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AGRO-MORPHOLOGICAL TRAITS OF RESISTANCE IN CHILLI AGAINST THRIPS, *SCIRTOTHRIPS DORSALIS* AND ANALYSING THE GEOGRAPHIC DIVERGENCE OF RESISTANCE THROUGH GIS

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ABSTRACT

Field screening studies were undertaken to evaluate 71 chilli genotypes sourced from 11 states of India, for their reaction to thrips, *Scirtothrips dorsalis* Hood. Among the genotypes, two accessions *viz*., IC342390 and IC572492 were found to be resistant; 11 were moderately resistant; 45 were susceptible and 13 were highly susceptible to the pest. The results on correlation between agro-morphological attributes and thrips infestation revealed that, the plant height (r = -0.482 at $P < 0.01$); days to 50 per cent flowering (r = -0.419 at $P < 0.01$); days to maturity (r = -0.925 at $P < 0.01$) and leaf chlorophyll content (r = -0.238 at $P < 0.05$) were negatively correlated with the thrips infestation. The plant canopy width, number of primary branches, mature leaf length and mature leaf width were not associated with the resistant traits in chilli. The GIS mapping and diversity analysis showed that the germplasm collected from Kullu (Himachal Pradesh); Sonipat (Haryana) and Kasaragod (Kerala) recorded the highest Shannon diversity index (1.92 - 3.00) and genotypes from Champawat and Dehradun (Uttarakhand) and Kullu (Himachal Pradesh) recorded the highest (86 - 108) co-efficient of variation for thrips infestation. Targeted exploration in the identified areas would provide good sources of resistance to thrips in chilli.

KEY WORDS
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INTRODUCTION

The chilli thrips, *Scirtothrips dorsalis* Hood, is a key pest of various vegetable, ornamental and fruit crops in India (Ananthakrishnan, 1993) and it causes profound crop damage and reduce the yield of chilli (*Capsicum annum* L.) to an extent of 50 to 90 per cent (Bagle, 1993; Meena *et al.*, 2013). Feeding injury by thrips affects leaf size, reduces photosynthetic capacity (Tommasini and Maini, 1995) and eventually reduces the yield (Steiner, 1990). The pest can also cause indirect damage by vectoring plant viruses and one of the most important viruses transmitted by them in chilli is Tomato Spotted Wilt Virus (TSWV) (Ulman *et al.*, 1992). Thrips develop resistance to chemical insecticides rapidly because of their polyphagous nature, high reproductive rate and facultative parthenogenetic mode of reproduction (Maharijaya *et al.*, 2011; Bharpoda *et al.*, 2014). Indiscriminate use of pesticides in chilli has posed problems of high residues in the fruits, pest resurgence and destruction of natural enemies (Joia *et al.*, 2001). However, insecticides are still extensively used to manage thrips and farmers take up nearly 18 to 26 rounds of spray for the management of sucking pests in irrigated chilli, which in turn immensely increases the cost of cultivation (Hosamani, 2007).

Host plant resistance (HPR) to insect pests is considered as one of the key strategies because of its compatibility with other components of pest management programmes and environment friendly nature. Many sources of resistance to *S. dorsalis* were reported in chilli (Mallapur, 2000; Tatagar *et al.*, 2000; Sarath Babu *et al.*, 2002; and Kulkarni *et al.*, 2011). However, the reports on the mechanism of resistance in chilli against thrips is very limited and no systematic study was undertaken to expedite the geographic divergence of resistance to *S. dorsalis* in India. Hence, the present investigation was carried out to screen 71 indigenous genotypes of chilli for their reaction to *S. dorsalis* and to assess their agro-morphological attributes of resistance to the pest. An attempt was also made to map the diversity of resistance in the screened chilli genotypes using geographical information system (GIS) to interpret geographic patterns in the distribution of resistance to thrips in chilli.

MATERIALS AND METHODS

A total of 71 chilli genotypes obtained from the National Seed Gene Bank of the ICAR- National Bureau of Plant Genetic Resources (NBPGR) were screened for their reaction to thrips, *Scirtothrips dorsalis* at the research farm of NBPGR Regional station, Rajendranagar, Hyderabad during *kharif* seasons of 2012-13 and 2013-14. The genotypes were sourced from 24 districts belonging to 11 states (Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Sikkim, Telangana, Uttar Pradesh and Uttarakhand) (Table. 1) through

the exploration missions of NBPGR.

For the screening trials, chilli seedlings were raised in pots under glasshouse conditions and transplanted after 40 days of sowing. Plants were spaced 60 cm between rows and 50 cm between plats. Each accession was sown in four rows with 10 plants per row in an augmented block deign with five check verities (*Arka Lohit* and *Pusa Jwala* as resistant check; *Arka Suphal* and LCA353 as moderately resistant and CA960 as susceptible check). The checks were repeated after every 12 test genotypes in each block. Recommended agronomic package of practices were adopted for raising the crop excluding the plant protection measures. Observations were recorded on the population of thrips from three terminal leaves on five randomly selected plants from each treatment at 45, 60 and 75 days after transplanting (DAT). The accessions were visually rated for thrips infestation based on the 'upward leaf curl' damage symptom on five randomly selected plants from each replication at fortnightly intervals at 45, 60 and 75 DAT. Scoring was done in the scale 0-4 as described by Niles (1980) and per cent leaf curl index (PLI) was calculated as described by Hosamani (2007).

Score	Symptoms
0	No leaf curl incidence (Healthy plant)
1	< 25 % leaves showing upward curl
2	26 to 50 % leaves showing upward curl
3	50 to 75 % leaves showing upward curl
4	> 75 % leaves showing upward curl

$$PLI = \frac{\text{Sum of scores of all plants}}{\text{Total no. of plants x No. of score category}} \times 100$$

The resistance reactions of chilli genotypes were classified in to four categories based on the PLI value, where, 0-10 = resistant; 11-25 = moderately resistant; 26-50 = susceptible and 51-100 = highly susceptible.

The morphological traits on plant height, plant canopy width, number of branches, mature leaf length, mature leaf width, days to 50 per cent flowering and days to maturity were recorded as per the minimal descriptors of chilli (Srivastava *et al.*, 2001). The leaf chlorophyll index was measured using SPAD 502 Plus® chlorophyll meter (Minolta Co., Ltd., Ramsey, NJ) on fully opened 30 leaves of each treatment at 60 DAT. The results were expressed as mean value of SPAD readings of 30 leaves samples. The data obtained from field experiments were analysed using the analysis of variance for augmented block design (Gomez and Gomez, 1984). The data on thrips count and the PLI values were subjected to square root and arcsine transformations, respectively and the treatment means were compared using least significant difference test at P=0.05. Pearson's correlation co-efficient were calculated between the agro-morphological traits and PLI value / thrips population. The data was subjected to GIS analysis (DIVA-GIS version 7.5) (Hijmans *et al.*, 2012) by plotting the PLI and thrips count of individual accessions corresponding to their georeferenced points. Grid maps on chilli diversity with respect to the PLI value and thrips count were generated on the basis of Shannon diversity index and coefficient of variation for the genotypes.

RESULTS AND DISCUSSION

The chilli genotypes exhibited a wider array of reaction to the infestation of *S. dorsalis* in terms of both mean population per leaf and PLI (Table 2). The mean thrips population ranged from 0.08 per leaf in the genotype IC342390 (sourced from Mathura, Uttar Pradesh) to 5.09 per leaf in IC537645 (from Kullu, Himachal Pradesh). The local checks *Arka Lohit, Arka Suphal*, CA960, LCA353 and *Pusa Jwala* recorded a mean thrips count of 0.07, 0.60, 3.60, 0.54 and 0.12 per leaf, respectively. The corresponding PLI values were also differing significantly with respect to the chilli genotypes screened. The accession IC342390 was found to be having the lowest mean PLI value (2.40), while the accession IC537578 (sourced from Naintal, Uttarakhand) recorded the highest (63.20) value. Based on the mean PLI value, chilli accessions were classified into four categories of resistance. Among the 71 accessions screened, two were identified as resistant; 11 were found to be moderately resistant; 45 were susceptible and 13 were highly susceptible to *S. dorsalis*. The resistant accessions, IC342390 and IC572492 were sourced from Mathura (Uttar Pradesh) and Gadag (Karnataka), respectively. The moderately resistant accession were collected from Panipat, Haryana (IC342426); Kullu, Himachal Pradesh (IC537659, IC537657); Belgaum, Karnataka (IC572479); Kasaragod, Kerala (IC344366, IC344364, IC344385) and Champawat, (IC338782); Dehradun (IC537595, IC537599) and Pauri (IC337281) districts of Uttarakhand.

The earlier screening trials in chilli against *S. dorsalis* also resulted in identification of several resistant genotypes. Sawant *et al.*, (1986) reported that out of 69 varieties screened for their resistance against thrips, only three varieties *viz.*, Pant C1, LIC-45 and NP-46 were found to be resistant, while the remaining entries were either susceptible (44) or highly susceptible (22). In a screening trial on 62 chilli genotypes, Mallapur (2000) found 13 genotypes were promising in their resistance reaction and recorded a lower PLI against thrips and mite infestation. Sarath Babu *et al.*, (2002) identified 17 promising genotypes, showing resistant and moderately resistant reactions to *S. dorsalis,* among the 308 accessions screened. Ahmed *et al.* (2001) evaluated 77 genotypes on the basis of mite incidence, their injury grade and damage index, and reported that only nine entries were found resistant against mite, while the remaining entries were categorized as either susceptible (31) or highly susceptible (37). Lima *et al.* (2003) stated that, in his greenhouse evaluation of 101 chilli accessions, only 7.5 per cent of the genotypes of *C. annuum* showed a resistant reaction to mite, while 50 per cent of the genotypes of *C. frutescens*, 57 per cent of *C. baccatum*, and *C. chinensis* were free from mite infestation. The present study as well as the earlier screening trials evidently indicated that, the widely cultivated species, *C. annum* has limited genetic variability for thrips resistance. An attempt for screening other cultivated species of chilli may yield a good numbers of resistant sources to *S. dorsalis*.

The agro-morphological characters recorded from chilli genotypes varied significantly in the present study. The mean

Table1: Location wise data of chilli genotypes screened for their reaction to *S. dorsalis*

State	District	Chilli Accessions*
Chhattisgarh	Bastar	IC561354 (19.2, 82.87)
Gujarat	Bhoruch	IC344636 (21.81, 74.14)
	Narmada	IC344650 (21.82, 73.63), IC344706 (21.5, 73.94), IC344727 (21.81, 73.51), IC330969 (21.8, 73.7)
Haryana	Rohtak	IC342410 (29.03, 76.32)
	Panipat	IC342420 (29.32, 76.97), IC342426 (29.34, 76.68)
	Karnal	IC342438 (29.7, 76.92)
	Jind	IC342442 (29.66, 76.11), IC342449 (29.31, 76.47)
	Sonipat	IC342457 (29.14, 76.56), IC342458 (29.16, 76.86), IC342461 (28.9, 77.15), IC342463 (29.2, 76.97), IC342464 (29.2, 76.97), IC342465 (29.05, 76.87)
	Saharanpur	IC342480 (29.8, 77.18)
Himachal Pradesh	Kullu	IC537623 (31.61, 77.35), IC537632 (32.09, 77.15), IC537645 (31.95, 77.18), IC537646 (31.95, 77.18), IC537650 (31.99, 77.23), IC537656 (32.09, 77.15), IC537657 (32.09, 77.15), IC537658 (31.61, 77.35), IC537659 (31.61, 77.35), IC537661 (31.94, 77.11), IC537662 (31.94, 77.11), IC537664 (31.97, 77.21)
	Lajaul & Spiti	IC537634 (32.7, 76.69)
Karnataka	Haveri	IC572454 (14.36, 75.3)
	Belgaum	IC572479 (16.27, 74.48)
	Gadag	IC572492 (15.25, 75.35)
Kerala	Kasaragod	IC344324 (12.29, 75.19), IC344325 (12.29, 75.19), IC344350 (11.84, 75.86), IC344364 (12.5, 75.27), IC344366 (12.5, 75.27), IC344367 (12.5, 75.27), IC344368 (12.5, 75.27), IC344370 (12.5, 75.27), IC344381 (12.4, 75.05), IC344383 (12.51, 74.98), IC344385 (12.51, 74.98), IC344386 (12.51, 74.98), IC344387 (12.51, 74.98)
Madhya Pradesh	Dhar	IC336754 (22.6, 75.3)
Sikkim	Namchi	IC274340 (27.23, 88.38)
Telangana	Warangal	IC344563 (17.97, 79.88), IC344575 (17.39, 79.89), IC344597 (17.39, 9.89)
Uttar Pradesh	Mathura	IC342390 (27.44, 77.73)
	Agra	IC342394 (27.25, 78.04), IC342400 (27.12, 78.02)
Uttarakhand	Pauri	IC337281 (29.28, 79.97)
	Champawat	IC338772 (29.43, 79.9), IC338775 (29.42, 80.08), IC338777 (29.31, 80.05), IC338778 (29.31, 80.05), IC338782 (29.22, 80.12), IC338786 (29.22, 80.12)
	Naintal	IC537578 (29.39, 79.53), IC537579 (29.39, 79.53), IC537581 (29.5, 79.48), IC537583 (29.22, 79.53)
	Dehradun	IC537595 (30.3, 78.01), IC537596 (30.3, 78.01), IC537599 (30.33, 78.01), IC537601 (30.33, 78.01)

* Figures in parentheses are the geographic co-ordinates of collection site designated as latitude and longitude

plant height ranged from 22.38 cm (IC537578) to 93.86 cm (IC342390); plant canopy width from 30.76 cm (IC537632) to 81.48 cm (IC342449) and the number of primary branches from 2.10 (IC537579) to 5.06 (IC537595). A significant variation was observed among the genotypes in the days to 50 per cent flowering and maturity. The accession IC344650 was observed to be having the shortest flowering (69.93 days) and maturity (115.63 days) time; while the accessions IC537583 (102.13 days) and IC337281 (208.83 days) recorded the longest time in flowering and maturity, respectively. The data on mature leaf length varied from 2.49 cm (IC344324) to 10.13 cm (IC342438); while the mature leaf width differed from 1.29 cm (IC344727) to 4.97 cm (IC537601). The leaf chlorophyll index ranged from 42.88 (IC344350) to 65.92 (IC572454) in different accessions. The results on the correlation between the agro-morphological attributes and thrips infestation (Table 3) revealed that, the thrips population had significant negative correlation with the plant height (r = -0.482 at $p<0.01$); days to flowering (r = -0.419 at $p<0.01$) days to maturity (r = -0.925 at $p<0.01$) and leaf chlorophyll index (r = -0.238 at $p<0.05$). A significant positive correlation between thrips population and the PLI value (0.872 at $p<0.01$) showed that the observations were complementing each other in measuring the infestation and damage of thrips in chilli. Analogous to the correlations between thrips populations and agro-morphological attributes, the PLI value also recorded a significant negative correlation with the plant height (r = -0.476 at $p<0.01$); days to flowering (r = -0.259 at $p<0.05$) and days to maturity (r = -0.866 at $p<0.01$); however the correlation with leaf chlorophyll index was not significant.

Borah (1987) reported a negative association between the plant height and susceptibility of chilli varieties to the thrips, *S. dorsalis*. In a spatial distribution study, Atakan *et al.,* (1996) found that, *Thrips tabaci* preferred shorter plants for their survival than the taller ones. The mean thrips population on cotton leaf was found to be 2.20, 1.37 and 0.99, respectively for the short, medium and tall plants. The present findings are in corroboration with the earlier results on the association between plant height and thrips damage. A negative correlation between the days to 50 per cent flowering & maturity and thrips infestation in the present study indicated that genotypes having long duration were less susceptible to thrips infestation. There is no prior report in chilli regarding the correlation between crop duration and resistance to thrips; however in cabbage, Trdan *et al.* (2005) stated that the cultivars having the shortest growing period were the most damaged by the

Table 2: Agro-morphological traits and reaction of chilli genotypes to infestation of thrips, *S. dorsalis* (pooled mean values of two seasons, *kharif* 2012-13 and 2013-14)

Accession	Plant height (cm)	Plant canopy width(cm)	Primary Branches (no)	Leaf length (cm)	Leaf width (cm)	Days to 50% flowering	Days to maturity	Chlorophyll Index	Thrips mean population per leaf #	Percent Leaf curl Index$	Category based on PLI *
IC274340	50.16	35.78	2.84	4.93	3.31	65.93	131.83	58.18	3.56(1.87)	46.40(41.97)	S
IC336754	64.86	58.78	4.54	4.13	2.61	80.93	163.83	60.48	1.73(1.35)	48.80(43.35)	S
IC337281	66.98	35.48	2.84	3.43	2.21	75.93	208.83	50.88	0.27(0.73)	11.20(18.6)	MR
IC338772	49.16	50.08	2.54	5.03	2.31	75.93	154.83	46.08	2.89(1.7)	44.80(41.05)	S
IC338775	60.16	56.48	2.84	5.23	2.61	71.93	122.83	56.48	3.44(1.84)	47.20(42.43)	S
IC338777	50.28	59.38	3.14	6.53	2.91	71.93	125.83	45.98	3.58(1.87)	56.80(47.94)	HS
IC338778	57.16	56.78	3.34	5.93	2.71	68.93	120.83	43.98	3.60(1.88)	48.80(43.35)	S
IC338782	54.98	41.08	2.14	5.23	2.51	75.93	200.83	46.98	0.13(0.65)	19.20(25.03)	MR
IC338786	51.86	50.78	2.14	7.13	3.11	78.93	122.83	50.78	3.84(1.94)	47.20(42.43)	S
IC342390	93.86	69.48	4.54	8.33	3.91	80.93	191.83	51.48	0.08(0.62)	2.40(7.96)	R
IC342394	56.86	60.08	3.54	5.93	2.91	78.93	128.83	45.38	3.56(1.87)	47.20(42.43)	S
IC342400	71.16	63.28	2.84	6.93	3.11	68.93	128.83	52.38	3.04(1.74)	47.20(42.43)	S
IC342410	52.28	58.48	3.32	7.93	3.97	78.93	134.23	50.92	2.44(1.77)	45.60(41.79)	S
IC342420	50.98	63.48	3.72	5.93	2.87	76.93	121.23	46.22	4.60(2.32)	56.80(48.22)	HS
IC342426	57.28	49.18	4.32	8.93	3.77	76.93	187.23	57.72	0.73(1.17)	22.40(27.57)	MR
IC342438	60.28	52.48	3.72	10.13	3.67	76.93	132.23	64.92	2.62(1.82)	45.60(41.79)	S
IC342442	41.98	63.48	3.72	3.93	1.97	76.93	127.23	50.22	3.78(2.13)	56.80(48.22)	HS
IC342449	89.68	81.48	3.32	4.13	1.87	78.93	176.23	49.82	1.40(1.44)	32.00(33.77)	S
IC342457	47.28	46.88	3.02	5.83	2.47	89.93	134.23	62.12	2.58(1.81)	45.60(41.79)	S
IC342458	83.68	67.88	4.32	4.13	2.17	83.93	160.23	47.72	1.58(1.5)	48.80(43.62)	S
IC342461	77.28	49.48	3.72	4.43	1.77	73.93	134.23	53.92	2.58(1.81)	45.60(41.79)	S
IC342463	50.98	53.18	3.32	4.13	1.67	83.93	139.23	54.92	2.40(1.76)	44.80(41.33)	S
IC342464	88.98	66.88	3.02	4.93	2.07	78.93	179.23	57.22	0.62(1.12)	30.40(32.78)	S
IC342465	61.68	52.48	3.02	4.83	2.47	83.93	148.23	60.02	2.09(1.67)	44.80(41.33)	S
IC342480	69.20	68.48	3.60	4.59	2.45	84.13	176.03	51.28	1.40(1.25)	41.60(39.79)	S
IC344324	28.50	46.18	2.90	2.49	1.75	69.13	121.03	50.78	3.96(1.98)	48.00(43.48)	S
IC344325	70.00	77.18	3.20	4.79	2.15	82.13	176.03	50.78	1.40(1.25)	42.40(40.25)	S
IC344350	60.50	67.18	3.90	3.39	2.15	82.13	126.03	42.88	3.29(1.82)	47.20(43.02)	S
IC344364	86.50	70.18	3.20	4.99	2.75	91.13	207.03	53.78	0.27(0.75)	16.80(23.83)	MR
IC344366	44.50	43.88	2.90	4.69	2.95	91.13	207.03	52.78	0.29(0.76)	12.80(20.6)	MR
IC344367	65.20	53.68	2.90	4.49	2.85	91.13	174.03	56.38	1.51(1.29)	37.60(37.45)	S
IC344368	69.50	60.48	2.90	5.49	2.75	84.13	162.03	53.28	2.04(1.47)	48.80(43.94)	S
IC344370	53.90	51.18	2.90	4.49	2.45	95.13	156.03	47.68	2.89(1.71)	44.80(41.64)	S
IC344381	68.20	53.88	3.90	4.79	2.35	82.13	135.03	45.48	2.44(1.59)	44.80(41.64)	S
IC344383	77.50	60.18	4.60	5.29	2.55	84.13	166.03	59.58	1.60(1.32)	45.60(42.1)	S
IC344385	53.50	68.48	3.90	5.29	2.75	84.13	207.03	53.58	0.33(0.78)	12.80(20.6)	MR
IC344386	49.08	61.54	3.80	5.79	2.69	81.93	162.63	46.28	1.73(1.63)	46.40(44.32)	S
IC344387	53.08	50.04	3.80	5.89	2.59	81.93	172.63	47.38	1.49(1.55)	33.60(36.82)	S
IC344563	71.08	69.04	3.40	4.89	2.99	88.93	164.63	51.18	1.11(1.41)	44.80(43.4)	S
IC344575	64.68	59.04	3.40	6.29	3.09	88.93	165.63	49.88	0.91(1.33)	42.40(42.02)	S
IC344597	59.68	62.04	3.80	5.79	2.39	86.93	156.63	45.88	2.62(1.91)	48.80(45.7)	S
IC344636	56.38	63.64	4.70	3.29	1.69	66.93	156.63	50.28	2.69(1.92)	48.80(45.7)	S
IC344650	27.68	35.44	3.80	4.59	2.59	69.93	115.63	47.68	4.27(2.32)	59.20(51.69)	HS
IC344706	61.08	61.44	4.80	5.09	1.99	81.93	128.63	52.28	3.69(2.18)	56.00(49.83)	HS
IC344727	42.38	57.44	4.80	3.79	1.29	69.93	115.63	55.88	4.31(2.33)	60.80(52.62)	HS
IC537578	22.38	45.54	4.80	7.89	3.39	79.93	115.63	59.18	4.09(2.28)	63.20(54.04)	HS
IC537579	36.88	32.24	2.10	6.09	3.69	88.93	166.63	52.88	1.51(1.56)	41.60(41.55)	S
IC537581	55.68	41.24	2.40	8.39	4.09	95.93	141.63	56.28	2.13(1.76)	44.80(43.4)	S
IC537583	28.44	31.76	3.66	6.89	2.97	102.13	175.23	56.32	0.24(0.93)	37.60(37.94)	S
IC537595	44.74	44.76	5.06	4.49	2.17	77.13	196.23	56.22	0.62(1.13)	20.80(27.26)	MR
IC537596	27.74	55.26	4.66	4.39	2.07	75.13	130.23	50.32	3.78(2.14)	56.00(48.56)	HS
IC537599	36.74	36.16	3.06	6.49	3.27	91.13	205.23	47.52	0.11(0.85)	15.20(23.08)	MR
IC537601	44.14	45.46	3.36	9.89	4.97	88.13	168.23	53.12	1.56(1.5)	46.60(43.17)	S
IC537623	68.44	75.46	3.36	4.59	2.77	82.13	130.23	51.72	3.49(2.07)	46.40(43.06)	S
IC537632	32.74	30.76	5.06	4.59	2.17	84.13	158.23	52.52	2.73(1.87)	44.80(42.14)	S
IC537634	45.14	67.16	2.66	4.09	3.27	88.13	119.23	46.72	4.62(2.33)	56.80(49.03)	HS
IC537645	50.14	37.76	4.06	4.69	2.37	91.13	119.23	53.52	5.09(2.44)	59.20(50.42)	HS
IC537646	37.44	46.16	3.66	4.19	2.27	77.13	157.23	56.32	1.00(1.21)	54.40(47.64)	HS
IC537650	46.14	46.16	3.36	5.09	2.27	84.13	162.23	47.82	1.73(1.57)	48.00(43.97)	S
IC537656	54.14	49.46	3.36	5.29	2.67	75.13	119.23	54.52	4.07(2.21)	48.00(43.97)	S
IC537657	54.52	40.98	2.48	4.27	2.11	87.93	204.03	53.12	0.11(0.79)	17.60(25.22)	MR
IC537658	57.82	37.38	4.48	4.67	2.41	101.93	171.03	50.82	1.51(1.43)	38.40(38.71)	S

Table 2: Cont.....

Accession	Plant height (cm)	Plant canopy width(cm)	Primary Branches (no)	Leaf length (cm)	Leaf width (cm)	Days to 50% flowering	Days to maturity	Chlorophyll Index	Thrips mean population per leaf #	Percent Leaf curl Index$	Category based on PLI *
IC537659	44.12	39.68	3.08	3.87	2.11	83.93	204.03	54.52	0.12(0.79)	19.20(26.41)	MR
IC537661	57.82	52.68	3.08	3.97	1.71	83.93	174.03	59.52	1.40(1.39)	33.60(35.84)	S
IC537662	35.52	68.38	4.14	4.27	2.11	81.93	145.03	56.52	3.69(2.05)	55.20(48.4)	HS
IC537664	39.82	31.98	4.48	4.17	1.91	83.93	147.03	53.42	3.67(2.05)	55.20(48.4)	HS
IC561354	56.52	68.38	3.48	4.27	1.91	83.93	124.03	56.52	3.27(1.95)	47.20(43.81)	S
IC572454	62.12	62.38	3.48	4.37	2.81	83.93	191.03	65.92	1.18(1.3)	25.60(30.81)	S
IC572479	88.82	79.68	3.08	4.17	1.91	81.93	167.03	55.02	0.17(0.83)	23.20(29.21)	MR
IC572492	87.82	63.98	3.78	4.47	2.31	81.93	203.03	56.02	0.19(0.84)	8.80(17.68)	R
IC330969	76.12	69.38	2.78	4.57	2.31	81.93	167.03	61.42	1.51(1.43)	40.80(40.11)	S
Arka Lohit	90.92	69.33	4.28	5.30	2.73	91.17	186.17	60.92	0.07(0.76)	9.40(17.54)	R
Arka Suphal	81.62	68.60	4.27	4.42	2.55	86.50	171.00	56.17	0.60(0.99)	23.27(28.82)	MR
CA960	60.88	59.67	2.95	4.40	2.30	85.83	171.17	56.30	3.60(2.1)	38.27(38.08)	S
LCA353	81.17	62.93	3.68	5.35	2.23	88.83	189.17	56.90	0.54(1.01)	21.47(27.59)	MR
Pusa Jwala	92.83	71.25	4.02	5.38	2.43	83.33	189.67	62.32	0.12(0.78)	10.67(18.33)	MR
CV (%)	5.28	6.74	7.30	6.78	6.74	3.36	3.21	2.76	(9.64)	(9.91)	
CD at 5%	9.95	11.51	0.78	1.03	0.51	8.27	15.53	4.43	(0.16)	(10.34)	

Figures in parentheses are #square root and $arc sine transformed values; * R - Resistant (PLI: 0-10); MR - Moderately resistant (PLI: 11-25): S- Susceptible (PLI: 26-50): HS - Highly susceptible (PLI: 51-100)

Table 3: Correlation between the traits of resistance in chilli with respect to infestation of *S. dorsalis*

	Plant height	Plant canopy width	Number of branches	Leaf length	Leaf width	Days to flowering	Days to maturity	Chlorophyll Index	%Leaf curl Index	Thrips population
Plant height	1									
Plant canopy width	.658**	1								
No. of branches	-.017	.091	1							
Leaf length	-.037	-.113	-.054	1						
Leaf width	-.072	-.158	-.212	.834**	1					
Days to flowering	.087	-.094	-.066	.104	.196	1				
Days to maturity	.352**	-.007	-.060	-.059	.026	.395**	1			
Chlorophyll Index	.190	.024	.101	.107	.035	.129	.179	1		
% Leaf curl Index	-.476**	-.069	.104	-.009	-.073	-.259*	-.866**	-.211	1	
Thrips population	-.482**	-.082	.100	-.061	-.093	-.419**	-.925**	-.238*	.872**	1

** - Correlation is significant at the 0.01 level (2-tailed); * - Correlation is significant at the 0.05 level (2-tailed).

infestation of thrips, *T. tabaci* than that of the longer duration varieties.

The earlier reports on association between the leaf chlorophyll content and thrips infestation were found to be positive and the results were in contrast with the present findings of negative correlation. Murugesan and Kavitha (2010) reported that, thrips and all other sucking insects had significant and positive correlation with leaf chlorophyll content in cotton. Similarly, the total chlorophyll and reducing sugar content were found to be positively correlated to the infestation of *T. tabaci* in onion (Bandi and Sivasubramanian, 2013). The reason for negative association in the present study may be due to the reduction of leaf size and leaf curl owing to thrips infestation and consequent decline in the photosynthetic activity and chlorophyll content of leaves. Das *et al.* (1991) reported a reduction in chlorophyll synthetase activity in response to thrips infestation in mulberry leaves and a subsequent lower chlorophyll a / b ratio was also reported in infested leaves (Das *et al.*, 1994). Similarly, Molenaar (1984) also reported that the thrips injury reduces the photosynthetic ability of onion by destroying chlorophyll-rich leaf mesophyll. The reasons stated for reduction in chlorophyll content in mulberry and onion leaves complemented the present findings in chilli.

The GIS grid map generated by plotting the diversity of chilli genotypes (based on mean thrips population per leaf) is furnished in Fig.1. The accessions sourced from Kullu (Himachal Pradesh); Sonipat (Haryana) and Kasaragod (Kerala) were found to be having the highest range of Shannon diversity index (1.92 - 3.00) and the accessions sourced from Naintal (Uttarakhand) was reported to be having a high range of diversity (1.44 - 1.92). A medium level in diversity index (0.96 - 1.44) was observed for the accessions sourced from Dehradun (Uttarakhand); Lajaul & Spiti (Himachal Pradesh), Narmada (Gujarat) and Warangal (Telangana). The grid map plotted for the diversity of chilli genotypes based on PLI (Fig. 3) also revealed a similar trend. The GIS map plotted on the basis of the coefficient of variation (based on mean thrips population per leaf) revealed that the genotypes collected from Champawat and Dehradun (Uttarakhand) and Kullu (Himachal Pradesh) recorded the highest (86-108) value (Fig.2). Accessions sourced from Kasaragod (Kerala) and Naintal (Uttarakhand) showed a high coefficient of variation (64-86); while the collections from Sonipat (Haryana) and Warangal (Telangana) recorded a medium (13-64) variation. The GIS

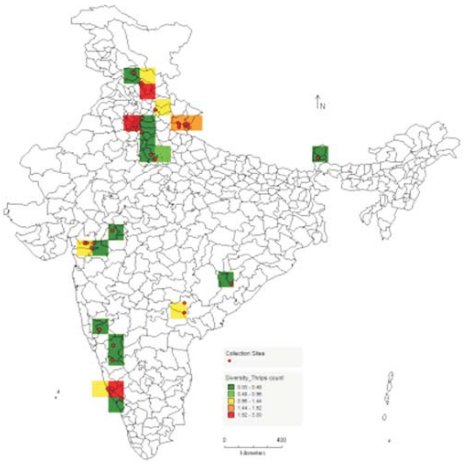

Figure 1: GIS grid map for diversity index in chilli genotypes with respect to thrips infestation

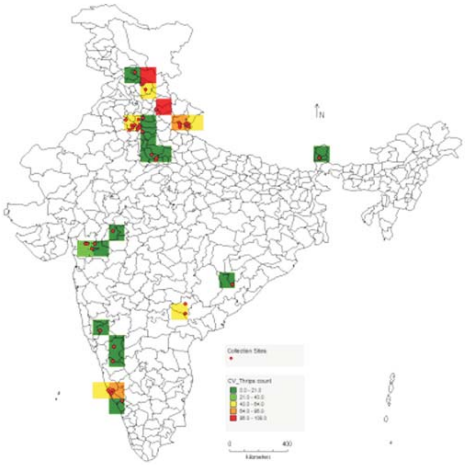

Figure 2: GIS grid map for coefficient of variation in chilli genotypes with respect to thrips infestation

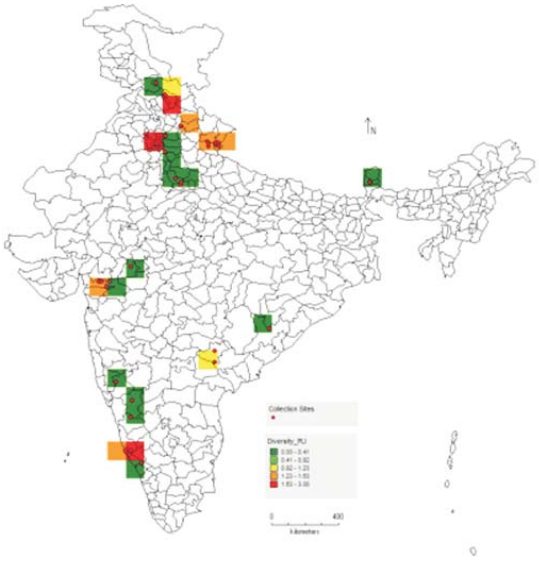

Figure 3: GIS grid map for diversity index in chilli genotypes with respect to PLI

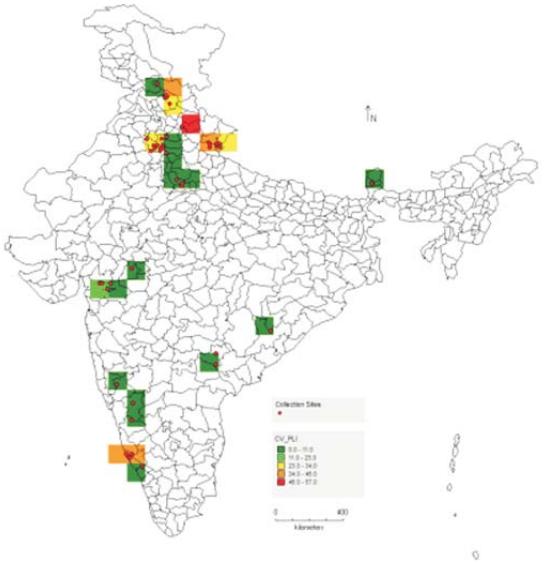

Figure 4: GIS grid map for coefficient of variation in chilli genotypes with respect to PLI

plot for the coefficient of variations based on the PLI values (Fig. 4) was also comparable with the mapping based on thrips population per leaf.

Geographical information system is a tool for the analysis of crop diversity and it enables us to comprehend the distribution of diversity on the geographical scale and also helps in planning targeted exploration trips to collect germplasm with preferred characters. GIS mapping may be effectively used for documentation, diversity analysis, identifying gaps in collection, assessment of loss of diversity, developing new strategies for conservation, and sustainable utilization, particularly in the wake of recent international developments related to food and nutritional security. Ganeshaiah *et al.*, (2003) successfully used DIVA-GIS in predicting the potential distribution of sugarcane wooly aphid, *Ceratova cunamanigera* Zehntner in South India. GIS mapping has been successfully used in assessing biodiversity and in identifying *Canavalia* genotypes with high fatty acid content (Sivaraj *et al.*, 2010); categorising areas of high diversity of *Phaseolus* bean (Jones *et al.*, 1997); wild potatoes (Hijmans and Spooner, 2001); horse gram (Sunil *et al.*, 2008); Piper (Parthasarathy *et al.*, 2006); linseed (Sivaraj *et al.*, 2009); blackgram (Babu Abraham *et al.*, 2010); and medicinal plants Southeast Coastal Zone (Varaprasad *et al.*, 2007). The current study on GIS mapping identified the areas with greater diversity in chilli genotypes possessing broader range of reaction to *S. dorsalis* infestation.

The present screening had resulted in identification of a good number of resistant sources amongst a wider collection of indigenous chilli genotypes sourced from different parts of the country. The identified resistant (IC342390 and IC572492) and 11 moderately resistant genotypes would be of immense use in the breeding programmes for the development resistance verities for *S. dorsalis*. The correlation between agro-

morphological characters and thrips infestation revealed that, the plant height; days to flowering and maturity; leaf chlorophyll content were negatively correlated, while the plant canopy width, number of primary branches, mature leaf length and width were not associated with the resistant traits in chilli. The GIS mapping and analysis identified the areas having wider diversity of genotypes having a greater range of reactions to thrips infestation. Further exploration could be targeted in the states of Karnataka, Himachal Pradesh and Haryana for identifying good sources of resistance in chilli for *S. dorsalis*.

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