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# EVALUATION OF PROMISING TOMATO HYBRIDS HAVING RESISTANCE TO LATE BLIGHT AND ROOT KNOT NEMATODES IN DIVERSE AGROCLIMATIC ZONES OF PUNJAB

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## ABSTRACT

**Six promising $F_1$ hybrids of tomato developed using parental lines resistant to late blight (LB) and root knot nematodes (RKN) along with two check hybrids (TH-1 and Shivaji) were evaluated during 2016-17 at three diverse locations of Punjab, India. Four round fruited experimental hybrids viz. TH-1014, TH-1214, TH-1514 and TH-2114 were resistant to LB and RKN when screened under artificial conditions, whereas, two hybrids viz. TH-925 and TH-1925 were moderately resistant to LB and moderately susceptible to RKN. The check hybrids viz., TH-1 and Shivaji were highly susceptible to LB and susceptible to RKN. The G × E interaction was non-significant for total yield, fruit weight and pericarp thickness. The pooled analysis revealed that the hybrid TH-1014 produced the maximum yield (72.8 t $ha^{-1}$) that was at par with TH-1214 (67.2 t $ha^{-1}$) and manifested 58.3% and 46.1% heterosis over TH-1 and 22.4% and 12.9% over Shivaji, respectively. In respect of fruit weight, hybrid TH-1014 exhibited non-significant heterosis whereas TH-1214 recorded 15.5% and 10.5% heterosis over TH-1 and Shivaji, respectively. Besides, TH-1214 manifested slightly better flavour attributes i.e. locule number and pericarp thickness than TH-1014 and was, therefore, considered superior to TH-1014.**

**Keywords:** G × E interaction, Heterosis, Late blight, Root knot nematode, Tomato

Tomato (*Solanum lycopersicum* L.) crop covers the largest area among all summer vegetables grown in Punjab and was cultivated over 9,000 hectare in 2017-18 producing 22,418 tonnes with an average productivity of 2.49 tonnes $ha^{-1}$ (Anonymous, 2018). The main-season tomato crop in Punjab is transplanted during mid-November to early-December under open field conditions. This crop faces many abiotic and biotic stresses including aphid, root knot nematodes, fruit borer, late blight and early blight etc. However, late blight and root knot nematodes have posed serious threats to successful tomato production. Late blight, caused by the oomycete, *Phytophthora infestans* (Mont.) de Bary, is a highly destructive disease of tomato worldwide and attacks all the aerial parts of the plant including leaves, stems and immature green fruits causing 100% yield loss under congenial environmental conditions (Dubey *et al*., 2018). Although various fungicides are available in the market to control the disease, development of resistance in the pathogen, high cost of chemicals and possible environmental and health hazards are some of the issues related to their use. Host-plant resistance is, therefore, considered an economically viable and environmentally safe approach throughout the world for the management of late blight of tomato. In Tanzania, two tomato varieties viz., 'Meru' and 'Kiboko' with enduring resistance to late blight were released for commercial cultivation (Ojiewo *et al*., 2010). In addition, *Meloidogyne incognita* is the predominant species of root knot nematodes (RKN) affecting tomato crop throughout the world. Being polyphagous in nature, these nematodes are difficult to control. Resistance to RKN is governed by single dominant gene (*Mi-1.2*) (Kumar *et al*., 2017) and therefore can be exploited by heterosis breeding.

In tomato crop, $F_1$ hybrids are quite popular among farmers because of earliness, high yield, uniformity of produce and higher adaptability to unfavourable environmental conditions (Yordanov, 1983). Moreover, heterosis breeding is the shortest, precise and most reliable way to combine the valuable dominant disease resistant genes of both the parents, as compared to other classical methods of breeding (Ram, 1999). Three $F_1$ hybrids of tomato, viz. TH-2312, TH-802 and TH-1 (Singh *et al*., 2004), have so far been released for commercial cultivation at state level by the Punjab Agricultural University, but none of them is resistant to late blight. However, disease resistance coupled with good horticultural traits viz. yield, fruit weight, fruit shape and flavor attributes, are pre-requisite for the hybrids for successful cultivation and popularity among the

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farmers. Further, before recommending any hybrid for commercial cultivation, its evaluation at diverse agro-climatic locations is very important because of genotype × environment interaction.

The present study was, therefore, conducted to estimate G × E interaction among promising eight $F_1$ hybrids of tomato, to ascertain the magnitude and direction of heterosis over two standard check hybrids for important horticultural traits and to screen them against late blight and root knot nematodes under artificial conditions.

## MATERIALS AND METHODS

Ten late blight resistant lines of tomato (incorporating *Ph-2* and *Ph-3*) genes) were crossed with 4 root knot nematode resistant testers (incorporating *Mi-1.2* gene) to develop 40 $F_1$ hybrids which along with two check hybrids were evaluated in a randomized complete block design (RCBD) with three replications at Ludhiana for 2 years. Of these 40 hybrids, six promising $F_1$ hybrids (TH-925, TH-1925, TH-1014, TH-1214, TH-1514, TH-2114) were identified which along with two check hybrids, viz., TH-1 (PAU, Ludhiana), and Shivaji (Golden Seeds Pvt. Ltd.) were evaluated in RCBD with three replications during *rabi* 2016-17 at three locations falling in different agro-climatic regions of Punjab viz., Vegetable Research Farm, Punjab Agricultural University, Ludhiana ($E_1$) (30° 54' N, 75° 48' E, 247 m altitude), Jodhpur Romana Farm, Regional Research Station, Punjab Agricultural University, Bathinda ($E_2$) (30° 13' N, 74° 57' E, 201 m altitude) and Farm Science Centre, Punjab Agricultural University, Amritsar ($E_3$) (31° 63' N, 74° 87' E, 237 m altitude). The characteristics of the experimental soil (0-15 cm soil profile) of all the three locations are presented in Table 1. The seeds of all the eight entries were sown in well prepared nursery beds in mid-October, 2016. The seedlings were transplanted on the southern side of beds made in East-West direction at a distance of 1.20 m × 0.30 m in last week of November, 2016. Ten plants of each entry were transplanted in a single row in each replication. Recommended cultural and insect-pest management measures were followed to raise the crop (Anonymous, 2018). However, control or preventive measures were not adopted for late blight and root knot nematodes.

The observations were recorded for five horticultural characters, viz., fruit weight (g), fruit shape index, number of locules per fruit, pericarp thickness and total fruit yield (kg plot$^{-1}$). Fruit polar and equatorial diameter was recorded on five randomly selected fruits from third picking with the help of Vernier Callipers. The ratio of polar to equatorial diameter was taken as fruit shape index. Number of locules and pericarp thickness was recorded on five randomly selected fruits from third picking whereas fruit weight was taken as average weight of ten fruits chosen randomly from third picking. A total of 5-6 pickings were done and total yield plot$^{-1}$ was converted into total yield (t ha$^{-1}$). The data were analyzed for analysis of variance using computer software programme CPCS1. The heterosis over check hybrids was estimated and tested for significance using standard methods (Rai and Rai, 2006).

### Screening for late blight and root knot nematodes

All the 8 entries were screened against late blight pathogen *Phytophthora infestans* using whole-plant assay. Data were recorded using the 0-5 scale and percent disease index (PDI) was estimated (Thind *et al*., 1989). The entries were also screened against root knot nematodes under artificial conditions. The 7-8 week old seedlings were uprooted and graded on 0-5 scale (Taylor and Sasser, 1978).

## RESULTS AND DISCUSSION

### Genotype × environment interaction

The mean sum of squares due to genotypes was significant in all the three environments and in pooled analysis for all the five traits studied (Table 2) manifesting the presence of genetic variability for the traits studied. The pooled analysis (Table 2) revealed that the mean squares due to environment were significant for three traits, viz., fruit shape index, number of locules and pericarp thickness signifying the important role played by environment in the expression of these traits. The G × E interaction was observed to be non-significant for three traits, viz., total yield, fruit weight and pericarp

**Table 1. Characteristics of the experimental soil (0-15 cm soil profile) at three locations in Punjab**

| Soil characteristic | $E_1$ (Ludhiana) | $E_2$ (Bathinda) | $E_3$ (Amritsar) |
|---|---|---|---|
| Soil texture | Sandy Loam | Loamy Sand | Clay loam |
| pH | 7.7 | 8.2 | 7.8 |
| Electrical conductivity (m mhos/cm) | 0.24 | 0.29 | 0.22 |
| Organic carbon (%) | 0.24 | 0.21 | 0.27 |
| Available phosphorus (kg ha$^{-1}$) | 22.0 | 16.5 | 18.0 |
| Available potassium (kg ha$^{-1}$) | 247.0 | 277.0 | 330.0 |

thickness which implied that the performance of the hybrids for these three traits was statistically at par in various environments. This may be due to the reason that $F_1$ hybrids are more homeostatic, have higher buffering capacity and are therefore more stable to environmental variation than open-pollinated varieties (Singh and Narayanan, 2004).

## Heterosis in relation to mean performance for yield and fruit parameters

High yield is one of the most important advantages of heterosis breeding in tomato. The maximum total fruit yield (pooled over environments) was exhibited by TH-1014 (72.8 t $ha^{-1}$) which was at par with TH-1214 (67.2 t $ha^{-1}$) (Table 3) manifesting heterosis of 58.28% and 46.10% over TH-1, and 22.37% and 12.95% over Shivaji, respectively (Table 4). Only these two experimental hybrids have manifested significant positive heterosis over Shivaji whereas all the six hybrids exhibited significant positive heterosis over TH-1 ranging from 15.03 to 58.28% (Table 4). Standard heterosis for fruit yield ranging from -48.74 to 165.88% (Garg *et al*., 2013) and 39.6 to 88.3% (Garg *et al*., 2016) has also been reported earlier in tomato.

Fruit weight contributes towards total yield and has an important role in acceptance of fruits by the consumer. The pooled analysis showed that the hybrid TH-925 produced the heaviest fruits (82.7 g) which was at par with TH-1214 (79.6 g) and TH-1514 (79.2 g) (Table 3). Only these three hybrids have expressed significant positive heterosis over TH-1 and Shivaji. The maximum heterosis was exhibited by TH-925 (19.98% and 14.81%) followed by TH-1214 (15.51% and 10.54%) and TH-1514 (14.92% and 9.97%) over TH-1 and Shivaji, respectively (Table 4). The hybrid TH-1925 recorded the lowest fruit weight (54.5 g) (Table 3) and expressed significant negative heterosis of -20.90% and -24.31% over TH-1 and Shivaji, respectively (Table 4). Standard heterosis for fruit weight ranging from -21.63 to 101.77% (Garg *et al*., 2013) and -30.67 to 73.33% (Kumar *et al*., 2015) has also been reported by earlier workers in tomato.

Fruit shape index (FSI) is an important fruit quality attribute of tomato. In general, round fruited cultivars are preferred for table purpose whereas oval fruited for processing purposes (Ram, 1999). The pooled analysis showed that the fruit shape of most of the experimental hybrids, viz., TH-1925, TH-1014, TH-2114, TH-1214 and TH-1514 was round with a FSI value of 0.91, 0.93, 0.93, 0.94 and 0.95, respectively. Fruit shape of check hybrid 'Shivaji' was oval with a FSI value of 1.15, whereas that of hybrids viz., TH-1 and TH-925 was flat

**Table 2. Analysis of variance for yield and fruit parameters in eight $F_1$ hybrids of tomato evaluated at three locations in Punjab**

| Source of variation | d.f. | *Total yield (t $ha^{-1}$)* | *Fruit weight (g)* | *Fruit shape index* | *No. of locules per fruit* | *Pericarp thickness (mm)* |
|---|---|---|---|---|---|---|
| *$E_1$ (Ludhiana)* | | | | Mean sum of squares | | |
| Replication | 2 | 58.79 | 32.00 | 0.00043 | 0.00664 | 0.00754 |
| Genotype | 7 | 105.72* | 145.04* | 0.02919* | 0.23481* | 0.35761* |
| Error | 14 | 17.95 | 29.52 | 0.00127 | 0.01291 | 0.00939 |
| *$E_2$ (Bathinda)* | | | | | | |
| Replication | 2 | 101.17 | 81.84 | 0.00292 | 0.02666 | 0.12173 |
| Genotype | 7 | 430.58* | 576.13* | 0.03609* | 0.45238* | 1.17239* |
| Error | 14 | 48.61 | 91.79 | 0.00277 | 0.07810 | 0.39595 |
| *$E_3$ (Amritsar)* | | | | | | |
| Replication | 2 | 115.82 | 23.29 | 0.00026 | 0.02071* | 0.00211 |
| Genotype | 7 | 242.76* | 173.85* | 0.02677* | 0.16039* | 0.34179* |
| Error | 14 | 64.87 | 43.24 | 0.00056 | 0.00289 | 0.00192 |
| *Pooled* | | | | | | |
| Replication (within environment) | 6 | 91.93 | 45.71 | 0.00120 | 0.01800 | 0.04379 |
| Environment (E) | 2 | 28.22 | 84.42 | 0.00803* | 0.75772* | 1.75964* |
| Genotype (G) | 7 | 666.44* | 742.49* | 0.07842* | 0.54003* | 1.53907* |
| Interaction (G × E) | 14 | 56.31 | 76.27 | 0.00682* | 0.15378* | 0.16636 |
| Error | 42 | 43.81 | 54.85 | 0.00154 | 0.03130 | 0.13575 |

*denote significance at 5% level of significance

**Table 3. Mean performance of eight $F_1$ hybrids of tomato evaluated at three locations in Punjab for yield and fruit parameters**

| Sr. No. | Hybrid | Total yield (t ha$^{-1}$) | | | | Fruit weight (g) | | | | Fruit shape index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| 1. | TH-925 | 57.8 | 47.8 | 61.3 | 55.6 | 81.7 | 89.7 | 76.7 | 82.7 | 0.82 | 0.96 | 0.81 | 0.86 |
| 2. | TH-1925 | 55.8 | 48.7 | 54.3 | 52.9 | 60.3 | 48.2 | 55.0 | 54.5 | 0.87 | 0.97 | 0.89 | 0.91 |
| 3. | TH-1014 | 66.0 | 77.5 | 74.9 | 72.8 | 70.3 | 81.5 | 71.7 | 74.5 | 0.90 | 0.98 | 0.89 | 0.93 |
| 4. | TH-1214 | 65.5 | 66.9 | 69.2 | 67.2 | 75.3 | 86.8 | 76.7 | 79.6 | 0.95 | 0.89 | 0.97 | 0.94 |
| 5. | TH-1514 | 59.1 | 66.0 | 62.0 | 62.3 | 82.0 | 78.9 | 76.7 | 79.2 | 0.98 | 0.89 | 0.98 | 0.95 |
| 6. | TH-2114 | 61.3 | 70.2 | 65.4 | 65.6 | 73.0 | 62.5 | 63.3 | 66.3 | 0.93 | 0.94 | 0.92 | 0.93 |
| 7. | TH-1 (SC 1) | 47.3 | 44.7 | 46.0 | 46.0 | 70.0 | 66.3 | 70.3 | 68.9 | 0.84 | 0.84 | 0.84 | 0.84 |
| 8. | Shivaji (SC 2) | 60.2 | 61.2 | 57.1 | 59.5 | 72.3 | 73.7 | 70.0 | 72.0 | 1.13 | 1.20 | 1.11 | 1.15 |
| General Mean | | 59.1 | 60.4 | 61.3 | 60.3 | 73.1 | 73.4 | 70.0 | 72.2 | 0.93 | 0.96 | 0.93 | 0.94 |
| C.V. (%) | | 7.16 | 11.55 | 13.14 | 10.98 | 7.43 | 13.05 | 9.39 | 10.26 | 3.84 | 5.49 | 2.56 | 4.18 |
| C.D. (G) (p=0.05) | | 7.4 | 12.2 | 14.1 | 6.3 | 9.5 | 16.8 | 11.5 | 7.0 | 0.06 | 0.09 | 0.04 | 0.04 |
| C.D. (E) (p=0.05) | | | | | NS | | | | NS | | | | 0.02 |
| C.D. (G × E) (p=0.05) | | | | | NS | | | | NS | | | | 0.06 |

| Sr. No. | Hybrid | No. of locules per fruit | | | | Pericarp thickness (mm) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $E_1$ | $E_2$ | $E_3$ | Pooled | $E_1$ | $E_2$ | $E_3$ | Pooled |
| 1. | TH-925 | 3.82 | 3.80 | 3.69 | 3.77 | 4.55 | 5.20 | 4.57 | 4.78 |
| 2. | TH-1925 | 3.84 | 2.87 | 3.83 | 3.51 | 4.53 | 4.87 | 4.56 | 4.65 |
| 3. | TH-1014 | 3.53 | 2.93 | 3.61 | 3.36 | 5.08 | 5.60 | 5.03 | 5.24 |
| 4. | TH-1214 | 3.60 | 3.53 | 3.61 | 3.58 | 5.35 | 5.67 | 5.37 | 5.46 |
| 5. | TH-1514 | 3.65 | 3.67 | 3.65 | 3.66 | 5.12 | 5.87 | 5.15 | 5.38 |
| 6. | TH-2114 | 3.80 | 3.13 | 3.79 | 3.57 | 4.73 | 4.80 | 4.80 | 4.78 |
| 7. | TH-1 | 3.73 | 3.67 | 3.76 | 3.72 | 4.36 | 4.33 | 4.38 | 4.36 |
| 8. | Shivaji | 2.98 | 2.93 | 3.09 | 3.00 | 4.98 | 6.20 | 4.98 | 5.39 |
| General Mean | | 3.62 | 3.32 | 3.63 | 3.52 | 4.84 | 5.32 | 4.86 | 5.00 |
| C V (%) | | 3.14 | 8.43 | 1.48 | 5.02 | 2.00 | 11.84 | 0.90 | 7.36 |
| C D (G) (p=0.05) | | 0.20 | 0.49 | 0.09 | 0.17 | 0.17 | 1.10 | 0.08 | 0.35 |
| C D (E) (p=0.05) | | | | | 0.10 | | | | 0.21 |
| C D (G × E) (p=0.05) | | | | | 0.29 | | | | NS |

round with a FSI value of 0.84 and 0.86, respectively (Table 3). Due to the presence of G × E interaction for this trait, the values of FSI of various hybrids differed across locations. Only two hybrids viz., TH-2114 and TH-1 performed consistently across environments for this trait. The magnitude of significant heterosis varied from 8.60% (TH-1925) to 13.10% (TH-1514) over TH-1, -24.83% (TH-925) to -17.39% (TH-1514) over Shivaji (Table 4).

Number of locules and pericarp thickness are important fruit quality attributes of tomato that influence flavour and post- harvest shelf-life of tomato fruits (Garg *et al*., 2016). Locule number in all the hybrids varied from 3.00 to 3.77 (Table 3). The pooled analysis revealed that the maximum number of locules was possessed by hybrid TH-925 (3.77) which was at par with TH-1 (3.72) and TH-1514 (3.66) and significantly higher than all other hybrids. The check hybrid 'Shivaji' recorded minimum number of locules (3.00), being an oval fruited hybrid (Table 3). Although G × E interaction was significant for locule number, six hybrids viz., TH-925, TH-1925, TH-1214, TH-1514, TH-1 and Shivaji recorded at par values of locule number across locations and only two hybrids viz., TH-1014 and TH-2114 manifested significant differences across environments (Table 3). The magnitude of significant heterosis ranged from -9.74% (TH-1014) to -5.56% (TH-1925) over TH-1, and 11.93% (TH-1014) to 25.63% (TH-925) over Shivaji (Table 4). Standard heterosis, for number of locules, ranging from -39.94 to 50.15% (Garg *et al*.,

**Table 4. Heterosis (%) (pooled over locations) exhibited by six elite $F_1$ hybrids of tomato over two standard checks for yield and fruit parameters**

| Sr. No. | Hybrid | Total yield (t ha$^{-1}$) | | Fruit weight (g) | | Fruit shape index | | No. of locules per fruit | | Pericarp thickness (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Heterosis (%) over | | Heterosis (%) over | | Heterosis (%) over | | Heterosis (%) over | | Heterosis (%) over | |
| | | TH-1 | Shivaji | TH-1 | Shivaji | TH-1 | Shivaji | TH-1 | Shivaji | TH-1 | Shivaji |
| 1. | TH-925 | 20.97* | -6.48 | 19.98* | 14.81* | 2.91 | -24.83* | 1.31 | 25.63* | 9.53* | -11.40* |
| 2. | TH-1925 | 15.03* | -11.07* | -20.90* | -24.31* | 8.60* | -20.68* | -5.56* | 17.11* | 6.75 | -13.65* |
| 3. | TH-1014 | 58.28* | 22.37* | 8.13 | 3.47 | 10.19* | -19.52* | -9.74* | 11.93* | 20.16* | -2.80 |
| 4. | TH-1214 | 46.10* | 12.95* | 15.51* | 10.54* | 11.38* | -18.65* | -3.67 | 19.44* | 25.28* | 1.34 |
| 5. | TH-1514 | 35.54* | 4.79 | 14.92* | 9.97* | 13.10* | -17.39* | -1.73 | 21.85* | 23.37* | -0.21 |
| 6. | TH-2114 | 42.68* | 10.30 | -3.81 | -7.95 | 10.71* | -19.13* | -3.94 | 19.11* | 9.61* | -11.34* |

*denote significance at 5% level of significance

**Table 5. Reaction of eight $F_1$ hybrids of tomato to late blight and root knot nematode under artificial conditions**

| Sr. No. | Hybrid | Reaction to late blight using whole plant assay* | | Reaction to root knot nematodes under artificial conditions** | |
|---|---|---|---|---|---|
| | | PDI (%) | Rating | RGI | Rating |
| 1. | TH-925 | 14.1 | MR | 2.3 | MS |
| 2. | TH-1925 | 14.2 | MR | 2.7 | MS |
| 3. | TH-1014 | 3.5 | R | 0.8 | R |
| 4. | TH-1214 | 2.3 | R | 0.2 | R |
| 5. | TH-1514 | 9.3 | R | 0.2 | R |
| 6. | TH-2114 | 7.3 | R | 0.1 | R |
| 7. | TH-1 | 59.8 | HS | 2.8 | MS |
| 8. | Shivaji | 52.1 | HS | 3.5 | S |

*R-Resistant, HS-Highly Susceptible, SC-Susceptible check; where, 0-immune, Traces/0.1-1.0: Highly resistant, 1.1-10%: Resistant, 10.1-15.0%: Moderately resistant,
15.1-40.0%: Moderate susceptible, 40.1-50.0%: Susceptible, >50.1%: Highly susceptible
**Root gall index was recorded using root knot index scale (0-5) given by Taylor and Sasser (1978); where 0-1.0: Resistant, 1.1-2.0: Moderately resistant, 2.1-3.0: Moderately susceptible, 3.1-4.0: Susceptible, 4.1-5.0: Highly susceptible

2013), -30.67 to 73.33% (Kumar *et al*., 2015) and -7.8 to -21.6% (Garg *et al*., 2016) has also been reported by earlier workers in tomato.

As per the pooled analysis, the pericarp thickness of all the hybrids varied from 4.36 mm to 5.46 mm (Table 3). The maximum pericarp thickness was recorded by hybrid TH-1214 (5.46 mm) which was at par with Shivaji (5.39 mm), TH-1514 (5.38 mm) and TH-1014 (5.24 mm). The minimum pericarp thickness was registered by TH-1 (4.36 mm) which was at par with TH-1925 (4.65 mm) (Table 3). The magnitude of significant heterosis ranged from 9.53% (TH-925) to 25.28% (TH-1214) over TH-1, and -13.65% (TH-1925) to -11.34% (TH-2114) over Shivaji (Table 3). Standard heterosis for pericarp thickness ranging from -21.88 to 71.51% (Garg *et al*., 2013) and -43.65 to 45.49% (Kumar et al., 2015) has also been reported by earlier workers in tomato.

## Screening of hybrids against late blight and root knot nematodes

All the hybrids were screened against late blight under artificial conditions using whole plant assay. The check hybrids viz., TH-1 and Shivaji were found to be highly susceptible to late blight with PDI values of 59.8% and 52.1%, respectively. Four experimental hybrids viz., TH-1014, TH-1214, TH-1514 and TH-2114 manifested resistance to late blight with PDI values ranging from 2.3% to 9.3%. On the other hand, hybrids TH-925 and TH-1925 were observed to be moderately resistant to late blight with PDI values of 14.1% and 14.2%, respectively (Table 5).

The check hybrid viz., Shivaji was found to be susceptible to root knot nematodes with RGI value of 3.5%. Whereas, hybrids TH-925, TH-1925 and TH-1 were observed to be moderately susceptible to root knot

nematodes with RGI values of 2.3%, 2.7% and 2.8%, respectively. On the other hand, four experimental hybrids viz., TH-1014, TH-1214, TH-1514 and TH-2114 were found to be resistant to root knot nematode with RGI values ranging from 0.1% to 0.8% (Table 5).

The G × E interaction was non-significant for total yield and fruit weight. Of eight tomato hybrids evaluated at three locations in Punjab, four round fruited hybrids viz., TH-1014, TH-1214, TH-1514 and TH-2114 recorded resistant reaction to both late blight and root knot nematodes. Among these four hybrids, TH-1014 registered the maximum average yield over locations (72.8 t $ha^{-1}$) which was at par with TH-1214 (67.2 t $ha^{-1}$) and significantly higher than other hybrids. Of these two hybrids, TH-1214 manifested slightly higher fruit weight (79.6 g), number of locules (3.58) and pericarp thickness (5.46 mm) as compared to TH-1014 (74.5 g, 3.36 and 5.24 mm). The hybrid TH-1214 was, therefore, considered superior to TH-1014.

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## Authors' contribution

Conceptualization and designing of the research work (SKJ); Execution of field/lab experiments and data collection (SKJ, NG, PS, SJ, SK); Analysis of data and interpretation (SKJ, NG, PS); Preparation of manuscript (SKJ, NG)

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