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RESEARCH ARTICLE

EVALUATION OF TOMATO GENOTYPES (*SOLANUM LYCOPERSICUM* L.) FOR FRUIT SHELF-LIFE AND TOMATO LEAF CURL DISEASE

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ABSTRACT

Tomato fruit shelf-life is an important fruit quality trait and tomato leaf curl is most devastating plant disease in the world. In this study, fifty-five genotypes were screened for resistance/ susceptible reaction against tomato leaf curl disease under field conditions (summer) 2014 at UAS, Bangalore and estimated the shelf-life of tomato. Out of fifty-five genotypes, seventeen genotypes recorded leaf curl resistance as shown in the bracket EC816103 (0%), EC816101 (0%), EC816099 (2.77 %), EC816098(0%), EC816100 (0%), EC816104 (0%), EC802390 (2.77 %), EC802400 (0%), EC802398(0%), EC-802391(0%), EC802404(0%), EC802402(4%), EC802394(0%), EC802397(0%), EC802399(0%), ARKA ABHA (0%) and H-7998 (0%). Three genotypes Arka-Samrat (18.36%), Arka-Rakshak (18.36%) and RIL-118(18.36%) moderately resistant, three genotypes Sankranti (19.74%), RIL-160 (25%) and RIL-119 (25%) were moderately susceptible, Anaga(51.84%) was susceptible and thirty-one genotypes were highly susceptible. The fruit shelf-life observed lowest in Pusa Ruby (14 days) and maximum in RIL-108 (60 Days) at 28^0C. The minimum weight losses observed in EC-802392 (3 g) and highest in Arka Rakshak (18 g). In this study, we have identified EC 802400 and EC 80404 having maximum shelf-life of 50 days, highly resistant to tomato leaf curl virus with no symptoms and minimum percent of Physiological loss of weight 15 and 23.6 respectively.

INTRODUCTION

Tomato (*Solanum lycopersicon* L.), belongs to Solanaceae family, its ranks third in priority after Potato and Onion in India. In India, the tomato is grown in 1204,000 ha with a production of 19402,000 mt and productivity of 16.1 mt ha^{-1} (Indian Horticulture Database, 2014). The productivity of tomato in India is very less compared to world scenario. There are many constraints for less productivity and quality. The production and quality of tomato fruits are considerably affected by an array of insect pests infesting at different stages of crop growth and perishable nature of fruit respectively. Over two hundred diseases are listed worldwide (Gry, 1994). Of these, leaf curl disease is an important and major constraint in the higher production of tomato fruits (Pico *et al*., 1996, Moriones and Navas- Castillo, 2000. TYLCV causes tomato leaves to curl and turn yellow. The virus, which is transmitted by the whitefly, *Bemisia tabaci* Gennadius, belongs to the group of “Geminiviruses” (Cohen and Harpaz, 1964; Czosnek *et al*., 1989; Czosnek and Laterrot, 1997; Fouquet *et al*., 2003). Severity of insect pest depend upon the genotype of crop and environmental condition, in Indian situation Meena and Bairwa, (2014) were observed the peak incidence of whitefly (62.12 mean population/6 leaves) in first week of November. In another study Rishikeshmandloi *et al*, (2015) observed the, *Bemisia tabaci* Genn population November 2012 to March 2013 with two distinct peaks during 7th and 9th Standard Week (9.84 and 11.85 flies/10 cm twig). The disease induces severe stunting, bushy growth and partial or complete sterility depending on the stage at which infection has taken place. The infected plant bears few or no fruit. The disease is serious throughout India and yield losses may be as high as 100% (Kalloo, 1988). Fruit shelf life is an important trait which determines the market value and availability of fruits in markets. Post-harvest losses estimate from farm gate to consumer stage 13-26% of total harvested tomatoes (Kalidas and Akila, 2014). Post-harvest losses are due to perishable nature of crop, method of harvesting, packaging, and transportation etc. perishability of crop improved by many ways but an exploration of genetic diversity within the available germplasm is a viable and environmentally safe option for improving shelf life. Many breeders have used the mutant germplasm for fruit shelf life and tried to increase shelf

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life of tomato (Mutschler *et al*., 1992, Dias *et al*. (2003), Faria *et al*. (2003), Garg *et al*. (2008), Garg and Cheema (2011), Rodríguez *et al*. (2011), Casals *et al*. (2012), CVIKIC *et al*. (2012), Yogendra and Gowda (2013) and Pech *et al*. (2013). It was, thus, hypothesized that in nature a lot of diversity is available, first and foremost work is identification of best germplasm for extended shelf life, minimum percent of Physiological loss of weight (PLW) and resistance for leaf curl disease and exploration of genetic diversity is the best methodology of crop improvement. Considering this, an investigation was undertaken to identify the tomato germplasm having extended shelf life with a minimum percent of Physiological loss of weight (PLW) and determine the level of resistance/susceptibility under glasshouse conditions.

MATERIALS AND METHODS

The experiment was carried out under field conditions at UAS, Bangalore, Karnataka during summer 2014. The fifty-five tomato genotypes/ cultivars/ lines were collected from different sources (Table 2). The seedlings were grown in greenhouse and 25 days old seedlings of fifty-five tomato genotypes/ cultivars/ lines were transplanted during summer 2014 in randomized block design, which was replicated thrice. All the Fifty-five tomato genotypes/ cultivars/ lines were screened against ToLCV causing leaf curl disease in tomato, fruit shelf-life and Physiological loss of weight (PLW).

ToLCV incidence and severity

Based on the percent of curling and puckering of leaves, the plants were scored using 0-4 scale as suggested by Banerjee and Kalloo (1987). 0: Symptoms absent; 1: very mild curling (up to 25% leaves); 2: curling and puckering of 26-50 % leaves; 3: curling and puckering of 51-75 % leaves; 4: severe curling and puckering of >75 % leaves. Based on the disease score, percent disease severity (PDS) was calculated using the following formula:

$$PDS = \frac{\text{Sum of numerical rating}}{\text{Total number of plants observed x maximum disease grade}} \times 100$$

Percent disease incidence (PDI) was calculated using the following formula.

$$PDI = \frac{\text{Number of plant infected}}{\text{Total number of plants observed}} \times 100$$

Based on the percent disease severity (PDS) and percent disease incidence (PDI) the coefficient of the infection (CI) was calculated using following formula.

$$CI = \frac{PDS \quad X \quad PDI}{100}$$

Based on the coefficient of infection the genotypes were categorized into six groups (Banerjee and Kalloo (1987). 0-4: Highly resistant (HR); 4.1-9: Resistant (R); 9.1-19: Moderately Resistant (MR); 19.1-39: Moderately Susceptible (MS); 39.1-69: Susceptible (S); 69.1-100 : Highly Susceptible (HS)

Evaluation of shelf life

For evaluation of tomato fruit shelf life we used methodology followed by Yogendra and Gowda, (2013). Five tomato fruits at breaker stage were harvested and stored at 28° ± 1°C and shelf life in days were assessed at weekly intervals. Shelf life was measured as the number of days elapsed between the harvest of fruits at the breaker stage and the end of the consumption stage (first symptoms of deterioration and excessive softening).

Physiological loss of weight (PLW)

For determining PLW of all tomato Genotype fruits, the weight of the fruit was recorded at the breaker stage and the total loss of physiological weight was then calculated by subtracting the final weight of the fruit from the initial weight. The results were then expressed in percentage using following formula (Koraddi and Devendrappa, 2011):

$$\% \; PLW = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \; X \; 100$$

RESULTS AND DISCUSSION

Analysis of variance (Table 1) for fruit shelf-life and percent of Physiological loss of weight revealed that the variance due to genotypes effects was highly significant (@ P = 0.01).

Screening for ToLCV- resistance under field conditions

Several methods have been developed to control ToLC, such as the use of healthy transplants, chemical and physical control of the vector, crop rotation, and breeding for resistance to ToLCV is considered to be the best method for the management of plant diseases (Nakhla and Maxwell 1998). The breeding of tomatoes resistant to ToLCV has been slow because of the complicated inheritance of the resistance/ tolerance trait. Depending on the source, resistance has been reported to be controlled by one to five genes that are either recessive or dominant (Zakai *et al*. 1990).

Table 1. Analysis of variance for fruit shelf-life and post-harvest losses traits in fifty-five tomato genotypes

Sl.no.	Source of variation	df	Fruit shelf-life (Days)	Post-harvest losses(g)
1	Treatments	54	310.53**	41.72**
2	Error	110	37.48**	9.09**
3	Total	164		
	SEm±		3.53	1.74
	CD at 1%		13.10	6.45

** Significant at 1%

Therefore, available varieties were screened in open fields so as to find out the source of the resistance in tomato against tomato leaf curl virus disease under field conditions. The severity of disease was determined by using percent disease severity, percent disease incidence and coefficient of infection.

Percent disease severity

Percent disease severity result as indicated in Table 2 revealed that tomato genotypes exhibited a wide range of resistance reaction to the tune of 0 to 100 % against ToLCV under field condition during summer season. Among the fifty-five genotypes, the fourteen genotypes (EC816103, EC816101, EC816098, EC816100, EC816104, EC802400, EC802398, EC-802391, EC802404, EC802394, EC802397, EC802399, Arka Abha and H-7998 recorded disease severity of 0.00 % without any symptoms. Two genotypes (EC816099 and EC802390) recorded disease severity of 16.66 %. Twenty-seven genotypes recorded disease severity of 100 %. In Seven genotypes the disease severity recorded < 20 to 50 > %. Camara *et al*., 2013 screened forty-one tomato genotypes for ToLCV under field condition and recorded percent disease severity 0 % to 89.3 %. They observed that eleven genotypes were totally symptom-free and percent disease of incidence up to 100%, severity was generally over 50%. Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan developed these EC series lines and also found percent disease severity

Table 2. Screening of fifty-five tomato genotypes against tomato leaf curl during 2013-2014

S. No.	Genotype	Source	PDS	PDI	CI	Reaction
1	EC816103	AVRDC,Taiwan	0.00	0.00	0.00	HR
2	EC816101	AVRDC,Taiwan	0.00	0.00	0.00	HR
3	EC816097	AVRDC,Taiwan	100	100	100	HS
4	EC816102	AVRDC,Taiwan	100	100	100	HS
5	EC816099	AVRDC,Taiwan	16.66	16.66	2.77	HR
6	EC816156	AVRDC,Taiwan	100	100	100	HS
7	EC816098	AVRDC,Taiwan	0.00	0.00	0.00	HR
8	EC816107	AVRDC,Taiwan	100	100	100	HS
9	EC815157	AVRDC,Taiwan	100	100	100	HS
10	EC816100	AVRDC,Taiwan	0.00	0.00	0.00	HR
11	EC816106	AVRDC,Taiwan	100	100	100	HS
12	EC816105	AVRDC,Taiwan	100	100	100	HS
13	EC816104	AVRDC,Taiwan	0.00	0.00	0.00	HR
14	EC816108	AVRDC,Taiwan	100	100	100	HS
15	EC802395	AVRDC,Hyderbad	25	100	100	HS
16	EC802393	AVRDC,Hyderbad	100	100	100	HS
17	EC802403	AVRDC,Hyderbad	100	100	100	HS
18	EC802401	AVRDC,Hyderbad	83.33	83.33	69.43	HS
19	EC802390	AVRDC,Hyderbad	16.66	16.66	2.77	HR
20	EC802400	AVRDC,Hyderbad	0.00	0.00	0.00	HR
21	EC802396	AVRDC,Hyderbad	100	100	100	HS
22	EC802398	AVRDC,Hyderbad	0.00	0.00	0.00	HR
23	EC-802391	AVRDC,Hyderbad	0.00	0.00	0.00	HS
24	EC802404	AVRDC,Hyderbad	0.00	0.00	0.00	HR
25	EC802402	AVRDC,Hyderbad	20.00	20.00	4.00	HR
26	EC802394	AVRDC,Hyderbad	0.00	0.00	0.00	HR
27	EC802397	AVRDC,Hyderbad	0.00	0.00	0.00	HR
28	EC-802392	AVRDC,Hyderbad	100	100	100	HS
29	EC802399	AVRDC,Hyderbad	0.00	0.00	0.00	HR
30	ARKA ALOK	IIHR,Bangalore	100	100	100	HS
31	ARKA MEGHALI	IIHR,Bangalore	100	100	100	HS
32	ARKA ABHA	IIHR,Bangalore	0.00	0.00	0.00	HR
33	VAIBHAV	UAS,Bangalore	85.71	85.71	73.46	HS
34	SANKRANTI	UAS,Bangalore	44.44	44.44	19.74	MR
35	PED	Ashoka Seed Pvt. Ltd.Bangalore	100	100	100	HS
36	L121	IIHR,Bangalore	100	100	100	HS
37	KASHI VISHES	IIVR, Varanasi	100	100	100	HS
38	KASHI AMRIT	IIVR, Varanasi	100	100	100	HS
39	INDAM-1004	Indo American Hybrid Seeds India Pvt. Ltd.Bangalore	100	100	100	HS
40	ARKA SAMRAT	IIHR,Bangalore	42.85	42.85	18.36	MR
41	PUSA RUBY	IARI, New Delhi	100	100	100	HS
42	IC3945	IIHR,Bangalore	100	100	100	HS
43	CRA66	IIHR,Bangalore	100	100	100	HS
44	NS2535	Namdhari Seed Pvt. Ltd. Bangalore	100	100	100	HS
45	PKM-1	TNAU, Coimbatore	100	100	100	HS
46	H-7998	IIHR,Bangalore	0.00	0.00	0.00	HR
47	ANAGA	Kerala Agricultural University	66.66	77.77	51.84	S
48	S-22	Ashoka Seed Pvt. Ltd.Bangalore	100	100	100	HS
49	ARKA RAKSHAK	IIHR,Bangalore	42.85	42.85	18.36	MR
50	RIL-108	UAS,Bangalore	100	100	100	HS
51	RIL-127	UAS,Bangalore	100	100	100	HS
52	RIL-160	UAS,Bangalore	50	50	25	MS
53	RIL-119	UAS,Bangalore	50	50	25	MS
54	RIL-118	UAS,Bangalore	42.85	42.85	18.36	MS
55	RIL-169	UAS,Bangalore	100	100	100	HS

PDS - Percent disease severity, PDI - Percent disease incidence, CI - Coefficient of the infection
HR- Highly Resistant, R- Resistant, MR- Moderately Resistant,
MS-Moderately Susceptible, S- Susceptible, HS- Highly Susceptible.

depends upon *TY* gene combinations. If any of the *TY* locus is present in germplasm that reduces the Percent disease severity. Lapidot et al. (1997), working on varieties TY 172 and TY 197, revealed their resistance to ToLCV and their low harvest losses compared to other commercial varieties susceptible to the disease.

(EC816097, EC816102, EC816156, EC816107, EC815157, EC816106, EC816105, EC816108, EC802395, EC802393, EC802403, EC802396, EC-802392, Arka Alok, Arka Meghali, PED, L121, Kashi Vishes, Kashi Amrit, INDAM-1004, Pusa Ruby, IC3945, CRA66, NS2535, PKM-1, S-22, RIL-108, RIL-127 and RIL-169) all the plants were infected, the percent

Table 3. Mean performance of fruit shelf-life and percent weight losses during storage of fifty-five tomato genotypes during 2013-2014

S. No.	Genotype	Fruit shelf life(Days)	Percent weight losses(g)
1	EC816103	21	24.0
2	EC816101	43	24.8
3	EC816097	50	14.0
4	EC816102	46	14.2
5	EC816099	50	14.7
6	EC816156	46	10.3
7	EC816098	25	9.3
8	EC816107	50	10.7
9	EC815157	36	14.0
10	EC816100	36	34.1
11	EC816106	42	17.5
12	EC816105	41	6.7
13	EC816104	37	15.6
14	EC816108	42	3.5
15	EC802395	50	7.1
16	EC802393	42	8.7
17	EC802403	42	31.9
18	EC802401	34	9.8
19	EC802390	25	27.1
20	EC802400	50	15.0
21	EC802396	36	13.3
22	EC802398	46	31.5
23	EC-802391	48	17.6
24	EC802404	50	23.6
25	EC802402	42	11.7
26	EC802394	42	10.2
27	EC802397	41	11.4
28	EC-802392	46	11.9
29	EC802399	39	57.9
30	ARKA ALOK	21	27.1
31	ARKA MEGHALI	50	25.0
32	ARKA ABHA	25	36.2
33	VAIBHAV	20	11.6
34	SANKRANTI	28	15.3
35	PED	25	61.9
36	L121	38	23.4
37	KASHI VISHES	35	8.9
38	KASHI AMRIT	30	12.1
39	INDAM-1004	38	54.4
40	ARKA SAMRAT	44	22.1
41	PUSA RUBY	14	15.2
42	IC3945	25	57.9
43	CRA66	30	13.6
44	NS2535	35	44.4
45	PKM-1	37	12.9
46	H-7998	34	25.6
47	ANAGA	22	23.1
48	S-22	29	25.2
49	ARKA RAKSHAK	43	11.6
50	RIL-108	60	8.2
51	RIL-127	44	8.7
52	RIL-160	56	8.9
53	RIL-119	50	16.9
54	RIL-118	46	13.1
55	RIL-169	50	13.0

Percent disease incidence

The percent disease incidence was calculated using formula, the number of plants infected divided by a total number of plant observed multiplied by 100. The result of percent disease incidence mentioned in Table 2. Out of fifty-five genotypes, fourteen genotypes were not infected by the virus, it means 0 % percent disease incidence. While in Twenty-nine genotypes,

disease incidence observed was 100 %. The Percent disease severity recorded in EC 802395 was 25 % and percent disease incidence was 100 % whereas Percent disease severity in Anaga was 66.66 % and percent disease incidence was 77.77%. The percent disease incidence and Percent disease severity values could be used to class the genotypes as tolerant or susceptible. Rao *et al*., (2016) reported, the percentage of disease incidence in tomato and chillies showed more than

77% in all villages during Hagay season but the severity was observed between 20 and 60%. Maruthi *et al*., 2003 screened thirty four tomato genotypes for ToLCV under glasshouse and field conditions and found sixteen Varieties were resistant. Joshi and Choudhury, 1981; Muniyappa *et al*., 1991; Nateshan *et al*., 1996 have also reported the Varieties resistant to tomato leaf curl virus.

Coefficient of the infection (CI)

The coefficient of the infection of fifty-five tomato genotypes are mentioned in Table 2. Based on the coefficient of infection, the genotypes were categorized into six groups Banerjee and Kalloo (1987).

evaluated hybrid tomatoes against ToLCV disease and none of the lines found resistant or tolerant. Sannaulla *et al.* (2007) evaluated 29 tomato genotypes for resistance to the virus and found that none of the genotypes showed resistance reaction. The EC series lines which were developed by Asian Vegetable Research Development Centre Taiwan has resistant reaction to ToLCV. The EC genotype which is highly resistant under natural condition can be used as a resistant source for developing resistant/ tolerant varieties/ hybrids against ToLCV. Several other important contributions were made on this aspect are also available in the literature (Singh *et al*., 2008; Mohanta *et al*., 1998; Pico *et al.,* 1998; Singh *et al*., 2011).

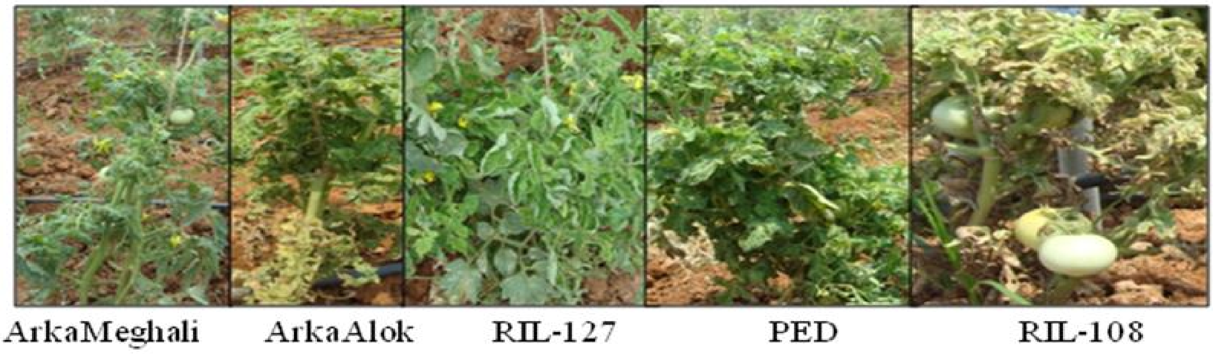

Fig.1. Severe tomato leaf curl symptoms in Arka Meghali, Arka Alok, RIL-127, PED and RIL-108

Fig. 2. Tomato leaf curl resistant lines EC-802399, EC-802400, EC-802398, EC802380 and H-7998

Highly resistant reaction was found in seventeen genotypes, EC816103 (0%), EC816101 (0%), EC816099 (2.77 %), EC816098(0%), EC816100 (0%), EC816104 (0%), EC802390 (2.77 %), EC802400 (0%), EC802398(0%), EC-802391(0%), EC802404(0%), EC802402(4%), EC802394(0%), EC802397(0%), EC802399(0%), ARKA ABHA (0%) and H-7998 (0%) (Fig.2). Three genotypes Arka-Samrat (18.36%), Arka-Rakshak (18.36%), and RIL-118 (18.36%) were found to be moderately resistant, where as Sankranti (19.74 %), RIL-160 (25 %) and RIL-119 (25 %) were moderately susceptible, Anaga (51.84 %) was observed susceptible, whereas thirty-one genotypes were observed highly susceptible (Fig.1) and none of the lines were observed resistant against ToLCV infection (Table 2). Singh 2014 also observed the coefficient of the infection in Kashi Vishesh (8.06 %), Kashi Amrit (8.20 %), Arka Meghali (52.74 %), Arka Alok (52.38 %) and Pusa Ruby (25.33 %). Yadav and Awasthi, 2009 reported the coefficient of the infection in Arka Meghali (68.34%), Arka Alok (75.00 %) and Pusa Ruby (62.42%). Many researchers reported that wild tomato accessions such as H-7998 as resistant sources for ToLCV (Banerjee and Kalloo, 1989 and Banerjee and Kalloo, 1990). Chakraborty *et al.* (2006)

Fruit shelf-life

With respect to fruit shelf-life, the Pusa Ruby was recorded minimum (14 days) whereas RIL-108 recorded maximum (60 days) (Table 3, Fig. 3). The Indian cultivar Arka Alok (21 days), Arka Abha (25 days), Vaibhav (20 days), Sankranti (28 days), PED (25 days), Kashi Vishes (35 days), Kashi Amrit (30 Days), Anaga (22 days) and S-22(29 days) were recorded. some of the genotypes recorded shelf-life of more than 50 days EC816097 (50 days), EC816099 (50 days), EC816107(50 days), EC802395 (50 days), EC802400(50 days), EC802404 (50 days), Arka Meghali (50 days), RIL-108 (60 days), RIL-160 (56 Days), RIL-119 (50 Days) and RIL-169 (50 days). Kumar *et al*., (2016) also observed some of the RILs 108, 160 and 169 have fruit shelf-life more than 60 Days these lines were derived from *alc* parent which is responsible for delayed ripening. In another study, Yogendra and Gowda, 2013, observed *alc* line fruit shelf-life was 44 days significantly higher than that in the other ripening gene mutants *rin* (38 days) and *nor* (38.5 days). Indian cultivars ‘Sankranti’ and ‘Vaibhav’ had observed fruit shelf-life of 19 and 18.50 days, respectively, which was higher than that of ‘Pusa Ruby’ 14.5

days. The RIL-108, RIL-160, RIL-119 and RIL-169 which were derived from the *alc* parent hence the fruit shelf-life is more. Kumar and Gowda, (2016) used *alc* derived RILs for development of hybrids with extended shelf-life and found that shelf-life of hybrids increased up to 60 Days. Pawar *et al*., 2016 also found that the fruit shelf-life increased up to 85 days in *alc* derived line. Similar results were also observed by de Vicente and Tanksley (1993) in F_7 lines which had higher and lower shelf-life compared to parental lines.

Physiological loss of weight (PLW)

Water loss is the principal cause of fruit softening and shriveling. Wilson *et al*., (1999) observed that many fruits, vegetables, and flowers become shriveled after losing only a small percentage of their original weight due to water loss. Therefore there is a need for fresh fruit to have adequate water to be able to prolong the shelf-life of the fruit even when it loses some amount of water during storage. Percent of physiological loss weight was observed minimum in EC816108 (3.5 %) and maximum in PED (61%) followed by EC802399 (57.9%) and INDAM-1004 (54.4%) Table 3. In some of the high shelf-life lines viz; EC816097 (14%), EC816099 (14.7%), EC816107 (10.7%), EC802395 (7.1%), EC802400 (15%), RIL-108(8.2%), RIL-160(8.9%) and RIL-169 (13%) less percent of physiological loss of weight was also observed. In similar study by Koraddi and Devendrappa, (2011) percent of Physiological loss of weight in tomato, chilli, French bean, cucumber, carrot, fenugreek, coriander and lady's finger was also observed in different packaging materials. They found that cumulative physiological loss of weight of all the selected vegetables was maximum in brown paper bags while it was minimum in polyethylene bags. We have also observed maximum loss of fruit weight kept in brown paper bags.

Conclusion

Our goal of this research was to identify those germplasms which have resistant to tomato leaf curl virus (ToLCV), extended shelf-life and minimum percent of Physiological loss of weight. In this study, we have identified EC 802400 and EC 80404 having highest shelf-life, highly resistant to tomato leaf curl virus and minimum percent of Physiological loss of weight. Further, these genotypes will be screened against tomato leaf curl virus with artificial inoculation and fruit quality traits.

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