	0.02
14.	Pant T3	50.33	0.21	20.07	26.77	0.58	4.93	1.41	0.15	0.14
15.	Punjab Upma	64.35	1.25	253.46	28.81	0.59	11.79	1.87	2.06	0.13
16.	Pusa Sadabahar	55.87	1.26	304.54	27.57	0.33	11.28	1.60	0.80	0.04
17.	Selection 7	64.95	1.16	144.36	29.95	0.29	42.11	2.24	2.19	0.17
18.	Shalimar 2	49.15	1.03	15.55	22.20	0.87	11.43	1.02	0.24	0.01
19.	Swarna Lalima	53.19	1.20	83.62	27.71	0.41	78.92	1.53	1.68	0.01
20.	Swarna Naveen	35.19	0.02	21.74	33.83	0.83	86.09	1.20	-0.69	0.11
21.	VR 20	45.74	0.09	212.09	41.46	2.10	77.40	1.45	0.47	0.02
Population mean		**58.9**			**28.7**			**1.5**		

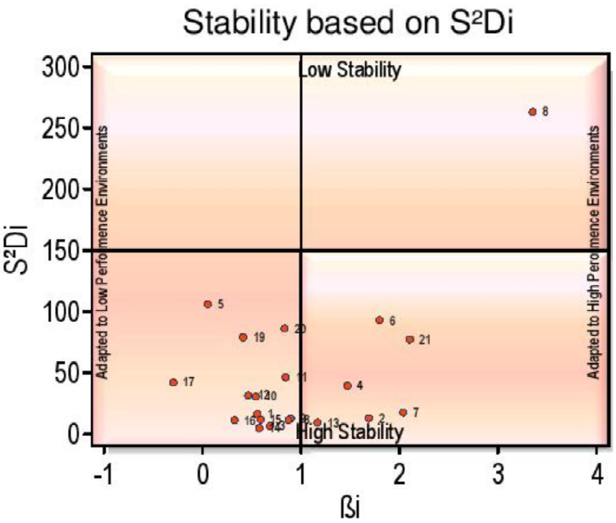

Fig 2.2: Stability of different genotypes based on S^2d_i for no of fruits/plant

Fruit yield/plant: Nine genotypes (FLA 7171, H 86, Kashi Amrit, Kashi Sharad, Punjab Upma, Pusa Sadabahar, Selection 7 and Swarna Lalima) recorded higher fruit yield/plant compared to the population mean (Table 2). Among these nine genotypes, three genotypes namely H 86, Kashi Amrit and Pusa Sadabahar recorded â$_i$H”1 (Figure 3.1). These three genotypes appeared to be the most stable as they fulfilled all the criteria of a stable genotype. The genotype GT also fulfills the criteria of stability but had slightly lesser yield compared to the population mean. Ten genotypes were grouped as low-responsive or adapted to low performance environments and 21 were grouped as adapted to high performance environments based on â$_i$ (Figure 3.2). Based on S^2d_i value, 16 genotypes were grouped as high-stable. Five genotypes were grouped as low-stable genotypes having higher value of S^2d_i. Among these, three genotypes (FLA 7171, Punjab Upma and Selection 7) were grouped as high-responsive and hence, suited to rich environments.

Discussion

Considering both the parameters, *i.e.,* â$_i$, S^2d_i, all the genotypes were grouped into different categories for number of fruits/plant (Table 3). The genotypes H 86, Kashi Amrit and Pusa Sadabahar were stable for fruit yield/plant. None of the genotypes were stable for all the traits and stability for one trait was independent of stability for other trait. This is in accordance to the reports of Mane et al. (2010). The genotypes that

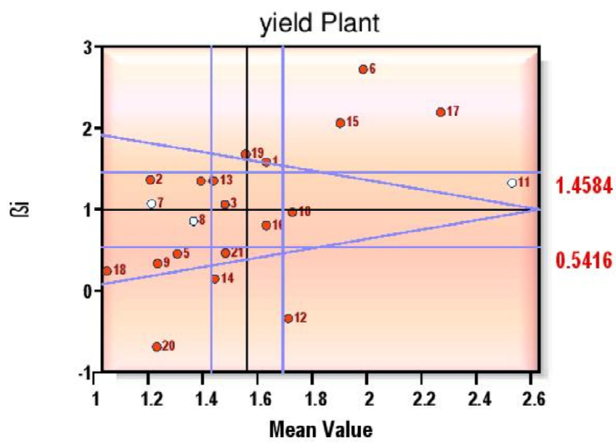

Fig 3.1: Mean performance of genotypes and their regression value (â$_i$) for fruit yield/plant

Table 3: Grouping of tomato genotypes for based on stability parameters

Trait	Adaptive specificity	Number of genotypes	Genotypes
Average fruit weight	Rich environments	4	BT 120, NDTVR 60 , Punjab Upma , Pusa Sadabahar
	Poor environments	5	Columbia, DT 10, FLA 7171 , H 24, VR 20
	Average environments	2	Pant T 3, Swarna Naveen
	Over all environments	10	Azad T 5, CO 3, Flawery, GT, H 86, Kashi Amrit, Kashi Sharad , Selection 7, Shalimar 2, Swarna Lalima
Number of fruits/plant	Rich environments	1	GT
	Poor environments	0	None
	Average environments	14	Azad T 5, CO 3, DT 10, H 24, H 86, Kashi Amrit, Kashi Sharad, Pant T3, Punjab Upma, Pusa Sadabahar, Selection 7, Shalimar 2, Swarna Lalima, Swarna Naveen
	Over all environments	6	BT 120, Columbia, FLA 7171, Flawery, NDTVR 60, VR 20
Fruit yield/plant	Rich environments	3	FLA 7171, Punjab Upma , Selection 7
	Poor environments	2	Pant T3, Swarna Naveen
	Average environments	8	DT 10, GT, H 24, H 86, Kashi Sharad, Pusa Sadabahar, Shalimar 2, VR 20
	Over all environments	8	Azad T 5, BT 120, Co 3, Columbia, Flawery, Kashi Amrit, NDTVR 60, Swarna Lalima

Table 4: Summary of stable and responsive genotypes for different yield traits in tomato

Trait	Stable genotype(s)	Responsive genotype(s)
Average fruit weight	Kashi Amrit, Azad T 5	BT 120, NDTVR 60, Punjab Upma, Pusa Sadabahar
Number of fruits/ plant	H 24	GT
Fruit Yield/Plant	H 86, Kashi Amrit, Pusa Sadabahar	FLA 7171, Punjab Upma, Selection 7

appeared to be stable were native of India. This is in agreement with the reports of Mohanty (2002) who reported that different varieties released from Orissa were stable for cultivation in Orissa. None of the exotic lines tested under the present investigation were found to be stable despite their introduction and naturalization in India. This reveals that long-term inherent association or interplay of gene-complexes with the environment is the key to the stability of the genotypes. The fact that none of the exotic lines were grouped as stable genotypes with the indigenous line is an indication of lack of gene flow from indigenous lines into exotic lines. This differentiation which is at the base of genetic or geographic diversity might be responsible for differences in their stability or adaptability (Bhandari et al. 2017).

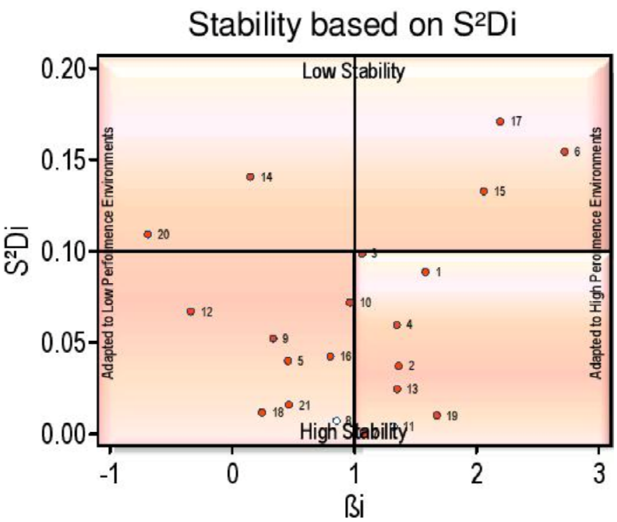

Fig 3.2: Stability of different genotypes based on S^2d_i for fruit yield/plant

Higher average fruit weight may be realised by the genotypes BT 120, NDTVR 60, Punjab Upma, Pusa Sadabahar under favourable environments as they appeared to be the responsive genotypes. The genotype GT was the most responsive for number of fruits/plant and the genotypes FLA 7171, Punjab Upma, Selection 7 were environment-responsive for fruit yield/plant. None of the genotypes were responsive for all the traits. The responsive genotypes included all the indigenous lines except FLA 7171. Extensive evaluation of 21 elite genotypes spanning over five-year period revealed that the genotypes Kashi Amrit and Azad T 5 were stable for average fruit weight and the genotype H 24 was stable for number of fruits/plant (Table 4).

This study suggests minimal temporal variability of H 86, Kashi Amrit, and Pusa Sadabahar hence, can be recommended for smaller farmers who seek sustainability in the fruit yield across environments and years. The genotypes FLA 7171, Punjab Upma, Selection 7 may be recommended for large farmers or industries where input-intensive cultivation is feasible.

सारांश

टमाटर की 21 प्रभेदों को उपज एवं उपज सम्बन्धी गुणों के लिए वर्ष 2010–11 से 2014–15 तक मूल्यांकन किया गया। पाँच वर्षीय ऑकड़ों के समाहित प्रसरण विश्लेषण के द्वारा सभी गुणों के लिए अत्यन्त महत्वपूर्ण प्रभेदात्मक एवं वातावरणात्मक असर पाया गया। प्रभेद वातावरण घटक जनित प्रसरण प्रति पौध फलों की संख्या एवं प्रति पौध फल उपज के लिए महत्वपूर्ण पाया गया। रैखिक वातावरणीय प्रसरण सभी गुणों के लिए महत्वपूर्ण पाया गया। प्रभेद वातावरण रैखिक घटक भी सभी गुणों के लिए महत्वपूर्ण पाया गया। औसत फल भार के लिए काशी अमृत एवं आजाद टी–5 एवं प्रति पौध फलों

की संख्या के लिए एच–24 प्रभेद अचल पाया गया। एच–86, काशी अमृत, पूसा सदाबहार प्रभेद प्रति पौध फल उपज के लिए स्थिर पाये गये। बीटी–120, एनडीटीवीआर–60, पंजाब उपमा, पूसा सदाबहार प्रभेद औसत फल भार के लिए एवं जीटी प्रभेद प्रति पौध फलों की संख्या के लिए पाये गये। फ्ला–7171, पंजाब उपमा एवं सेलेक्शन–7 प्रभेद प्रति पौध फल उपज के लिए प्रभावनीय पाये गये।

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