Journal of Applied and Natural Science 7 (2) : 672 - 680 (2015)

JANS

Impact of *Alternaria solani* (Early blight) on cultivated tomato (*Solanum lycopersicum* L.) in North-eastern region of India and identification of early blight disease resistant tomato genotypes

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Received: January 29, 2015; Revised received: June 22, 2015; Accepted: August 25, 2015

Abstract: The present investigation was carried out to screen genotypes for resistance to Early blight disease of tomato (*Solanum lycopersicum* L.) of North Eastern region of India. Field trial was conducted in the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat during the years 2012-13 and 2013-14 consecutively. The disease severity of tomato genotypes was assessed by 0-5 points scale, percent Disease Incidence (PDI). Of the total materials screened, Sel-35 (TLBRH-6 X Konbilahi) and Sel-19 (TLBRH-6 X Konbilahi) were highly resistant, 7 were resistant, 14 were moderately resistant, 16 were susceptible and 6 were highly susceptible under field condition after inoculation during both years. The genotype having high yield and resistant to early blight was 10/TOLCVRES-3. The genotypes resistant to early blight but having low yield (Sel-35, Sel-19, Sel-9 and Sel-16) may be utilized in future breeding programme for improving yield through selection for higher fruit weight and fruit diameter. Alternatively, they may be used as parents in hybridization or backcrossing programme in order to transfer the gene for resistance to early blight to already adapted high yield varieties.

Keyword: Early blight, North-eastern region, Resistant, *Solanum lycopersicum*

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) [formerly *Lycopersicon esculentum* Miller] is one of the most significant vegetable crops and cultivated in throughout the globe. In plant breeding study, the main objective of a breeder is to improve the fruit yield, a complex quantitative trait leading continuous variation, especially in major vegetable crops like tomato. Determining the appropriate selection indicia and development of efficient breeding scheme, the studies on genetic parameters and association analysis is much important (Chaerani *et al*., 2007; Sharma *et al*., 2008). The maladies leading to various horticultural yield loses in tomato is caused by fungi, bacteria, viruses, nematodes and also abiotic factors (Balanchard, 1992). Globally, early blight caused by the pathogen *Alternaria solani* (Ellis and Martin) Sorauer, most aggressive and destructive disease (Fry, 2008; Kumar and Srivastava, 2013) is an economically remarkable malady (Peralta *et al*., 2005; Singh *et al*., 2013) of cultivated tomato. The different agro-climatic zones suffer with heavy dew (Rotem and Reichert, 1964; Singh *et al*., 2011), heavy rainfall [Northeast region of India reported the highest rainfall receiving on the earth (Jain *et al*., 2012), high humidity (Sherf and MacNab, 1986; Singh *et al*., 2013) and fairly high temperatures (24-29°C) (Yadav and Singh, 1998; Singh *et al*., 2013) are more prevalent of this malady. Thus, it leads the most difficult tasks for plant breeder when high temperature and humidity conditions are prevalent. The damages caused by early blight from various parts of the countries *viz.,* India, Canada, United States and Nigeria (Basu, 1974) reported agricultural yield losses up to 79% (Basu, 1974; Singh, 1985; Datar and Mayee, 1981, Yadav and Dabbas, 2012). In horticultural fruit crops loss may be as high as 95% under severe epiphytotic condition (Sridha and Naik, 1983). Disease-management strategies mainly depend on chemical fungicide applications, which are uneconomical and less effective due to increasing resistance of the pathogen against fungicides. Thus, identification of resistant sources from wild tomato species may be an effective method of integrated disease management strategy by reducing the environmental pollution by chemical toxicity. Early blight resistance was conferred by recessive polygenes at both seedling and adult plant stages (Thirthammallappa and Lohithaswa, 2000). Many researchers identified the potent resistant to moderate resistant sources mainly in wild species *S.*

ISSN : 0974-9411 (Print), 2231-5209 (Online)

pimpinellifolium L. [formerly *L. pimpinellifolium* (L.) Mill.] (Kalloo and Banerjee, 1993; Foolad, 2002 and 2005), S. *peruvianum* L. [formerly *L. peruvianum* (L.) Mill.] (Chaerani *et al*., 2007) and *S. habrochaites* (formerly *L. hirsutum* Dunal) (Barksdale and Stoner, 1977; Chaerani *et al*., 2007; Kalloo and Banerjee, 1993; Poysa and Tu, 1997; Foolad *et al*., 2000; Thirthamalappa and Lohithaswa, 2000; Singh *et al*., 2013).

Development and screening of early blight-resistant tomato cultivars following appropriate plants breeding tools is the only possible path for the identification and utilization of genetic resources resistant to *Alternaria solani* (Ellis and Martin) Sorauer in tomato. Although vast genetic diversity exists in well adapted cultivars/ germplasms in tomato in North-eastern region of India, so far not much systematic study on resistance or susceptibility level of existing tomato genetic resources has been conducted. The production of this crop is low in North-eastern states of India, which falls in the highest rainfall receiving regions on the earth (Jain *et al*., 2012), as compared to the other states of the country. Besides other reasons, the problems associated with lower production are non availability of good varieties and incidence of diseases affecting the crop. Therefore, it is important to study the available genotypes of the crop in order to identify high yielding varieties with desirable characteristics like earliness and resistance to pest and diseases. Considering the points mentioned above, a study for finding out the extent of genetic variability for yield and resistance to early blight in tomato (*Solanum lycopersicum* L.) was undertaken to evaluate tomato genotypes for variability in yield and yield attributes and screening the genotypes for tolerance/ resistance to early blight.

MATERIALS AND METHODS

The present investigation was carried out in the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat. Forty-five (Table-1) tomato genotypes were planted during *Rabi* season 2012-13 and 2013-14 consecutively in a randomized block design with two replications. The crops were grown following recommended package of practices. They were evaluated for yield and resistance to early blight in field conditions.

Observations were taken from five randomly selected plants from each treatment and each replication in the field trial conducted as specified below to screen the cultivars against the pathogen. The disease severity was assessed on all leaves and scored on 0-5 points scale as suggested by Pandey *et al*. (2003) and percent disease incidence (PDI) was calculated following Mckinney (1923) formula. Later, the disease reaction based on PDI (Fig.3) was recorded according to the scale given by Peteira e*t al*. (2002). After 7 days of incubation, plants were individually evaluated for disease scoring following disease scale (Pandey *et al.,* 2003). The percentage of infection on the leaves were observed and recorded.

The disease severity was scored on a five-point scale:

0 - Free from infection,

1 -One or two necrotic spots on a few lower leaves of plants,

2 - A few isolated spots on leaves, covering nearly 5-10% of the surface area of the plant,

3 - Many spots coalesced on the leaves, covering 25% of the surface area of the plant,

4 - Irregular, blighted leaves and sunken lesions with prominent concentric rings on the stem, petiole, and fruit, covering 40-50% of the surface area,

5 - Whole plant blighted, leaves and fruits starting to fall; foliar part free of disease.

From the disease scored obtained from the above five point scale, percent disease index (PDI) (McKinney, 1923; Pandey *et al*., 2003) is calculated.

$$PDI = \frac{\text{Sum of all rating X 100}}{\text{Total no. of observations X maximum rating grade}}$$

After finding out the PDI values, the disease reaction classes for early blight infection based on percent disease severity in tomato were given as prepared by Peteira *et al*. (2002).

Disease reaction	**PDI range**
Highly resistant	0-12.5
Resistant	12.6–25.0
Moderately resistant	25.1–37.5
Susceptible	37.6–50.0
Highly susceptible	50.1 and above

The yield per ha data from each genotype obtained from disease free condition and that from disease infested conditions were taken separately to find out the loss in yield due to disease incidence. Later, it is calculated in percentage loss.

RESULTS AND DISCUSSION

The tomato genotypes differed in their resistance reaction against early blight (Table -3). Of the total forty five genotypes screened, Sel-35 (TLBRH-6 X Konbilahi) and Sel-19 (TLBRH-6 X Konbilahi) were highly resistant (which are the selections in segregating generations of the crosses between TLBRH-6 and *S. pimpinellifolium* L. [formerly *L. pimpinellifolium* (L.) Mill.] with PDI value range (0-12.5 %), 7 varieties were resistant with PDI value range (12.6-12.5 %), 14 were moderately resistant with PDI value range (25.6 -37.5 %), 16 were susceptible with PDI value range (37.6-50 %) and 6 were highly susceptible with PDI value range (50.1 and above %) under field condition after inoculation during both years (Tables 2-4, Fig. 1). The genotype with earliness, high yield (Khaidem *et al.,* 2014) and resistance to early blight was 10/

Table 1. Genotypes used for study and their salient characteristics.

S. N.	Genotypes	Source	Plant type	Duration (days)	Fruit size	Fruit shape
1	2012/TOLCVRES-1	AICRP (VC)	Determinate	124	Medium	Oval
2	2012/TOLCVRES-2	AICRP (VC)	Determinate	122	Medium	Flat
3	2012/TOLCVRES-3	AICRP (VC)	Determinate	111	Large	Oblong
4	2012/TOLCVRES-4	AICRP (VC)	Determinate	122	Medium	Round
5	2012/TOLCVRES-5	AICRP (VC)	Determinate	119	Medium	Round
6	2012/TOLCVRES-6	AICRP (VC)	Determinate	124	Medium	Round
7	2012/TOLCVRES-7	AICRP (VC)	Determinate	120	Large	Round
8	2012/TOLCVRES-8	AICRP (VC)	Determinate	124	Large	Round
9	2012/TOLCVRES-9	AICRP (VC)	Determinate	117	Medium	Round
10	2012/SPT/TOINDVAR-1	AICRP (VC)	Indeterminate	131	Medium	Round
11	2012/SPT/TOINDVAR-2	AICRP (VC)	Indeterminate	133	Large	Oblong
12	2012/SPT/TOINDVAR-3	AICRP (VC)	Indeterminate	131	Medium	Oval
13	2012/SPT/TOINDVAR-4	AICRP (VC)	Indeterminate	130	Medium	Round
14	2012/SPT/TOINDVAR-5	AICRP (VC)	Indeterminate	130	Medium	Round
15	2012/SPT/TOINDVAR-6	AICRP (VC)	Indeterminate	122	Medium	Round
16	2012/SPT/TOINDVAR-7	AICRP (VC)	Indeterminate	132	Medium	Flat round
17	2012/SPT/TOINDVAR-8	AICRP (VC)	Indeterminate	130	Large	Flat round
18	2012/SPT/TOINDVAR-9	AICRP (VC)	Indeterminate	134	Medium	Round
19	2012/SPT/TOINDVAR-10	AICRP (VC)	Indeterminate	124	Medium	Round
20	2012/SPT/TODVAR-1	AICRP (VC)	Determinate	117	Medium	Round
21	2012/SPT/TODVAR-2	AICRP (VC)	Determinate	117	Large	Flat round
22	2012/SPT/TODVAR-3	AICRP (VC)	Determinate	120	Medium	Round
23	2012/SPT/TODVAR-4	AICRP (VC)	Determinate	110	Medium	Round
24	2012/SPT/TODVAR-5	AICRP (VC)	Determinate	120	Medium	Oval
25	2012/SPT/TODVAR-6	AICRP (VC)	Determinate	123	Medium	Round
26	2012/SPT/TODVAR-7	AICRP (VC)	Determinate	122	Medium	Pear
27	2012/SPT/TODVAR-8	AICRP (VC)	Determinate	123	Medium	Round
28	2012/SPT/TODVAR-9	AICRP (VC)	Determinate	121	Medium	Round
29	2012/SPT/TODVAR10	AICRP (VC)	Determinate	117	Medium	Round
30	10/TOLCVRES-1	AICRP (VC)	Determinate	122	Medium	Flat round
31	10/TOLCVRES-2	AICRP (VC)	Determinate	118	Large	Pear
32	10/TOLCVRES-3	AICRP (VC)	Determinate	117	Medium	Oval
33	10/TOLCVRES-5	AICRP (VC)	Determinate	115	Medium	Round
34	10/TOLCVRES-6	AICRP (VC)	Determinate	118	Medium	Round
35	Sel-35(TLBRH-6 X Konbilahi)	AAU, Jorhat	Indeterminate	130	Small	Round
36	Sel-19 (TLBRH-6 X Konbilahi)	AAU, Jorhat	Indeterminate	128	Small	Round
37	Sel-46 (H-24 X Konbilahi)	AAU, Jorhat	Semi-indeterminate	125	Small	Round
38	Sel-16 (H-24 X Konbilahi)	AAU, Jorhat	Indeterminate	122	Small	Round
39	Sel-9 (TLBRH-5 X Konbilahi)	AAU, Jorhat	Semi-indeterminate	126	Small	Round
40	Arka vikas	IIHR, Bangalore	Semi- Determinate	124	Medium	Oval
41	Hisar Arun	HAU, Hisar	Determinate	118	Medium	Round
42	H-86	IIVR,Varanasi	Determinate	117	Medium	Flat round
43	Punjab Chhuhara(C)	PAU, Ludhiana	Determinate	116	Medium	Oblong
44	H-24(C)	IIVR, Varanasi	Determinate	106	Slightly small	Round
45	NDT-3(C)	NDUAT, Faizabad	Semi-indeterminate	128	Medium	Oval

Note: AICRP (VC)-All India Coordinated Research Project (Vegetable Crops), AAU-Assam Agricultural University, IIHR-Indian Institute of Horticultural research, HAU-Haryana Agricultural University, IIVR-Indian Institute of Vegetable Research, NDUAT- Narendra Deva University of Agriculture & Technology

Table 2. Percent disease incidence of early blight in the tomato genotypes.

Genotypes/Sources of Origin	Percent disease index (PDI)						Score	
	7 Days after inoculation		22Days after inoculation		37 Days after inoculation		37 Days after inoculation	
	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14	2012-13	2013-14
2012/TOLCVRES-1/	39.25 (38.78)^{a}	42.34 (40.58)^{a}	51.08 (45.60)^{bc}	54.45 (47.56)^{a}	73.56 (59.04)^{b}	72.25 (58.19)^{b}	5	5
2012/TOLCVRES-2/	27.04 (31.30)^{defg}	27.45 (31.56) sdef	36.20 (36.97)^{fgh}	37.35 (37.62)^{e}	48.32 (44.02)^{ef}	49.33 (44.60)^{ef}	4	4
2012/TOLCVRES-3/	11.98 (20.19)^{qr}	10.24 (18.59)st	12.66 (20.83)st	14.35 (22.35)^{tv}	14.34 (22.24)^{uv}	20.34 (26.80)^{r}	2	2
2012/TOLCVRES-4/	21.53 (27.63)^{ijkl}	20.12 (26.64) hijklmno	29.28 (32.74) klmn	27.45 (31.65)^{lmn}	35.55 (36.58) lmno	32.12 (34.51) opq	3	3
2012/TOLCVRES-5/	41.23 (39.93)^{a}	39.09 (38.68)^{a}	55.33 (48.04)^{a}	53.69 (46.60)^{b}	79.43 (63.03)^{a}	77.53 (61.70)^{a}	5	5
2012/TOLCVRES-6/	22.35 (28.20)^{hijkl}	23.00 (28.64) efghijk	31.24 (33.97)^{jkl}	29.76 (32.74) jklm	36.44 (37.11) klmno	36.99 (37.44) jklm	3	3
2012/TOLCVRES-7/	23.02 (28.65)^{hijk}	21.99 (27.95) efghijkl	33.22 (35.18)^{kij}	35.24 (36.43) efgh	42.54 (40.69) ghij	41.21 (39.92)^{hij}	4	4
2012/TOLCVRES-8/	40.01 (39.22)^{a}	33.45 (35.32)^{b}	53.65 (47.08)^{ab}	42.32 (40.74)^{d}	75.32 (60.19)^{ab}	54.45 (47.54)^{d}	5	5
2012/TOLCVRES-9/	20.16 (26.67) jklmnop	19.31 (26.06) hijklmnop	25.03 (30.00)^{p}	24.31 (29.40)^{nop}	30.43 (33.46)^{pq}	31.21 (33.94) opq	3	3
2012/SPT/TOINDVAR-1/	19.35 (26.08) klmno	18.33 (25.34) jklmnopqr	28.25 (32.09) lmno	27.35 (31.44)^{lmn}	36.64 (37.23) klmno	34.11 (35.72) mnopq	3	3
2012/SPT/TOINDVAR-2/	20.25 (26.73) jklmnop	18.73 (25.63) ijklmnopq	29.14 (32.66) klmn	27.35 (31.51)^{lmn}	35.35 (36.46) lmnop	36.47 (37.13) klmn	4	4
2012/SPT/TOINDVAR-3/	35.36 (36.47)^{bc}	24.31 (29.53) defghij	49.71 (44.82)^{c}	36.35 (37.07)^{ef}	72.56 (58.41)^{b}	58.78 (50.04)^{c}	5	5
2012/SPT/TOINDVAR-4/	12.47 (20.66)^{qr}	13.45 (21.50) pqrst	17.25 (24.52)^{qr}	16.34 (24.05)st	24.34 (29.55)^{rs}	20.24 (26.72)^{r}	2	2
2012/SPT/TOINDVAR-5/	28.35 (32.16)^{de}	25.33 (30.20) defgh	39.60 (38.98)^{de}	35.24 (36.36) efgh	50.00 (44.98)^{e}	42.33 (40.57)^{hi}	5	5
2012/SPT/TOINDVAR-6/	27.16 (31.39)^{def}	21.35 (27.50) fghijklm	38.71 (38.46)^{ef}	33.25 (35.18)^{fghi}	49.54 (44.72)^{ef}	40.33 (39.41) hijk	4	4
2012/SPT/TOINDVAR-7/	30.22 (33.33)^{d}	29.45 (32.85) bcd	41.66 (40.18)^{d}	37.55 (37.62)^{e}	49.50 (44.70)^{ef}	47.64 (43.63)^{ef}	5	5
2012/SPT/TOINDVAR-8/	13.10 (21.20)^{qr}	12.20 (20.42)^{rst}	15.24 (22.96)^{rs}	17.34 (24.92)^{rst}	23.44 (28.94)^{rs}	24.10 (29.38)^{r}	3	3
2012/SPT/TOINDVAR-9/	34.25 (35.80)^{d}	25.25 (30.15) defghi	42.34 (40.58)^{d}	36.66 (37.15)^{ef}	54.56 (47.60)^{d}	45.44 (42.37)^{fg}	4	4
2012/SPT/TOINDVAR-10/	18.90 (25.75)^{lmno}	21.01 (27.26) fghijklm	29.00 (32.57) klmno	27.45 (31.44)^{lmn}	36.46 (37.13) klmno	35.44 (36.52) lmno	3	3
2012/SPT/TODVAR-1/	17.34 (24.59)^{nop}	18.33 (25.33) jklmnopqr	26.75 (31.13)^{nop}	23.13 (28.78)^{op}	33.67 (35.45) nopq	32.22 (34.57) nopq	3	3
2012/SPT/TODVAR-2/	22.44 (28.26)^{hijkl}	20.73 (27.07) ghijklmn	32.14 (34.52)^{ijk}	31.35 (34.20)^{hijk}	37.50 (37.75) klmno	37.00 (37.44) jklm	4	4

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2012/SPT/ TODVAR-3/	21.45 (27.57)^{ijklm}	21.75 (27.78)^{fghijkl}	35.08 (36.30)^{ghi}	32.66 (34.74)^{ghij}	44.66 (41.92)^{fgh}	42.24 (40.52)^{hi}	4	4
2012/SPT/ TODVAR-4/	23.46 (28.96)^{ghij}	22.44 (28.26) efghijkl	30.14 (33.28)^{klm}	32.33 (34.50)^{ghij}	38.64 (38.42)^{ijklmn}	40.44 (39.47)^{hijk}	4	4
2012/SPT/ TODVAR-5/	13.45 (21.50)^{qr}	15.21 (22.94)^{nopqrs}	14.35 (22.24)^{rs}	16.25 (23.65)st	18.65 (25.56)^{tu}	20.14 (26.64)^{r}	2	2
2012/SPT/ TODVAR-6/	17.35 (24.60)^{nop}	15.45 (30.45)^{defg}	19.25 (26.01)^{q}	19.85 (26.28)^{qrs}	23.34 (28.87)^{rs}	24.00 (29.32)^{r}	2	2
2012/SPT/ TODVAR-7/	21.34 (27.48)^{ijklm}	20.01 (26.54) hijklmno	26.54 (30.99)^{nop}	24.31 (29.66)^{nop}	30.21 (33.33)^{q}	30.99 (33.81)^{pq}	3	3
2012/SPT/ TODVAR-8/	19.08 (25.88)^{lmno}	19.09 (25.89) hijklmnop	27.33 (31.50) mnop	24.13 (29.65)^{nop}	32.35 (34.65)^{opq}	30.12 (33.27)^{q}	3	3
2012/SPT/ TODVAR-9/	28.21 (32.06)^{de}	33.13 (35.12)^{bc}	37.10 (37.51)^{fg}	42.43 (40.67)^{d}	46.23 (42.82)^{efg}	50.00 (44.98)^{e}	4	4
2012/SPT/ TODVAR10/	38.25 (38.19)^{ab}	39.12 (38.70)^{a}	49.21 (44.53)^{c}	47.27 (43.42)^{c}	64.34 (53.31)^{c}	60.45 (51.01)^{c}	5	5
10/TOLCVRES-1/	17.67 (24.83)^{nop}	16.24 (23.74) lmnopqrs	28.00 (31.93) lmnop	26.45 (30.79)^{mno}	32.91 (34.98)^{nopq}	30.44 (33.45)^{q}	3	3
10/TOLCVRES-2/	25.80 (30.50)^{defgh}	24.31 (29.51)^{defghij}	33.41 (35.29)^{hij}	35.13 (36.55)^{efg}	41.58 (40.14)^{ghijk}	43.00 (40.96)^{gh}	4	4
10/TOLCVRES-3/	24.35 (29.55)^{fghi}	23.12 (28.72) defghijk	34.12 (35.73)^{ghij}	30.24 (33.51)^{ijkl}	45.66 (42.49)^{efg}	43.56 (41.28)^{gh}	4	4
10/TOLCVRES-5/	21.00 (27.26)^{ijklmn}	19.13 (25.92) hijklmnop	28.00 (31.93) lmnop	27.54 (31.44)^{lmn}	37.68 (37.85)^{jklmn}	37.68 (37.85)^{jklm}	3	3
10/TOLCVRES-6/	22.54 (28.33)^{hijkl}	21.15 (27.37) fghijklm	28.71 (32.38) lmno	27.75 (31.44)^{lmn}	36.66 (37.25)^{klmno}	37.00 (37.45)^{jklm}	3	3
Sel-35/	10.23 (18.64)^{r}	7.75 (16.15)^{t}	12.25 (20.47)st	11.46 (19.78)^{uv}	12.50 (20.69)^{v}	12.30 (20.51)^{s}	2	2
Sel-19/	10.50 (18.84)^{r}	7.56 (15.86)^{t}	11.20 (19.53)^{t}	10.00 (18.34)^{v}	12.00 (20.15)^{v}	11.68 (19.95)^{s}	2	2
Sel-46/	9.78 (18.20)^{r}	12.45 (20.64)^{qrst}	15.23 (22.94)^{rs}	21.70 (27.26)^{pqr}	20.19 (26.68)st	24.34 (29.54)^{r}	2	2
Sel-16/	15.20 (22.93)^{pq}	14.32 (22.22)^{nopqrs}	17.34 (24.60)^{qr}	19.74 (26.05)^{qrs}	25.34 (30.21)^{r}	24.45 (29.62)^{r}	2	2
Sel-9/	10.28 (18.68)^{r}	10.25 (18.65)st	12.13 (20.36)st	11.45 (19.56)^{uv}	13.00 (21.11)^{v}	13.00 (21.11)^{s}	2	2
Arka vikas/	29.73 (33.03)^{d}	28.42 (32.20)^{bcde}	30.08 (33.25)^{klm}	32.95 (34.50)^{ghij}	38.12 (38.11)^{jklmn}	40.99 (39.79)^{hijk}	4	4
Hisar Arun /(CCS Haryana Agri. Uni., Hisar)	21.44 (27.57)^{ijklm}	14.05 (21.99)^{opqrs}	25.77 (30.48)^{op}	22.02 (27.96)^{pq}	33.00 (35.05)^{nopq}	35.24 (36.40)^{lmnop}	3	3
H-86/	28.29 (32.12)^{de}	17.72 (24.87) kmnopqr	34.48 (35.94)^{ghi}	22.45 (27.93)^{pq}	43.24 (41.10)^{ghi}	38.54 (38.36)^{ijklm}	4	4
Punjab Chhuhara/ (Punjab Agri. Univ., Ludhiana)	25.34 (30.20)^{efgh}	24.34 (29.54)^{defghij}	29.12 (32.64) klmn	28.75 (32.15)^{klm}	37.00 (37.44)^{klmno}	37.45 (37.70)^{jklm}	3	3
H-24/	16.89 (24.25)^{op}	24.75 (29.82)^{defghij}	29.45 (32.84) klmn	32.45 (34.81)^{ghij}	40.35 (39.42)^{hijkl}	39.46 (38.90)^{hijkl}	3	3
NDT-3/	28.37 (32.17)^{de}	23.37 (28.90) defghijk	36.00 (36.85)^{gh}	36.54 (37.15)^{ef}	45.45 (42.37)^{efg}	42.34 (40.58)^{hi}	4	4
C.D. (5%)	3.26	5.37	2.79	3.20	4.40	3.84		
S.E. (m)	1.14	1.8	0.98	1.12	1.54	1.34		

Table 3. Reaction of tomato genotypes against early blight on the basis percent disease index (PDI).

Score	Reaction	PDI value range (%)	Genotypes
1	Highly resistant	0-12.5	Sel-35 and Sel-19 [2]
2	Resistant	12.6–25.0	2012/SPT/TOINDVAR-4, 2012/SPT/TODVAR-5, 2012/SPT/TODVAR-6, 2012/TOLCVRES-3, Sel-46, Sel-16 and Sel-9 [7]
3	Moderately resistant	25.1–37.5	2012/TOLCVRES-4, 2012/TOLCVRES-6, 2012/TOLCVRES-9, 2012/SPT/TOINDVAR-1, 2012/SPT/TOINDVAR-8, 2012/SPT/TOINDVAR-10, 2012/SPT/TODVAR-1, 2012/SPT/TODVAR-2, 2012/SPT/TODVAR-7, 2012/SPT/TODVAR-8, 10/TOLCVRES-1, 10/TOLCVRES-6, Punjab Chhuhara and Hisar Arun [14]
4	Susceptible	37.6–50.0	2012/TOLCVRES-2, 10/TOLCVRES-3, 2012/TOLCVRES-7, 2012/SPT/TOINDVAR-2, 2012/SPT/TOINDVAR-5, 2012/SPT/TOINDVAR-6, 2012/SPT/TOINDVAR-7, 2012/SPT/TODVAR-3, 2012/SPT/TODVAR-4, 2012/SPT/TODVAR-9, 10/TOLCVRES-9, 10/TOLCVRES-2, 10/TOLCVRES-5, H-24, Arka Vikas, NDT-3 and H-86 [16]
5	Highly susceptible	50.1 and above	2012/TOLCVRES-1, 2012/TOLCVRES-5, 2012/TOLCVRES-8, 2012/SPT/TOINDVAR-3, 2012/SPT/TOINDVAR-9 and 2012/SPT/TODVAR-10 [6]

TOLCVRES-3 which combined all three desirable characters in tomato. The genotypes with low yield (Table- 4) need to be improved by transferring and accumulating the resistant genes from either Sel-35 or Sel-19 or resistant varieties through backcross breeding or gene pyramiding. Gardner, 1988 developed breeding lines NC63EB, NC870, NCEBR-2, NCEBR-3 and NCEBR-4 from C1943 using as a source of early blight resistance. Upadhyay *et al*., (2009) also observed that 'EC 520061', wild species of tomato showed appreciable resistance to early blight disease and can be utilized as a source of resistance in future breeding programme. Singh *et al*., (2011) mentioned about the development of tolerant/resistant tomato plant from wild accessions. Kamble *et al*. (2007) and Mahantesha *et al*., (2012) reported difference in resistance reaction for tomato plants against early blight disease. It was also evident from the study conducted that there was variations in yield and also reduction in yield due to early blight ranges from 2.15% (highly resistant, found on genotype Sel-19) to 42.75% (highly susceptible, found on genotype 2012/ SPT/TOINDVAR-9) (Table -4, Fig.2). The loss in yield varied in the current finding and is directly related with the PDI reading. The tomato genotypes that has higher loss but with greater yield advantages may be useful if they are transferred with suitable resistant gene. In susceptible genotypes the loss in yield due to disease incidence ranges from 16.17% -19.86%. Similar findings in tomato plant with 78% loss in yield was also reported by Datar and Mayee (1981) and 95% tomato fruit loss in under severe epiphytic condition as reported by Sridha and Naik (1983).

Conclusion

The results obtained from the present work have given some important future line of work. The genotypes highly resistant to early blight were Sel-35 and Sel-19 and can be used as parents in hybridization or backcrossing programme in order to transfer the gene for resistance to already adapted varieties or susceptible varieties with desirable characters. The genotypes 2012/SPT/TOINDVAR-4, 2012/SPT/TODVAR-5, 2012/SPT/TODVAR-6, 2012/TOLCVRES-3, Sel-46, Sel-16 and Sel-9 showed resistant against *Alternaria solani* pathogen which may be further evaluated for stability in performance and for their durable resistance. The genotype 10/TOLCVRES-3 was found good for both high yield and resistant to early blight. Sel-35 and Sel-19 may be studied by combining classical breeding methods with molecular markers in future breeding programme.

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Table 4. Comparison of yield and its loss percentage between disease free condition and disease infested condition for the year 2012-13.

S. N.	Genotypes	Resistant reaction from PDI reading	Yield per ha (q) (disease free condition)	Yield per ha (q) (disease infested condition)	Loss in yield per ha (q) (due to disease incidence)	% loss in yield (due to disease incidence)
1	2012/TOLCVRES-1	HS	246.53	172.21	74.32	30.15
2	2012/TOLCVRES-2	S	192.4	154.21	38.19	19.85
3	2012/TOLCVRES-3	S	240.00	220.21	45.59	17.15
4	2012/TOLCVRES-4	MR	237.9	203.43	34.47	14.49
5	2012/TOLCVRES-5	HS	221.83	151.34	70.49	31.78
6	2012/TOLCVRES-6	MR	222.47	190.21	32.26	14.50
7	2012/TOLCVRES-7	S	181.6	146.42	35.18	19.37
8	2012/TOLCVRES-8	HS	230.2	160.24	69.96	30.39
9	2012/TOLCVRES-9	MR	250.87	220.12	30.75	12.26
10	2012/SPT/TOINDVAR-1	MR	205.48	176.48	29.00	14.11
11	2012/SPT/TOINDVAR-2	S	173.43	136.42	37.01	21.34
12	2012/SPT/TOINDVAR-3	HS	196.96	131.00	65.96	33.49
13	2012/SPT/TOINDVAR-4	R	126.1	118.80	7.30	5.79
14	2012/SPT/TOINDVAR-5	S	116.55	94.42	22.13	18.99
15	2012/SPT/TOINDVAR-6	S	159.55	132.21	27.34	17.14
16	2012/SPT/TOINDVAR-7	S	145.93	116.98	28.95	19.84
17	2012/SPT/TOINDVAR-8	MR	190.69	166.59	24.10	12.64
18	2012/SPT/TOINDVAR-9	HS	192.78	110.37	82.41	42.75
19	2012/SPT/TOINDVAR-10	MR	211.9	186.21	25.69	12.12
20	2012/SPT/TODVAR-1	MR	224.22	198.42	25.80	11.51
21	2012/SPT/TODVAR-2	MR	240.13	214.24	25.89	10.78
22	2012/SPT/TODVAR-3	S	264.67	212.11	52.56	19.86
23	2012/SPT/TODVAR-4	S	168.15	135.00	33.15	19.71
24	2012/SPT/TODVAR-5	R	188.52	170.21	18.31	9.71
25	2012/SPT/TODVAR-6	R	244.2	230.12	14.08	5.77
26	2012/SPT/TODVAR-7	MR	211.2	184.21	26.99	12.78
27	2012/SPT/TODVAR-8	MR	195.68	172.42	23.26	11.89
28	2012/SPT/TODVAR-9	S	235.62	189.00	46.62	19.79
29	2012/SPT/TODVAR10	HS	194.7	121.72	72.98	37.48
30	10/TOLCVRES-1	MR	201.29	178.34	22.95	11.40
31	10/TOLCVRES-2	S	208.67	168.21	40.46	19.39
32	10/TOLCVRES-3	R	268.82	250.12	18.70	6.96
33	10/TOLCVRES-5	S	196.78	158.21	38.57	19.60
34	10/TOLCVRES-6	MR	142.74	123.35	19.39	13.58
35	Sel-35	HR	80	77.56	2.44	3.05
36	Sel-19	HR	77.67	76.00	1.67	2.15
37	Sel-46	R	95.67	86.24	9.43	9.86
38	Sel-16	R	90.67	83.46	7.21	7.95
39	Sel-9	R	81.33	74.56	6.77	8.32
40	Arka Vikas	S	194.48	156.22	38.26	19.67
41	Hisar Arun	MR	205.56	182.24	23.32	11.34
42	H-86	S	146.27	118.21	28.06	19.18
43	Punjab Chhuhara	MR	221.76	198.24	23.52	10.61
44	H-24	S	303	252.21	50.79	16.76
45	NDT-3	S	258.19	212.12	46.07	17.84

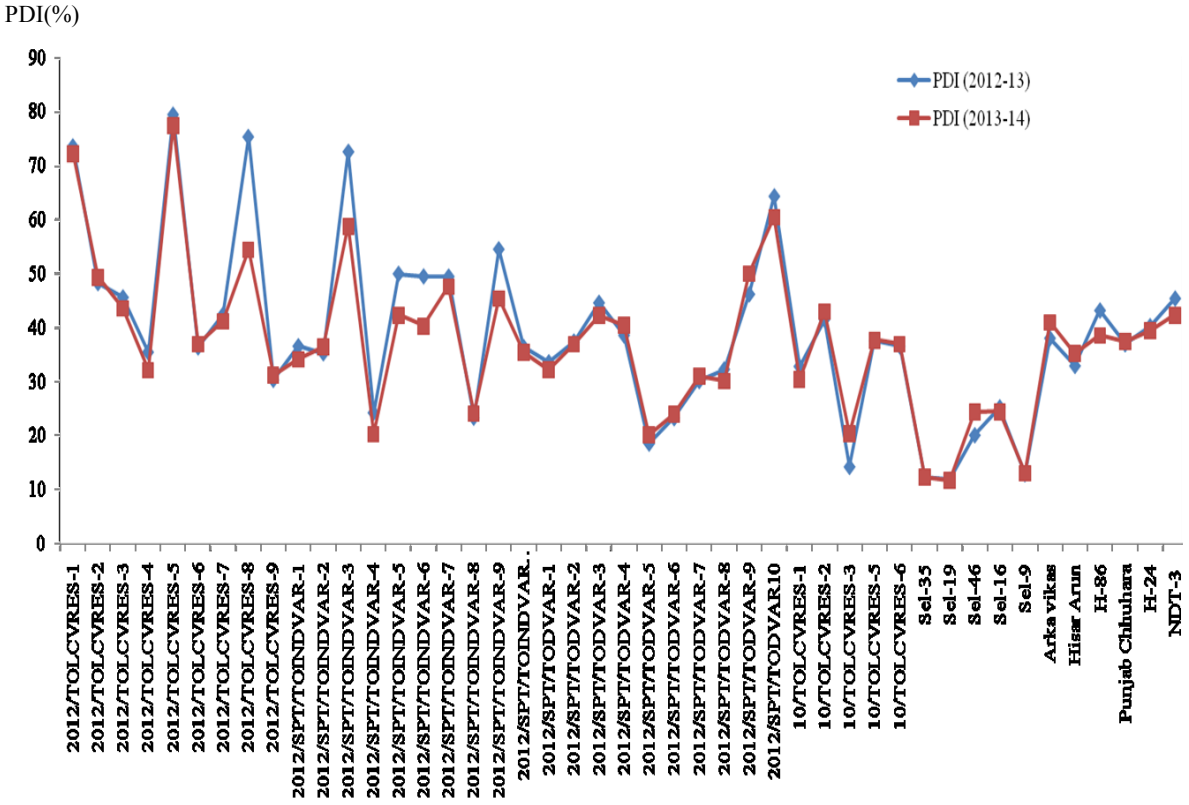

Fig. 1. *Comparison of percent disease index (PDI) on the genotypes artificially inoculated by A. solani for both the years 2012 -13 and 2013-14.*

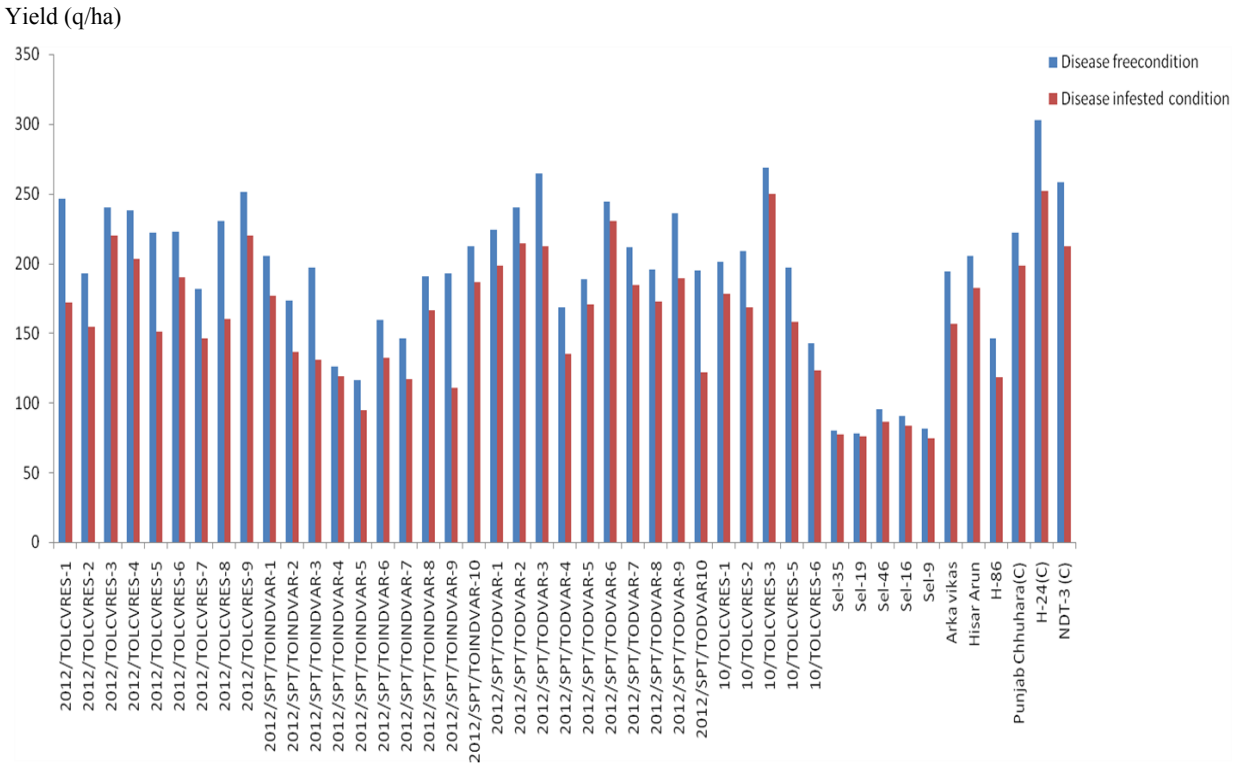

Fig. 2. *Yield comparision under early blight free and early blight infested condition during 2012-13.*

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