FIELD TOLERANCE OF CHILLI VARIETIES AGAINST SUCKING PEST COMPLEX

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by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"FIELD TOLERANCE OF CHILLI VARIETIES AGAINST SUCKING PEST COMPLEX"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
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CERTIFICATE

Certified that this thesis entitled **"FIELD TOLERANCE OF CHILLI VARIETIES AGAINST SUCKING PEST COMPLEX"** is a record of research work done independently by Ms. Haritha N.K. (2019-11-132) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

%	Percentage
µg	Microgram
µl	Microlitre
ANOVA	Analysis of variance
^{0}C	Degree Celsius
CD	Critical difference
cm	Centimetre
cm^2	Centimetre square
CRD	Completely Randomized Design
DAT	Days after transplanting
et al	And others
Fig	Figure
g	Gram
h	Hour
i.e	That is
KAU	Kerala Agricultural University
kg	Kilogram
LCI	Leaf Curl Index
$leaf^{-1}$	Per leaf
mg	Milligram
mg g^{-1}	Milligram per gram
min	Minute
mL	Millilitre
N	Normal
NBPGR	National Bureau of Plant Genetic Resources

nm	Nanometre
No.	Number
NS	Not significant
PCA	Principal Component Analysis
pH	Negative logarithm of H^+ ion concentration
$plant^{-1}$	Per plant
PLI	Per cent Leaf Curl Index
ppm	Parts per million
rpm	Revolutions per minute
SEm	Standard error of means
Sl.	Serial
T	Treatment
TV	Titrate Volume
UV	Ultraviolet
Viz.,	Namely
$\mu g\ ml^{-1}$	Microgram per millilitre

Introduction

1. INTRODUCTION

Chilli (*Capsicum annuum* L.) (Solanaceae) is the most widely used and universal spice of India. It is raised over an area of 2020 thousand hectares in the world, with a production of 3762 thousand tonnes (Geetha and Selvarani, 2017). Major chilli growing countries include India, China, Indonesia, Korea, Pakistan, Turkey and Sri Lanka in Asia; Nigeria, Ghana, Tunisia and Egypt in Africa; Mexico, United States of America in North – Central America; Yugoslavia, Spain, Romania, Bulgaria, Italy and Hungary in Europe and Argentina and Peru in South America.

India is the world leader in chilli production followed by China and Pakistan. India accounts for 13.76 million tonnes of production annually followed by China with a production of around 3 million tonnes. India contributes about 36% to the total world production. In India, chillies are grown in almost all the states throughout the country. India is not only the largest producer but also the largest consumer of chilli in the world (Sridhar *et al*., 2014).

Chilli is specially used for its pungency, spicy taste, besides the appealing colour it adds to the food. It is used in pickles, sauces, ketchup, essences, oleoresins and it is an inevitable ingredient in Indian dishes. Every 100 g of dried pods yield about 160 calories of energy through 36 g carbohydrates, 18 g proteins, 16 g fat, 480 mg calcium, 3.1 mg phosphorous, 31 mg iron, 2.5 mg niacin, 640 I.U. vitamin 'A' and 40 mg vitamin ‘C’. Capsaicin is an alkaloid, extracted from chilli fruits which has high medicinal value (Jagtap *et al*., 2012)

Chilli is the largest spice item exported from India and it occupies first position in terms of value. Total chilli exports in 2020-21 were 6,01,500 tonnes valued Rs. 8,430 crore, upto 21 per cent in quantity and 26 per cent in value (Kumar, 2021). The mandatory quality testing of chilli and chilli products has made Indian chilli more acceptable in the international market and helped to achieve this higher level of exports (Geetha and Selvarani, 2017). However, chilli exports to the western countries have been rejected due to the presence of excess pesticide residues and toxins in them and their related products.

Among the various constraints relating to the cultivation of chilli, which includes high cost of input, lack of irrigation, shortage of storage facilities, lack of scientific knowledge, the most important constraint is the incidence of pests and diseases.

Chilli is known to be affected by a number of insect and non-insect pests of which tarsonemid mite *Polyphagotarsonemus latus* (Banks) and thrips *Scirtothrips dorsalis* Hood are most destructive sucking pests and are considered as major pests (Reddy and Puttaswamy, 1984) resulting in a typical damage known as 'leaf curl syndrome'. The mites attack young apical leaves, flower buds and cause curling and crumpling of young developing plant parts and shedding of flower buds while, the thrips lacerate the tender leaf surface.

The whitefly *Bemisia tabaci* (Gennadius), the cotton aphid *Aphis gossypii* (Glover) and the green peach aphid *Myzus persicae* (Sulzer) are commonly found infesting chilli in which the nymphs and adults are found in large colonies on the under surface of leaves and growing shoots of plants (Butani, 1976). They suck the cell sap from the undersurface of the leaves and growing shoots. As a result, leaves curl, internodal length shortened, leaf size gets reduced and growth gets retarded.

The damage due to aphids and whiteflies cause a yield loss up to 50 per cent in chilli (Ahmad *et al.*, 1987). The thrips and mites cause yield loss to the tune of 12 to 90 per cent at national level (Rai *et al.*, 2014) and in Kerala, the yield loss of green chilli due to thrips and mites had been estimated as 60 to 75 per cent.

Sucking pests have high reproductive rates, a fast generation turnover, wide genetic diversity across locations, and an ability to withstand, metabolize, and avoid toxic chemicals. As a result, it has become practically difficult to control these sucking pests through the chemical pesticides. To manage these sucking pests, farmers used to apply several rounds of pesticide sprays indiscriminately. This unsystematic use of pesticides has led to serious concerns such as adverse effects on the non-target organisms, pesticide residues in food and food products, pest-resurgence, development of resistance in insects to insecticides, toxic effects on human beings, and environmental pollution. Therefore, it is important to adopt pest control strategies

that are ecologically sound, economically practical and socially acceptable and with the least possible disruption to agro-ecosystems which encourages natural pest control mechanisms.

Host plant resistance (HPR) along with natural enemies and cultural practices, is a central component of any pest management strategy. As an IPM tactic, it is an effective, economical and environment friendly method of pest control in which farmers virtually do not need any capital investment and skill in application techniques.

Considering this, the present study entitled “Field tolerance of chilli varieties against sucking pest complex” aims at evaluating the field tolerance of chilli to sucking pest complex, one of the most important constraints in chilli production.

Review of Literature

2. REVIEW OF LITERATURE

Chilli (*Capsicum annuum* L.) (Solanaceae) is the most widely used and universal spice of India. There are a number of factors responsible for depressing the yield of chilli in which, incidence of various insect and non-insect pests is one of the major bottlenecks of production (Chintkuntlawar *et al*., 2015)

Insecticides in general are effective in controlling these pests, but farmers have to apply pesticides more frequently and at higher doses, which results in the failure of control operations and environmental pollution and also resistance in insects. Host plant resistance has been deployed alone as an approach for pest management or can be combined with other pest control methods (Kalode and Sharma, 1995).

The literature pertaining to sucking pests in chilli, field tolerance and morphological and biochemical basis of resistance in chilli and other major crops is reviewed in this chapter.

2.1 SUCKING PESTS OF CHILLI

The insect pests which cause significant damage to the chilli crop comprises more than 39 genera and 51 species of insects and mite species in the field as well as in the storage (Jayadeep *et al*., 2016).

2.1.1 Chilli Thrips, *Scirtothrips dorsalis* (Hood) (Thysanoptera: Thripidae)

S. dorsalis is considered as the most destructive pest leading to 30 to 50 per cent yield loss under severe infestation (Reddy and Puttaswamy, 1984). First appearance of chilli thrips occurs when the crop is in the vegetative stage. Nymph and adult thrips are the damaging stages and feed by rasping and sucking on the leaf, tender shoot, flower buds and fruits. Under heavy infestations, when buds and flowers are attacked, abortion usually occurs. Thrips attack may also result in premature fruit shed. Thrips feeding causes scarring of flowers and skin blemishes and distortion of fruits (scarring, russeting, fruit cracking or splitting), and thus affects fruit quality (Chintkuntlawar *et al*., 2015).

The studies on species composition of thrips in chilli leaves, flowers and fruits indicated the existence of five species of thrips: *S. dorsalis, Frankliniella schultzei*

(Trybom), *Thrips hawaiiensis* (Morgan), and *Thrips palmi* (Karmy) (Terebrantia) and *Haplothrips verbasci* (Osborn) (Tubulifera). Among the five species, *S. dorsalis* was the dominant species and this was the only species found both in chilli leaves and fruits (Gopal *et al*., 2018)

2.1.2 Yellow Mite, *Polyphagotarsonemus latus* (Banks) (Trombidiformes: Tarsonemidae)

Yellow mite, *P. latus* is considered another most notorious and damaging pest all over the chilli growing pockets (Jayadeep *et al*., 2016). Damage by mite is usually found to be heavier on the upper parts of the plant than on the middle or lower parts.

In chilli, the most obvious symptoms caused by *P. latus* is progressive inward rolling of leaves in an inverted boat-shaped manner and has a shiny, silvery lining on their ventral flowers, distorted, shoots grow twisted and fruit may be misshapen and russeted. (Rai *et al*., 2007)

2.1.3 Aphid, *Aphis gossypii* (Glover) (Hemiptera: Aphididae)

The cotton aphid, *A. gossypii* is found commonly infesting chilli. The nymphs which are small, ovate, soft greenish brown and sluggish, along with the adults are found in large colonies on the under surface of leaves as well as the growing shoots and suck the cell sap. They also excrete honey dew on which black sooty mould develops which covers the leaves and twigs. The black coating due to sooty mould growth hinders the photosynthetic activity of the plant and results in further retardation in growth and fruiting capacity of the plant (Varghese and Mathew, 2012).

2.1.4 Whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae)

B. tabaci is one of the most important and notorious pests of chilli. Its infestation reduces the plant growth by sucking cell sap and excretes honey dew. As a result, leaves get curled, internodal length shortened, leaf size reduced and growth gets retarded. Both nymph and adult whitefly are the damaging stages and also transmits more than 90 types of viral diseases in varied commercial crops. Incidence and severity of chilli leaf curl virus transmitted by *B. tabaci* have been reported in the tune of 71.11 per cent and 21.84 per cent, respectively (Chintkuntlawar *et al*., 2016).

2.1.5 Jassid, *Amrasca biguttula biguttula* (Ishida) (Hemiptera:Cicadellidae)

Damage is caused by the nymphs and adults of *A. biguttula biguttula*. They suck the plant sap and inject salivary toxins which damage the tissues and impair photosynthesis. The affected leaves turn yellowish, then brownish starting from the margins and migrate to the midrib. Leaves gradually grow signs of curling, before drying completely and shedding. Severe incidence of the pest results in "hopper burn" injury and death of leaves, eventually leading to the stunting of young plants (Saini *et al*., 2017).

2.1.6 Spiralling Whitefly, *Aleurodicus dispersus* (Russell) (Hemiptera: Aleyrodidae)

A. dispersus is a polyphagous pest. The damage is caused by the adults and nymphs of the whitefly by direct feeding on plant sap and when they are present in very large numbers, leaf fall occur. Honeydew excreted by the nymphs encourages sooty mould growth on leaf surfaces, reducing the photosynthetic capacity of the plant (Ramani *et al*., 2002).

2.1.7 Mealybug, *Phenacoccus solenopsis* (Tinsley) (Hemiptera:Pseudococcidae)

P. solenopsis is a recently emerged serious pest in cotton and has a wide host range including solanaceous crops. The mealybugs extract the phloem sap and as a result, leaves turn yellow and become crinkled and malformed, which results in loss of plant vigour, foliage and fruit drop, and potential death of the plant. Phloem feeding also affects the growing regions of the plant, resulting in bunched and stunted growth, with plants producing smaller fruits or flowers, which ultimately leads to a reduction in seed or fruit yields (Fand and Suroshe, 2015).

2.2 FIELD TOLERANCE OF CROPS AGAINST SUCKING PESTS

2.2.1 Chilli

Field screening of 71 chilli genotypes were carried out to identify sources of resistance to *S. dorsalis*. The chilli genotypes showed differential reaction to the infestation of thrips in terms of both mean populations per leaf and per cent leaf curl index. 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 (Rameash *et al*., 2015).

Sawant *et al*. (1986) reported that out of 69 varieties screened for their resistance against *S. dorsalis*, only three varieties *viz*., Pant C1, LIC-45 and NP-46 were found to be resistant, while the remaining 44 and 22 varieties were found susceptible and highly susceptible respectively. In a screening trial on 62 chilli genotypes, Mallapur (2000) found that 13 genotypes were promising and showed a lower per centage leaf curl due to thrips and mite infestation. Ahmed *et al*. (2001) evaluated 77 genotypes on the basis of *P. latus* incidence, their injury grade and damage index, and reported that only nine genotypes were found resistant against mite, while the remaining were categorized as either susceptible (31) or highly susceptible (37). Babu *et al*. (2002) identified 17 promising genotypes, showing resistant and moderately resistant reactions to *S. dorsalis*, among the 308 accessions screened.

Priyadarshini *et al*. (2017) conducted screening of six chilli varieties against *S. dorsalis* in West Bengal. The results revealed that the mean population of thrips was lowest in the variety Bhanger which was followed by Bullet and Jhumko. The susceptible varieties were Mocha, followed by Suryamukhi and Akashi. Correlation studies between thrips population and weather parameters revealed that population of thrips showed significant positive correlation with average temperature, maximum and minimum temperature and a significant negative correlation with maximum relative humidity.

In a screening trial conducted by Girish *et al*. (2019), 30 chilli genotypes were screened for their resistance against *P. latus* based on mean population of mites and per centage of mite infested plants. Among the tested genotypes, two, namely, Aparna and

S 49 were designated as highly resistant, one as resistant, two genotypes as moderately resistant, three as susceptible and the remaining 22 genotypes as highly susceptible.

Among the 46 chilli genotypes evaluated for thrips resistance under field condition in Bagalkot, 7 genotypes *viz*., Phule Jyothi, DCA-232, DCA-106, DCA-142, DCA-139, etc. showed moderate resistance to thrips, while 37 genotypes were susceptible and two genotypes were highly susceptible to the thrips infestation. (Megharaj *et al*., 2016).

Kaur *et al*. (2010) screened sixty-three varieties of chilli against chilli thrips and yellow mite in Ludhiana. The results of the study revealed that the chilli lines, DCL-524, EC 532386 and Selection-40 showed the comparative resistance to both chilli thrips and yellow mite under field conditions and the varieties, EC 532399 and Kashmir Long-1 were highly susceptible to both the pests. Latha and Hanumanthraya (2018) conducted investigations on screening of chilli genotypes against chilli thrips and mite in Karnataka. Out of thirty-one chilli genotypes screened against thrips and mites, four genotypes, DCC-109, 185, 3 and DCC-89 were found moderately resistant, eleven genotypes were found susceptible and two genotypes were highly susceptible to both thrips and mite.

Sixteen cultivars of chilli were screened in field condition for their resistance to the yellow mite infestation at two different locations in Madurai. Based on the mean population of mites and eggs/leaf, intensity of leaf curling and grading index, the varieties were grouped as resistant and susceptible lines. Pusa Sadabahar and Pusa Jwala exhibited high degree of field resistance to yellow mite of chilli and other fourteen cultivars were susceptible to yellow mite infestation (Ambika *et al*., 2008).

Kulkarni *et al*. (2011) evaluated 80 chilli genotypes to mites and thrips infestation under natural conditions. Sixteen genotypes of chilli showed resistance to thrips, while fourteen were susceptible to the thrips infestation. The promising genotypes with resistant reaction included IC 324894, Pant C-1, DCA-7, DCA11, DCA-40 and Arka Lohit to both the pests, while 50 and 45 genotypes were found to be moderately resistant to thrips and mites respectively.

Field experiments on screening of twenty-nine chilli germplasm against yellow mite and thrips damage was conducted in West Bengal. The results revealed that highest mean population of yellow mites and thrips was recorded on chilli hybrid 2011/CHYB-8 and 2012/CHYB-10 respectively whereas lowest mean population of yellow mites and thrips was found on the genotype 2012/CHYB-11 and BSS-453 respectively. The results of the field screening trials based on per cent of plant infested with visible symptoms revealed that out of 29 chilli hybrids, 4 and 3 cultivars were found field tolerant, 7 and 12 lines were moderately field tolerant and 18 and 14 hybrids were categorised as susceptible against yellow mites and thrips, respectively (Samantha *et al*., 2016).

Satpathy *et al*. (2008) evaluated eighty-one chilli germplasms consisting of local and indigenous collections, released varieties and local cultivars with diverse phenotypic and genetic makeup under field conditions against yellow mite and thrips complex in Varanasi. Among these, the genotype PDG-1A was found as resistant and VNS-4 as highly susceptible with a maximum leaf curl grade of 4.34.

Investigations on varietal screening of chilli against thrips and whitefly was conducted and out of ten varieties of chilli screened, none was found completely free from the attack of pests. The varieties Pant C-1, Mathania Local and Alakhpura Selection were categorized as least susceptible while, Pusa Jawala and PS-64 as highly susceptible to thrips and whitefly (Samota *et al*., 2018).

Priyadarshini *et al.* (2019) conducted screening of six varieties of chilli against important sucking pests of chilli *viz*., whitefly, thrips, aphids, mites and jassids. Among the tested cultivars, Jhumko was found to be tolerant to chilli mite and Bullet was susceptible against it. Suryamukhi was recorded as the tolerant one against whitefly and Akashi was the susceptible one. Bhangar and Mocha were found to be tolerant and susceptible cultivars against thrips respectively. Similarly, Bhangar was tolerant and Suryamukhi was susceptible to aphid infestation. Mocha was found to be tolerant against jassid whereas Bullet was recorded as the susceptible one against it.

Kumar *et al*. (2021) screened ten chilli varieties for their relative tolerance and susceptibility to major insect pests. According to their findings, Arka Khyati was

categorized as resistant while, the varieties, Pusa Sadabahar and Pusa Jwala showed the highest degree of leaf curling index and were categorized as highly susceptible varieties.

Fourty-four chilli germplasms were screened against yellow mite and its incidence was observed during the growth period of the crop. It was revealed from the study that none of the germplasms were resistant against the yellow mite, however the germplasm, BCCH-SL-4 (IC 564032) was found to be least susceptible to yellow mite followed by SBD-1-1. On the other hand, the germplasms SB-5-4-1-2 and SB-5-4-1 were recorded to be the most susceptible against yellow mite (Bala *et al*., 2016). Kumar *et al*. (2020) screened seventy chilli varieties against *S.dorsalis* and *Myzus persicae* in Kanpur. Out of these, five lines of chilli *viz*., Pusa Jwala, NT-74, Selection-2010, G-4 and GS-15 were found highly resistant and 9 lines *viz.*, 2031, 2014, M-2-1, 810-42, Selection-2017, Selection-25-1, 35-30-1, Chaman and Selection-2 (yellow) were highly susceptible.

A total of 70 chilli germplasms were evaluated against *S. dorsalis* and *P. latus* based on the damage caused by them. Based on the per cent leaf curl index, four genotypes were found to be moderately resistant to thrips and four were categorised as moderately resistant against mites. (Kurbett *et al*., 2018). Murtiningsih *et al*. (2021) evaluated thirty chilli accessions for resistance against thrips based on the pest population, leaf damage and assessing the morphological characters. According to their findings, accession numbers 5, 18, 19, 21, 22, 24, 27, 28, 29 and 30 were selected as resistant against thrips and proposed to be used as female parent in the new variety developing program.

Choudhary and Pandya (2019) conducted a study on biochemical basis of resistance against *S. dorsalis* in eight chilli varieties, in Navsari. As per their results, the variety GVC-121 recorded the lowest population of thrips and GCH-3 recorded the highest. Among the thirteen chilli accessions evaluated for the reaction to *S. dorsalis* in Hyderabad, the accessions *viz.*, EC-596952, EC-390033 and EC-391082 were least preferred by thrips having lowest thrips population and least per cent leaf curl index and two accessions *viz*., EC-599976 and EC-599994 were highly susceptible to the pest incidence (Gopal *et al*., 2019).

2.2.2 Other Crops

Twenty tomato genotypes were screened in Bihar, to study the effects of morphological and biochemical traits on the population of aphids and whiteflies. Among the genotypes, BRDT-1, EC-620421, *Solanum peruvianum*, EC-538455 and *S. cheesmaniae* had lowest number of aphids and whiteflies (Anu *et al*., 2021).

Among the six tomato genotypes evaluated for their tolerance to sucking pest complex *viz.*, aphids, mites, thrips, jassids and whiteflies, the genotypes Rutgar and Eden Oblong were the least susceptible against the sucking pests and the genotype Nagina was the most susceptible (Solangi *et al*., 2017). Sarkar *et al*. (2018) screened six tomato genotypes for their tolerance against *A. gossypii* and *B. tabaci* in West Bengal. According to their findings, the genotype Patherkuchi was found less susceptible to both aphid and whitefly, while NS 501 was highly susceptible.

Wade *et al*. (2020) screened fifteen genotypes of tomato against whiteflies, aphids and leaf miner under field conditions in Wakawali. Among the genotypes, N-2257 was resistant to aphids and whiteflies and genotype BT-1 was resistant to leaf miner infestation. Fifty tomato genotypes were evaluated for their non-preference (antixenosis) against *B. tabaci*. The results from the study revealed that the genotypes *viz*., EC-520078, EC-631364, EC-315477 and EC-620389 had the highest non-preference mechanism of plant resistance against *B. tabaci* as compared to the other genotypes (Ponselvakumari *et al*., 2021).

Seven tomato hybrids were evaluated against *B. tabaci* in Garhakota, in which the results revealed that none of the hybrids was found completely free from infestation. Among the hybrids, Vaishnavi showed highest resistance against whitefly and PKM-1 was the most susceptible (Mishra *et al*.,2019).

Thirteen genotypes of brinjal were evaluated for their resistance against major sucking pests *viz*., *M. persicae, Amrasca devastans, B. tabaci* and *Frankliniella occidentalis*. The study revealed that the genotype ADVANTA-314 was found resistant to aphid, whereas TWINKLE STAR showed resistance to both leaf hopper and whitefly. The cultivar KHBR-202 was recorded deterrent to thrips (Jafir *et al*., 2018). Salve *et al*. (2020) screened ten genotypes of brinjal against the sucking pests in

Parbhani. Among the genotypes, BH-2 showed moderate resistance to infestation of whitefly and jassids whereas, SBJH-691, Aussay, Utkal Jyoti and VR-2 were moderately susceptible to the pests. The cultivar JBH-3 was highly susceptible to the major sucking pests of brinjal.

Ashraf *et al*. (2017) evaluated the relative performance of ten brinjal varieties against the population of *B. tabaci* and *A. biguttula biguttula* in Pakistan. According to their findings, populations of both pests were recorded significantly more on Xingchangjishi while least populations of these pests were recorded on Egg plant deep black and Sandhya F1.

Nine cultivars of brinjal were tested for their susceptibility against *A. biguttula biguttula* in Pakistan based on pest preference, host plant susceptibility indices and yield. Among the cultivars, the most preferred variety was Bemissal whereas the least preferred variety recorded was Rubi (Ali *et al*., 2016). Among the five genotypes of brinjal screened in Peshawar, against the sucking insect pests *viz.*, aphids, jassids and whitefly, the genotype Shamli hybrid had significantly lower mean density of aphids, jassids and whiteflies, whereas the genotype Local round had higher mean density of the pests (Ayub *et al*., 2020).

An experiment conducted in Kerala to screen 36 brinjal genotypes against *A. biguttula biguttula* revealed that accessions SM 363, SM 364, SM 366, SM 384 and SM 385 were found resistant to jassid infestation (Malini *et al*., 2013). Habib *et al*. (2015) evaluated three brinjal genotypes, Shamli, Pearl long and Black beauty for their responses against *A. gossypii* and *A. biguttula biguttula*. Acoording to their findings, overall mean density of *A. gossypii* and *A. biguttula biguttula* was lower on Pearl long and higher in Black beauty.

Berani *et al*. (2020) screened sixteen genotyoes of brinjal against aphid, jassid, whitefly and mite. The results revealed that the genotypes, GJLB – 4, JBGR – 1, Pusa Purple Cluster, GBL – 2 and GJB – 3 were found tolerant, whereas GOB – 1 and GJB – 2 were found susceptible to the sucking pest complex.

Three hundred and ninety-one *Gossypium hirsutum* and 34 *Gossypium barbadense* accessions were screened for thrips (*Frankliniella fusca* and *Frankliniella*

occidentalis) resistance in North Carolina, in which five resistant *G. barbadense* accessions and five moderately resistant upland cotton accessions were identified (Kaur *et al*., 2018).

Five cultivars of cotton were evaluated for their resistance to *B. tabaci*, *Thrips tabaci, A. devastans* and *A. gossypii* and among them, the cultivar FH-634 was found to be most resistant to the sucking pest complex and FS-628 was most susceptible (Amjad *et al*., 2009). Nishant *et al*. (2016) screened 480 germplasm lines of *G. hirsutum* against thrips and jassids, in which CPD-1015 showed resistance to thrips, whereas SEC-6 and FQT-36 were found to be resistant to jassids.

Pathan *et al*. (2007) tested six cotton strains for their resistance against sucking pest complex (*A. devastans, B. tabaci* and *T. tabaci*). According to their findings, the genotype CRIS-468 was highly resistant and CRIS-467 was highly susceptible to the insect pest complex. Khan (2011) screened nine varieties of cotton to evaluate their comparative resistance to whitefly, jassid and thrips. Among all the tested varieties, DNH-105 and CIM-506 were found relatively resistant to the sucking insect pests. Amin *et al*. (2016) evaluated five cotton cultivars for their resistance against *A. gossypii* and *A. devastans* and the results revealed that CB1 and CB3 showed the least leaf and boll infestation and infestation was highest in CB12.

Halder *et al*. (2016) evaluated the reaction of ten okra genotypes to *A. biguttula biguttula* and the genotype VROB-181 was found highly resistant to jassids whereas SB-6 was recorded as highly susceptible. Field screening studies for *B. tabaci* resistance were conducted with 25 okra germplasm accessions at National Bureau of Plant Genetic Resources (NBPGR) Regional Station, Hyderabad. Lowest mean population of whiteflies was recorded in accessions PSRJ-12952, IC344598 and RJR-124, while the accessions PSRJ-13040 and RJR-193 recorded the highest number of whiteflies (Manjua *et al*., 2018).

A study on evaluation of 30 genotypes of okra for their resistance against jassids was conducted by Iqbal *et al*. (2008) and found that the genotypes, Makhmali, Punjab selection and Green wonder were resistant and Pusa sawani, Dera local and Okra-3 were susceptible. In a screening study conducted on fifteen okra germplasms, Sandhi

et al. (2017) reported that *Abelmoschus moschatus*, *A. angulosus* and *A. tetraphyllus* showed high degree of field resistance to jassids.

A screening trial of eight genotypes of okra for resistance against aphids, jassids and whitefly were conducted by Biswas *et al*. (2016), in which the genotype Nirmal 101 was comparatively tolerant and Local cultivar showed maximum susceptibility. Ten okra genotypes were evaluated for their response against *A. gossypii*, *A. biguttula biguttula* and *Dysdercus cingulatus* and among these, VRO-6 was resistant to aphid, IIVR-10 showed resistance to jassid and red cotton bug and 317-10-1 was susceptible to all the pests (Navneet *et al*., 2018). Tanni *et al*. (2019) evaluated the performance of ten Japanese okra genotypes against *A. gossypii*, *A. biguttula* and *Tetranychus* sp. and found that the genotype JO5 was least susceptible to the pest incidence.

Narayanan and Muthiah (2017) conducted *in vivo* screening of thirty okra accessions against aphids, jassids and whiteflies and reported that the accession IC 15027 showed resistance and IC 90202, IC 90203, IC 90213 and IC 90214 were found to be moderately resistant to sucking pests. In a screening study conducted by Priyanka *et al*. (2020), in ten varieties of okra against *A. biguttula biguttula* and *B. tabaci*, it was reported that the varieties IIVR-11 and VRO-4 were resistant and Kashi Satdhari and Parbhani Kranti were highly susceptible.

Khoso *et al*. (2017) screened three okra varieties against sucking pest complex including thrips, jassid, aphid, whitefly and mealybug and found that the variety Rama Krishna was relatively tolerant and Bharat Kaiwari was susceptible to the sucking pest complex. Screening of twenty okra genotypes were conducted against *A. biguttula biguttula* and the results revealed that genotypes OK-7, OK-9 and Arka Anamika were categorized as resistant and IC-282268, IC-282292, IC-282288 and IC-140906 showed maximum population and categorized as susceptible to leafhopper (Kadu *et al*., 2018).

Four okra varieties were screened against whitefly and jassid and found that, among them, the variety Sada Bahar was less infested with the pests and Sabz Peri and Arka Anamika were susceptible to jassid and whitefly respectively (Rehman *et al*., 2017). Prithiva *et al*. (2019) screened twenty-three okra genotypes for their resistance

against *A. biguttula biguttula* and reported that the genotypes AE 65 and AE 23 were moderately resistant and AE 26 and Pusa Sawani were highly susceptible.

Antibiosis studies on selected genotypes of okra were conducted against jassids by Hussain *et al*. (2014) and the results revealed that the genotype Sanam was found to be comparatively resistant and Pusa Swani proved to be comparatively susceptible. Bhalu *et al*. (2019) conducted investigations on screening of ten okra genotypes against *B. tabaci* and found that lowest whitefly incidence was recorded in HRB-108- 2 and the highest whitefly population was recorded in Pusa sawani.

Ashraf *et al*. (2017) screened five varieties of okra against *A. biguttula biguttula* and reported that the minimum jassid population was on the variety Green wonder and maximum was on Pusa Sawani. Correlation of environmental factors showed that temperature had negative and humidity had a positive correlation with jassid population.

Twenty-three genotypes of okra were screened against A. biguttula biguttula and the minimum population of leafhopper was observed in the genotypes HBT 12 and HBT 36, whereas the population was maximum in HBT 35-1 (Verma *et al*., 2015).

2.3 MORPHOLOGICAL AND BIOCHEMICAL BASIS OF RESISTANCE AGAINST SUCKING PESTS IN MAJOR CROPS

2.3.1 Chilli

Rameash *et al*. (2015) screened 71 genotypes of chilli against *S. dorsalis* and the results on correlation between agro-morphological attributes and thrips infestation revealed that, the plant height, days to 50 per cent flowering, days to maturity and leaf chlorophyll content were negatively correlated with the thrips infestation. In a screening study conducted in 30 chilli genotypes for their resistance against *P. latus*, Girish *et al*. (2019) observed that the resistant genotypes had high phenol content, whereas the levels of total sugars and protein were higher in the susceptible genotypes.

Fourty-six chilli genotypes were evaluated for thrips resistance by Megharaj *et al*. (2016) and the results revealed that, thrips incidence had negative correlation with fruit yield, number of fruits/plant, number of primary branches/plant etc. They also

reported that biochemical components like non reducing sugars, phenols and total chlorophyll showed negative association with the thrips incidence, but reducing sugars, calcium and sulphur resulted positive correlation with the thrips infestation.

Mondal *et al*. (2013) reported that phenols provide resistance in plants during host plant interactions, in a screening study conducted in 37 genotypes of chilli against leaf curl virus. A screening study in thirty-one chilli genotypes were conducted by Latha and Hanumanthraya (2018) and they observed that the morphological and biochemical characters *viz.,* trichome density, chlorophyll and phenol content were significantly negatively correlated with the population of thrips and mites.

Samota *et al*. (2018) conducted screening of ten chilli varieties against thrips and whitefly and reported that biochemical characters of these varieties *viz*., free amino acid and total soluble sugar content had positive correlation whereas, total phenol had negative correlation with the population of thrips, whitefly and per cent leaf curling.

Eight chilli varieties were screened for their biochemical basis of resistance against *S. dorsalis* and the results revealed that the biochemical characters *viz.*, moisture, non-reducing sugar, total phenol and chlorophyll were higher in resistant variety, whereas ash, total soluble sugars, reducing sugar, nitrogen and protein were higher in susceptible variety as compared to resistant variety (Choudhary and Pandya, 2019). Gopal *et al*. (2019) evaluated thirteen chilli accessions for their reaction to *S. dorsalis.* The morphological traits and yield attributes observed in the study showed that the resistant accessions were not only least preferred by the pest but also possessed good morphological traits and gave good yield.

2.3.2 Other Crops

Anu *et al*. (2021) screened twenty genotypes of tomato for their morphological and biochemical basis of resistance against aphids and whiteflies. They observed that the morphological traits like more trichome density and thick stem diameter as well as the presence of biochemical attributes like phenol and tannins were present in the resistant genotypes at higher concentration. The higher content of leaf chlorophyll also had resistance effect against the population of aphids and whiteflies.

Ponselvakumari *et al*. (2021) screened fifty tomato genotypes for their non-preference against *B. tabaci* and observed that the highest non-preference mechanism in the genotypes can be attributed to the high trichome density and epicuticular wax content.

An experiment was conducted in Kerala to screen 36 brinjal genotypes against *A. biguttula biguttula* and they reported that high midrib hair density and longer midrib hairs imparted resistance to jassids in the resistant accessions (Malini *et al*., 2013). Ramzan *et al*. (2020) evaluated the relationship of plant characters in brinjal genotypes to jassid incidence in Faisalabad. The results revealed that the hair density and length on leaf lamina, midrib and vein were negatively correlated whereas the moisture content and thickness of leaves showed positive correlation with the incidence of jassids.

Kaur *et al*. (2018) screened three hundred and ninety-one *Gossypium hirsutum* and 34 *Gossypium barbadense* accessions against *Frankliniella fusca* and *Frankliniella occidentalis* and reported that the leaf pubescence and relative growth rate were significantly higher in resistant accessions compared with susceptible accessions.

Nishant *et al*. (2016) screened 480 germplasm lines of *G. hirsutum* against thrips and jassids and found that mean value of phenols and gossypol content was higher in the resistant accessions and reducing sugar content was higher in the susceptible accessions. Five cotton cultivars were screened for their resistance against *A. gossypii* and *A. devastans* by Amin *et al*. (2016) and they observed that the resistant cultivars possessed higher number of trichomes.

A study on morphological and biochemical characters of fourteen cotton genotypes against *A. devastans* was conducted by Raju *et al*. (2020) and the results revealed that the genotypes with more leaf hair density, more per cent phenol and tannin content recorded least number of leafhoppers. Twelve cotton cultivars were evaluated for their morphological and biochemical resistance traits against sucking pest complex and the resistant variety NIAB-Kiran showed less soluble sugars, soluble proteins and more phenols and flavonoids as compared with the susceptible check Glandless-1. Moreover, the pest populations exhibited negative response to leaf gossypol glands, total phenols, tannins and flavonoids (Muhammed *et al*., 2021).

Ten okra genotypes were evaluated for their reaction to *A. biguttula biguttula* and it was reported that trichome density and total phenol content were negatively correlated with the incidence of jassids whereas leaf length and angle between mid-ribs showed a strong positive correlation (Halder *et al*., 2016). In a screening study conducted on fifteen okra germplasms, Sandhi *et al*. (2017) reported that high mid vein hair density, longer hair, erect hair, broader leaves, higher level of total sugars, total phenols, tannins and silica, and lower levels of reducing sugars were found in the resistant germplasms. Tanni *et al*. (2019) evaluated the performance of ten Japanese okra genotypes against *A. gossypii, A. biguttula* and *Tetranychus* sp. And found that the resistant genotype possessed high trichome density.

Field screening studies were conducted with 25 okra germplasm accessions against *B. tabaci* and okra yellow vein mosaic virus and it was reported that morphological traits like high trichome density, less leaf area and dark green leaf colour and biochemicals like low nitrogen, protein, less total and reducing sugars and high phenol content offered resistance mechanism against whitefly (Manju *et al*., 2021).Biochemical components of ten okra germplasms were assessed for resistance or susceptibility to the leafhopper, *A. biguttula biguttula* and the results revealed that that highest total sugars and phenol content imparted resistance into the okra germplasm, whereas highest reducing sugars, protein content and excess chlorophyll content were responsible for susceptibility. The resistant germplasms also exhibited high catalase, peroxidase and polyphenol oxidase activities as compared to susceptible germplasm (Kumar *et al*., 2021).

Impact of trichomes on the population of *A. biguttula biguttula* was investigated in twenty-three okra genotypes and found that the trichome density and trichome length had negative influence on the leafhopper population (Prithiva *et al*., 2019).

Chatterjee *et al*. (2019) studied the varietal preference of *B. tabaci* and *A. biguttula biguttula* on fifteen varieties of okra. The morphological characters, *viz*., length of fruit had significant positive effect on the infestation of whitefly and jassid. Hairiness on shoot and leaf as well as yield had significant negative effect on the infestation of whitefly and jassid.

Materials and Methods

3.MATERIALS AND METHODS

A study on “Field tolerance of chilli varieties against sucking pest complex” was conducted at College of Agriculture, Vellayani during the period 2019-2021.The main objective of the study was to evaluate the field tolerance of chilli genotypes against sucking pest complex.

3.1 EVALUATION OF FIELD TOLERANCE OF CHILLI GENOTYPES AGAINST SUCKING PEST COMPLEX

The experiment was laid in Completely Randomized Design (CRD) with three replications. 30 chilli genotypes (Table 1) including local and indigenous collections, released varieties from Kerala Agricultural University and accessions from NBPGR were selected for the study.

3.1.1 Raising of Test Plants

The seeds of chilli were procured from various sources, sown in protrays and 28 days old seedlings were transplanted to grow bags. The genotypes were screened for their relative susceptibility to major sucking pests. The recommended packages of practices (KAU, 2016) except pesticide application were followed to raise the crop. The observations were taken at 15 days interval starting from 20 days after transplanting.

3.1.2 Population Density of the Sucking Pest Complex

The population of thrips, mites and aphids were counted from three leaves per plant from the top, middle and bottom canopy of randomly selected three plants. The count of both adults and nymphs were taken at 20, 35, 50 and 65 days after transplanting with the help of a stereo-binocular microscope.

3.1.3 Assessment of Damage

3.1.3.1 Scoring for Thrips and Mites Damage

Leaf curl index was worked out to assess the extent of damage caused by chilli mites and thrips (Table 2)**.** Leaf damage was scored visually following the standard

Table 1. Chilli genotypes evaluated for field tolerance to sucking pest complex.

Treatments	**Genotypes**	**Source**
T1	Anugraha	Kerala Agricultural University, Thrissur
T2	Athulya	Department of Vegetable Science, College of Agriculture, Vellayani
T3	Baji chilli (L1)	Guruvayoor
T4	Bhaskara (L2)	Guruvayoor
T5	Blue Kanthari (CF1)	Nellimoodu, Thiruvananthapuram
T6	Bullet (L3)	Guruvayoor
T7	Edayoor chilli (L4)	Edayoor, Malappuram
T8	Guruvayoor local (L5)	Guruvayoor
T9	Green Kanthari (CF2)	Nellimoodu, Thiruvananthapuram
T10	Green Unda (L6)	Malappuram
T11	IC272868	NBPGR Regional Station, Hyderabad
T12	IC284628	NBPGR Regional Station, Hyderabad
T13	IC312916	NBPGR Regional Station, Hyderabad
T14	IC342426	NBPGR Regional Station, Hyderabad
T15	IC342464	NBPGR Regional Station, Hyderabad

T16	IC344367	NBPGR Regional Station, Hyderabad
T17	IC537657	NBPGR Regional Station, Hyderabad
T18	IC572454	NBPGR Regional Station, Hyderabad
T19	Jwalamukhi	Department of Vegetable Science, College of Agriculture, Vellayani
T20	Neelamulaku (L7)	Malappuram
T21	Odankolli (L8)	Nellimoodu, Thiruvananthapuram
T22	Sira (L9)	Guruvayoor
T23	Suryamukhi (L10)	Vellayani, Thiruvananthapuram
T24	Thondan (L11)	Nellimoodu, Thiruvananthapuram
T25	Ujwala	Kerala Agricultural University, Thrissur
T26	Unda Mulaku (L12)	Malappuram
T27	Vattal (L13)	Malappuram
T28	Violet chilli (L14)	Guruvayoor
T29	White kanthari (CF3)	Nellimoodu, Thiruvananthapuram
T30	White unda (L15)	Thrissur

Table 2. Standard procedure for scoring Leaf Curl Index (LCI)

LCI/Grade (0-4)	Category	Symptoms
0	Immune (I)	No symptom (No curling, completely healthy plant)
1	Resistant (R)	1-25 per cent leaves/plant show curling, less damage
2	Moderately Resistant (MR)	26-50 per cent leaves/ plant show curling, moderately damaged
3	Susceptible (S)	51-75 per cent leaves/plant show curling, heavily damaged, malformation of growing points and reduction in plant height
4	Highly Susceptible (HS)	> 75 per cent leaves/ plant show curling, severe and complete destruction of growing points, and drastic reduction in plant height, defoliation and severe malformation.

scoring procedure by Niles (1980) mentioned below based on the genotype performance and all the genotypes were categorized into five categories.

$$\text{Per cent leaf damage} = \frac{\text{Number of infested leaves}}{\text{Total number of leaves}} \times 100$$

Per cent Leaf Curl Index (PLI) was calculated for the chilli genotypes using the formula:

$$\text{Per cent Leaf Curl Index} = \frac{\text{Sum of numerical ratings}}{\text{Total number of plants observed}} \times \frac{100}{\text{Maximum leaf curl index grade in the score chart}}$$

The chilli genotypes were classified into four categories *viz*., 0-10- resistant; 11-25- moderately resistant; 26-50 susceptible and 51-100- highly susceptible, based on the percent leaf curl index values.

3.2 MORPHOLOGICAL, BIOCHEMICAL AND NUTRIENT BASIS OF RESISTANCE

Analysis of morphological characters, biochemicals and nutrients were carried out for the tolerant and susceptible genotypes obtained after the evaluation of field tolerance of 30 chilli genotypes.

3.2.1 Morphological Characters

The following morphological characters were recorded for the tolerant and susceptible genotypes:

3.2.1.1 Total Number of Leaves Plant^{-1}

The number of leaves were counted from one plant in each replication and denoted as the total number of leaves plant^{-1}.

3.2.1.2 Leaf Area

The area of the leaves was measured using a graph.

3.2.1.3 Length Width Ratio of Leaves

The length of the leaves was divided with width of the leaves and expressed as length-width ratio.

3.2.1.4 Number of Trichomes Leaf^{-1}

The number of trichomes were counted from the leaves using a stereo-zoom microscope.

3.2.1.5 Number of Branches Plant^{-1}

The number of branches were counted from each plant in a replication and expressed as number of branches plant^{-1}.

3.2.1.6 Plant Height (cm)

Height of the plant from the base to the top most leaf bud was measured using a measuring scale and recorded.

3.2.1.7 Yield (kg plant^{-1})

The total weight of the fruits was recorded after each harvest.

3.2.2 Biochemical Analysis

3.2.2.1 Total Phenol Content

The total phenol content of the leaf was estimated by the Folin-Ciocalteau reagent method described by Malick and Singh (1980). 100 mg of samples was homogenized in phosphate buffered saline (pH 7.4) and homogenized samples were centrifuged at 1000 rpm for 2 minutes. Supernatant thus obtained was used for the study. 5 mL of Folin-Ciocalteau reagent was added to 0.2 mL of the sample. After 5 minutes of incubation, 4 mL of 20% sodium carbonate solution was added to it. It was stirred and incubated at room temperature for 45 minutes. After incubation, the absorbance was measured at 750 nm using UV-VISIBLE spectrophotometer (Agilent,

Cary 60), and the total phenol content was calculated using the standard graph of Gallic acid.

3.2.2.2 Total Protein Content

The total soluble protein content of leaf samples was estimated as per the method described by Bradford (1976). 100 mg of sample was homogenized in phosphate buffered saline (pH 7.4) and homogenized samples were centrifuged at 1000 rpm for 2 minutes. Supernatant thus obtained was used for the study. 10 µl of sample were added with 200 µL of diluted dye binding solution. One volume of concentrated dye solution was added with four volumes of distilled water for use. It was mixed well and allowed the colour to develop for at least 5 minutes but not longer than 30 minutes. Absorbance was read at 595 nm after incubation. A standard graph was plotted with Bovine serum albumin as the standard and calculated the protein concentration using the standard curve.

3.2.2.3 Total Sugars

The total sugar content of leaf samples was estimated by the Anthrone method suggested by Hedge and Hofreiter (1962). 100 mg of samples were homogenized in phosphate buffered saline (pH 7.4) and homogenized samples were kept in boiling water bath for three hours with 5 mL of 2.5 N HCl and cooled to room temperature. After cooling, solid sodium carbonate was added to neutralize it. The volume was made up to 100 mL and centrifuged at 5000 rpm for 5 minutes. The supernatant thus obtained was collected and used for the study. To 500 µL of sample 4 mL of anthrone reagent was added and kept it in boiling water bath for eight minutes. After cooling, the absorbance (Green to Dark green) was read at 630 nm. The amount of total carbohydrate present in the sample was calculated using the standard graph of glucose.

3.2.2.4 Capsaicin

Dry chilli powder (0.5 g) was weighed into a glass-stoppered test tube or volumetric flask. 10 mL of dry acetone was pipetted out into the flask and shook it for 3 h in a mechanical shaker. The contents were allowed to settle down or centrifuge (10000 rpm for 10 min).1 mL of the clear supernatant was pipetted out into a test tube

and evaporated to dryness in a hot water bath and dissolved the residue in 5 mL of 0.4% sodium hydroxide solution.3 mL of 3% phosphomolybdic acid was added and shook the contents and allowed to stand for 1 h. The solution was filtered and centrifuged at about 5000 rpm for 10-15 min. The clear blue coloured solution was transferred directly into the cuvette and the absorbance was read at 650 nm. A reagent blank was run along with the test samples. A standard graph was prepared using 0-200 µg capsaicin and amount of capsaicin present in the sample was calculated using the graph.

3.2.3 Analysis of Total Nitrogen, Phosphorous and Potassium

3.2.3.1 Nitrogen Estimation

Single Acid Digestion

Accurately weighed 0.5 g of dried and ground leaf sample. The sample was fed into tubes of Kjelplus digestion assembly. A pinch of digestion mixture (K_2SO4/ Na_2SO4, CuSO4 and Selenium powder in 100:10:1 ratio) was added. 10 mL of Con. H_2SO4 was added. Water was supplied to the instrument. The instrument was switched on and waited for the temperature to attain 350^0C, which was already set in the instrument. When it reached 350^0C, or when the digestion was completed, the solution became clear. Then the instrument was switched off. The tap was closed only after 15 min for cooling the instrument. The contents were transferred into 100 mL volumetric flask and made up to 100 mL after cooling of the sample.

Estimation

Apparatus Required- Kjeldplus Distillation Assembly

It was made sure that bottle on the top of the distillation assembly unit was filled with enough distilled water. The tube of alkali was dipped in conical flask containing distilled water. A blank long tube was placed in the space provided in the instrument. The tap was opened for water supply to the instrument. The instrument was switched on, pressed POWER button and waited for red light to blink in the ready button. The RUN button was pressed near alkali to rinse the tube with distilled water, already taken in conical flask. Next the conical flask was replaced with alkali bottle and dipped the

alkali tube in alkali bottle.10 mL of boric acid was taken in 250 mL conical flask and added 2-3 drops of mixed indicator (colour of solution is pink). The conical flask was placed on the right side of the unit. The time was set in alkali for 6 sec and pressed RUN button or added 10 mL of 40% NaOH manually. The processing time was set for 6 min and pressed RUN key. The conical flask was taken out and titrated against 0.02 N H_2SO4 taken in the burette. End point was the appearance of light pink colour

The % of N was determined as detailed below:

1 mL of 1 N H2SO4 = 0.014 g N_2

$$\% \text{ of N in the plant sample} = \frac{TV \times N \times 0.014 \times 100 \times 100}{W \times 10}$$

N -Normality of acid (0.02 N)

W- Weight of dried and ground plant sample taken (0.5 g)

3.2.3.2 Phosphorus Estimation

Wet Digestion Method

Accurately 1.0 g powdered dry leaf sample or 0.625 g fresh leaf sample was weighed and transferred into 250 mL microkjeldahl flask. 6.25 mL diacid mixture and 2-3 glass beads were added. The solution was warmed and the flame was subsequently increased to strong flame in a fuming chamber with exhaust fan. The digestion was continued with occasional swirling of the flask until no visible particles were left and the solution became clear. It was cooled and 0.5 mL HNO_3 was added and digestion was continued until dense white fumes in digestion flask. The contents were diluted with distilled water, cooled and filtered in a 50 ml volumetric flask. The volume was made with distilled water and mixed thoroughly. The aliquots were used for determination of mineral constituents.

Estimation

Different concentrations of phosphorous at 1.56-25 μg ml^{-1} and 1.25 mL test sample were pipetted out in 25 mL flask. 2.5 ml of the bray reagent and 2 mL of reagent

B (Ascorbic acid) was added. The volume was made up to 12.5 mL with distilled water. The contents were shaken well and tubes were kept for incubation for 10 minutes. The optical density was read colorimetrically at 660 nm in a spectrophotometer.

3.2.3.3 Potassium Estimation

Standard and sample solutions were set up. Working standards were prepared by pipetting out 1,2,3,4,5 mL of 100 ppm potassium solution into separate 50 ml volumetric flasks. 5 mL of plant sample was pipetted out to 50 mL volumetric flask and made up the volume. Flame photometer was powered up in accordance with the instrument's instruction manual. The blank was set with the diluent used for sample and standard preparation. This was usually deionised water. The prepared standards were aspirated in increasing concentrations and recorded their stable display readings. The unknown solution was aspirated and recorded the stable display reading.

The % of K was determined as detailed below:

$$\% \text{ K in plant sample} = \frac{\text{'X' ppm} \times 50 \times 100}{5 \times 0.5 \times 10000}$$

X = Concentration of K in plant sample from the instrument

3.2.4 Statistical Analysis

Data was analysed by Analysis of variance (ANOVA) in GRAPES software in Completely Randomized Design (CRD) (Gopinath *et al*., 2020).

Results

4.RESULTS

An experiment was conducted at College of Agriculture, Vellayani during 2019-2021 to evaluate chilli genotypes for their field tolerance to sucking pest complex. The results obtained were analysed statistically after proper transformation and important findings obtained from the present study are presented in Tables 3 to 16.

4.1 FIELD TOLERANCE OF CHILLI GENOTYPES AGAINST SUCKING PEST COMPLEX

The sucking pests observed in the chilli plants during the study were *Aphis gossypii*, *Polyphagotarsonemus latus* and *Scirtothrips dorsalis* (Plate 1). Various symptoms due to the infestation of sucking pests are shown in Plate 2.

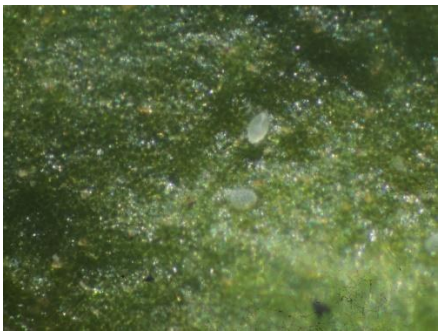
4.1.1 Screening of Chilli Genotypes Against Sucking Pests Based on Population Study

The results presented in Tables 3 to 5 shows the mean population count of *A. gossypii*, *P. latus* and *S. dorsalis* in different chilli genotypes at four different time intervals.

4.1.1.1 Aphis gossypii

A significant difference was observed in the number of aphids per leaf among the different genotypes of chilli screened against *A. gossypii* in all the four observation dates (Table 3). The number of aphids present on the leaves varied from 1.66 to 25.89 leaf^{-1} on 20 DAT. Lowest population of aphids leaf^{-1} was observed in the genotype L3 (1.66) and this was on par with the genotypes L5 (3.11), L2 (3.66), L9 (3.77), L1 (4.66), IC 342426 (5.11), L14 (6.11), Anugraha (6.44), L7 (6.55) and CF1 (7.00). The highest population of aphids leaf^{-1} was recorded on the genotype L11 (25.89) which was significantly different from other genotypes. This was followed by L10 (15.55), which was on par with L15 (15.55), L4 (15.00), IC272868 (14.22), IC572454 (13.55), IC 284628(13.44), L12 (13.33), L13 (13.33), IC537657(12,89), Ujwala (12.89), Athulya (12.77), CF2 (12.55), IC312916 (12.33), IC344367 (12.11), IC342464 (11.11), CF3 (11.11) and Jwalamukhi (10.44). The number of aphids leaf^{-1} in L8 (10.00) was statistically on par with L6 (9.33).

Aphis gossypii



Polyphagotarsonemus latus

Scirtothrips dorsalis

Plate 1. Sucking pests observed in chilli

A. Symptoms caused by mites

B. Symptoms caused by thrips

C. Symptoms caused by aphids

Plate 2. Symptoms due to sucking pest infestation

Table 3. Mean population of *Aphis gossypii* in different chilli genotypes at different time intervals.

Sl. No.	Genotype	No: of aphids leaf^{-1}			
		20 DAT	35 DAT	50 DAT	65 DAT
1.	Anugraha	6.44 (2.54) ^{fghi}	11.33 (3.37) ^{efgh}	11.67 (3.42)^{defghi}	11.22 (3.35)^{fghij}
2.	Athulya	12.77 (3.57) ^{bcd}	9.00 (3) ^{fghijk}	9.33 (3.06)^{fghijkl}	10.00 (3.16)^{ghijkl}
3.	L1	4.66 (2.16) ^{hi}	10.00 (3.16) ^{fghij}	10.33 (3.21)^{efghijk}	10.67 (3.27)^{fghijk}
4.	L2	3.66 (1.91) ^{i}	8.67 (2.94) ^{ghijk}	9.11 (3.02)^{ghijkl}	9.56 (3.09)^{hijkl}
5.	CF1	7.00 (2.65) ^{efghi}	9.00 (3) ^{fghijk}	9.33 (3.06)^{fghijkl}	9.78 (3.13)^{hijkl}
6.	L3	1.66 (1.29) ^{i}	2.89 (1.7) ^{l}	3.22 (1.79)^{m}	3.56 (1.89)^{m}
7.	L4	15.00 (3.87) ^{bc}	16.44 (4.06) ^{bcd}	16.00 (4)^{bcd}	16.33 (4.04)^{bcde}
8.	L5	3.11 (1.76) ^{i}	7.11 (2.67) ^{hijkl}	7.44 (2.73)^{ijklm}	7.78 (2.79)^{jklm}
9.	CF2	12.55 (3.54) ^{bcd}	9.55 (3.09) ^{hijkl}	10.00 (3.16) ^{efghijk}	10.44 (3.23)^{fghijk}
10.	L6	9.33 (3.06) ^{defgh}	11.78 (3.43) ^{cdefgh}	12.11 (3.48)^{cdefghi}	12.67 (3.56)^{defghi}
11.	IC272868	14.22 (3.77)^{bcd}	11.44 (3.38)^{defgh}	11.78 (3.43)^{defghi}	12.11 (3.48)^{efghij}

12.	IC284628	13.44 (3.67)^{bcd}	8.56 (2.93)^{ghijk}	8.89 (2.98)^{hijkl}	9.56 (3.09)^{hijkl}
13.	IC312916	12.33 (3.51)^{bcde}	10.56 (3.25)^{fghi}	10.89 (3.3)^{efghij}	11.22 (3.35)^{fghij}
14.	IC342426	5.11 (2.26)^{ghi}	7.22 (2.69)^{hijkl}	7.56 (2.75)^{hijklm}	8.33 (2.89)^{ijklm}
15.	IC342464	11.11 (3.33)^{bcdef}	16.56 (4.07)^{bc}	16.89 (4.11)^{bc}	17.56 (4.19)^{bc}
16.	IC344367	12.11 (3.48)^{bcde}	9.45 (3.07)^{fghijk}	9.78 (3.13)^{efghijk}	10.22 (3.2)^{fghijkl}
17.	IC537657	12.89 (3.59)^{bcd}	12.00 (3.46)^{cdefgh}	12.33 (3.51)^{cdefgh}	12.11 (3.48)^{efghij}
18.	IC572454	13.55 (3.68)^{bcd}	11.22 (3.35)^{efgh}	11.55 (3.4)^{defghi}	12.11 (3.48)^{efghij}
19.	Jwalamukhi	10.44 (3.23)^{bcdefg}	7.67 (2.77)^{hijkl}	8.11 (2.85)^{hijkl}	8.78 (2.96)^{ijkl}
20.	L7	6.55 (2.56)^{fghi}	5.89 (2.43)^{ijkl}	6.56 (2.56)^{jklm}	7.33 (2.71)^{jklm}
21.	L8	10.00 (3.16)^{cdefgh}	10.89 (3.3)^{fghi}	11.22 (3.35)^{defghij}	11.55 (3.4)^{efghij}
22.	L9	3.77 (1.94)^{i}	4.44 (2.11)^{kl}	4.78 (2.19)^{lm}	5.44 (2.33)^{lm}
23.	L10	15.55 (3.94)^{b}	10.45 (3.23)^{fghi}	11.00 (3.32)^{efghij}	10.44 (3.23)^{fghijk}

24.	L11	25.89 (5.09)^{a}	22.44 (4.74)^{a}	22.78 (4.77)^{a}	23.78 (4.88)^{a}
25.	Ujwala	12.89 (3.59)^{bcd}	14.00 (3.74)^{bcdef}	14.56 (3.82)^{bcde}	15.00 (3.87)^{bcdef}
26.	L12	13.33 (3.65)^{bcd}	18.33 (4.28)^{ab}	18.67 (4.32)^{ab}	19.78 (4.45)^{ab}
27.	L13	13.33 (3.65)^{bcd}	13.56 (3.68)^{bcdefg}	13.89 (3.73)^{bcdefg}	14.22 (3.77)^{cdefgh}
28.	L14	6.11 (2.47)^{fghi}	5.33 (2.31)^{jkl}	5.56 (2.36)^{klm}	5.99 (2.45)^{klm}
29.	CF3	11.11 (3.33)^{bcdef}	16.22 (4.03)^{bcde}	16.67 (4.08)^{bc}	17.11 (4.14)^{bcd}
30.	L15	15.55 (3.94)^{b}	13.78 (3.71)^{bcdef}	14.11 (3.76)^{bcdef}	14.78 (3.84)^{cdefg}
	SEm (±)	**1.95**	**1.78**	**1.71**	**1.73**
	CD (0.05)	**(5.506)**	**(5.039)**	**(4.842)**	**(4.891)**

Figures in parentheses are square root transformed values

DAT – Days after transplanting

The population of *A. gossypii* varied from 2.89 to 22.44 leaf^{-1} at 35 days after transplanting. Similar trend was continued as on 20 DAT where the minimum incidence of aphids leaf^{-1} was recorded on genotype L3 (2.89), which was on par with L9 (4.44), L14 (5.33), L7 (5.89), L5 (7.11), IC342426 (7.22) and Jwalamukhi (7.67). The highest population was recorded on L11 (22.44) which was on par with L12 (18.33). L12 was statistically on par with IC342464 (16.56), L4 (16.44), CF3 (16.22), Ujwala (14.00), L15 (13.78) and L13 (13.56) which were significantly different from L11. L13 was statistically on par with the genotypes IC537657 (12.00), L6 (11.78), IC 272868 (11.44), Anugraha (11.33), IC572454 (11.22), L8 (10.89), IC312916(10.56), L10 (10.45), L1 (10.00), CF2 (9.55), IC344367 (9.45), Athulya (9.00), CF1 (9.00), L2 (8.67) and IC284628 (8.56).

According to the observations recorded at 50 days after transplanting, the number of *A. gossypii* varied from 3.22 to 22.78 leaf^{-1}. Here also the data revealed the same trend where the genotypes which showed the less population continued to show same performance. The lowest population of aphids was observed in the genotype L3 (3.22), which was on par with L9 (4.78), L14 (5.56), L7 (6.56), L5 (7.44) and IC342426 (7.56) statistically. The highest population of aphids was recorded in the genotype L11 (22.78), which was statistically on par with L12 (18.67). The genotype L12 was on par with the genotypes IC 342464 (16.89), CF3 (16.67), L4 (16.00), Ujwala (14.56), L15 (14.11) and L13 (13.89) which were significantly different from L11. L13 was statistically on par with IC 537657(12.33), L6 (12.11), IC272868 (11.78), Anugraha (11.67), IC 572454 (11.55) L8 (11.22), L10 (11.00), IC312916 (10.89), L1 (10.33), CF2 (10.00), IC344367 (9.77), Athulya (9.33), CF1 (9.33) and L2 (9.11). The genotype L2 was statistically on par with the genotypes IC284628 (8.89) and Jwalamukhi (8.11).

The number of *A. gossypii* varied from 3.56 to 23.78 leaf^{-1} at 65 days after transplanting. The minimum population of aphids per leaf was recorded in the genotype L3 (3.56) which was statistically on par with the genotypes L9 (5.44), L14 (5.99), L7 (7.33), L5 (7.78) and IC342426 (8.33). The highest population of aphids was observed in the genotype L11 (23.78) which was statistically on par with L12 (19.78). L12 was on par with IC342464 (17.56), CF3 (17.11), L4 (16.33) and Ujwala (15.00). Ujwala was statistically on par with L15 (14.78), L13(14.22), L6 (12.67), IC537657 (12.11),

IC572454(12.11), IC272868 (12.11), L8 (11.55), Anugraha (11.22), IC312916 (11.22), L1 (10.67), CF2 (10.44), L10 (10.44) and IC344367 (10.22). IC344367 was statistically on par with the genotypes Athulya (10.00), CF1 (9.78), L2 (9.56), IC284628 (9.56) and Jwalamukhi (8.78).

4.1.1.2 Polyphagotarsonemus latus

The mean population of *P. latus* in different chilli genotypes at four different time intervals are given in Table 4.

There was a significant difference in the number of mites leaf^{-1} among the 30 chilli genotypes screened against *P. latus* on all the four observation dates. The number of mites present leaf^{-1} varied from 0.55 to 5.33 at 20 days after transplanting. The lowest incidence of chilli mites was observed in the genotype L5 (0.55) which was on par with the genotype L14 (1.56), L3 (1.66), Athulya (1.78), IC572454(1.89), IC537657 (1.89) and L6 (1.89). The highest population of mites leaf^{-1} was recorded on the genotype L11 (5.33), which was statistically on par with the genotype L9 (4.45). L9 was statistically on par with L4 (3.44), which was on par with IC284628 (3.11), CF1 (3.00), L7 (2.78), Ujwala (2.78), IC272868 (2.67), Jwalamukhi (2.67), IC342464 (2.66), L8 (2.66), CF3 (2.56), L12 (2.45), CF2 (2.33), L10 (2.33), L13(2.33), Anugraha (2.22), IC312916 (2.22), IC342426 (2.22), L1 (2.11), IC344367 (2.11) and L15 (2.11). L15 was also statistically on par with L2 (2.00).

At 35 days after transplanting, the population of *P. latus* varied from 1.55 to 6.33 leaf^{-1}. Minimum number of mites leaf^{-1} was observed in the genotype L5 (1.55) which was on par with L14 (1.89), L1 (2.55), L3 (2.56), IC572454 (2.78) Athulya (2.78), L6 (2.89), L2 (2.89) and IC537657 (2.89). The highest number of mites leaf^{-1} was recorded on the genotype L11 (6.33) which was statistically on par with the genotype L9 (5.11). Statistically, the population of *P. latus* was on par with L4 (4.44), IC284628 (4.11), L7 (3.78) and CF1 (3.78). L4 was also on par with IC272868 (3.67), Jwalamukhi (3.67), Ujwala (3.67), IC342464 (3.66), L8 (3.66), L12 (3.45), CF3 (3.44), CF2 (3.34), L10 (3.34), L13(3.33), IC342426 (3.22), Anugraha (3.22), IC312916 (3.22), IC344367 (3.11) and L15 (3.11).

Table 4. Mean population of *Polyphagotarsonemus latus* in chilli genotypes at different time intervals.

Sl. No.	Genotype	No: of mites leaf^{-1}			
		20 DAT	35 DAT	50 DAT	65 DAT
1.	Anugraha	2.22 (1.49)^{cdef}	3.22 (1.79)^{cdef}	3.44 (1.86)^{bcdef}	3.67 (1.91)^{def}
2.	Athulya	1.78 (1.33)^{defg}	2.78 (1.67)^{defg}	2.89 (1.7)^{efg}	3.11 (1.76)^{fg}
3.	L1	2.11 (1.45)^{cdef}	2.55 (1.6)^{efg}	3.56 (1.89)^{bcdef}	3.78 (1.94)^{cdef}
4.	L2	2.00 (1.41)^{def}	2.89 (1.7)^{defg}	3.89 (1.97)^{bcdef}	4.00 (2)^{bcdef}
5.	CF1	3.00 (1.73)^{cde}	3.78 (1.94)^{bcde}	4.00 (2)^{bcdef}	4.11 (2.03)^{bcdef}
6.	L3	1.66 (1.29)^{efg}	2.56 (1.6)^{efg}	2.78 (1.67)^{fg}	3.00 (1.73)^{fg}
7.	L4	3.44 (1.86)^{bc}	4.44 (2.11)^{bc}	4.67 (2.16)^{b}	4.89 (2.21)^{bc}
8.	L5	0.55 (0.74)^{g}	1.55 (1.25)^{g}	1.67 (1.29)^{g}	2.11 (1.45)^{g}
9.	CF2	2.33 (1.53)^{cdef}	3.34 (1.83)^{cde}	3.56 (1.89)^{bcdef}	3.78 (1.94)^{cdef}
10.	L6	1.89 (1.37)^{defg}	2.89 (1.7)^{defg}	3.11 (1.76)^{def}	3.33 (1.83)^{ef}
11.	IC272868	2.67 (1.63)^{cdef}	3.67 (1.91)^{cde}	3.89 (1.97)^{bcdef}	4.11 (2.03)^{bcdef}

12.	IC284628	3.11 (1.76)^{bcd}	4.11 (2.03)^{bcd}	4.33 (2.08)^{bcd}	5.00 (2.24)^{b}
13.	IC312916	2.22 (1.49)^{cdef}	3.22 (1.79)^{cdef}	3.45 (1.86)^{bcdef}	3.67 (1.91)^{def}
14.	IC342426	2.22 (1.49)^{cdef}	3.22 (1.8)^{cdef}	3.56 (1.89)^{bcdef}	3.78 (1.94)^{cdef}
15.	IC342464	2.66 (1.63)^{cdef}	3.66 (1.91)^{cde}	3.89 (1.97)^{bcdef}	4.11 (2.03)^{bcdef}
16.	IC344367	2.11 (1.45)^{cdef}	3.11 (1.76)^{cdef}	3.33 (1.83)^{cdef}	3.55 (1.89)^{def}
17.	IC537657	1.89 (1.37)^{defg}	2.89 (1.7)^{defg}	3.11 (1.76)^{def}	3.33 (1.83)^{ef}
18.	IC572454	1.89 (1.37)^{defg}	2.78 (1.67)^{defg}	3.11 (1.76)^{def}	3.56 (1.89)^{def}
19.	Jwalamukhi	2.67 (1.63)^{cdef}	3.67 (1.91)^{cde}	3.89 (1.97)^{bcdef}	4.11 (2.03)^{bcdef}
20.	L7	2.78 (1.67)^{cdef}	3.78 (1.94)^{bcde}	4.11 (2.03)^{bcde}	4.44 (2.11)^{bcde}
21.	L8	2.66 (1.63)^{cdef}	3.66 (1.91)^{cde}	3.89 (1.97)^{bcdef}	3.78 (1.94)^{cdef}
22.	L9	4.45 (2.11)^{ab}	5.11 (2.26)^{ab}	6.11 (2.47)^{a}	6.33 (2.52)^{a}
23.	L10	2.33 (1.53)^{cdef}	3.34 (1.83)^{cde}	3.56 (1.89)^{bcdef}	3.78 (1.94)^{cdef}

24.	L11	5.33 (2.31)^{a}	6.33 (2.52)^{a}	6.67 (2.58)^{a}	6.89 (2.62)^{a}
25.	Ujwala	2.78 (1.67)^{cdef}	3.67 (1.91)^{cde}	4.67 (2.16)^{b}	4.89 (2.21)^{bc}
26.	L12	2.45 (1.56)^{cdef}	3.45 (1.86)^{cde}	3.67 (1.91)^{bcdef}	3.89 (1.97)^{bcdef}
27.	L13	2.33 (1.53)^{cdef}	3.33 (1.83)^{cde}	3.56 (1.89)^{bcdef}	3.78 (1.94)^{cdef}
28.	L14	1.56 (1.25)^{fg}	1.89 (1.37)^{fg}	2.89 (1.7)^{efg}	3.11 (1.76)^{fg}
29.	CF3	2.56 (1.6)^{cdef}	3.44 (1.86)^{cde}	4.44 (2.11)^{bc}	4.67 (2.16)^{bcd}
30.	L15	2.11 (1.45)^{cdef}	3.11 (1.76)^{cdef}	3.33 (1.83)^{cdef}	3.56 (1.89)^{def}
	SEm (±)	**0.48**	**0.474**	**0.454**	**0.427**
	CD (0.05)	**(1.358)**	**(1.341)**	**(1.285)**	**(1.209)**

Figures in parentheses are square root transformed values

DAT- Days after transplanting

The number of *P. latus* varied from 1.67 to 6.67 leaf^{-1} at 50 days after transplanting. The population of mites increased, when compared to observation at 35 DAT. The lowest incidence of mites leaf^{-1} was observed in the genotype L5 (1.67) which was on par with L3 (2.78), L14 (2.89) and Athulya (2.89). The highest number of mites leaf^{-1} was observed in the genotype L11 (6.67) which was statistically on par with L9 (6.11). L4 (4.67) was significantly different from L11 and L9, but was statistically on par with Ujwala (4.67), CF3 (4.44), IC284628 (4.33), L7 (4.11), CF1 (4.00), IC272868 (3.89), L8 (3.89), L2 (3.89), IC342464 (3.89), Jwalamukhi (3.89), L12 (3.67), L1 (3.56), CF2 (3.56), IC342426 (3.56), L10 (3.56), L13(3.56), IC312916 (3.45) and Anugraha (3.44). IC344367 had a mite population of 3.33 mites leaf^{-1} which was statistically on par with L15 (3.33), L6 (3.11), IC537657 (3.11) and IC572454 (3.11).

On 65 days after transplanting, there was an increase in the mite population with the population ranging from 2.11 to 6.89 mites leaf^{-1}. The minimum number of mites leaf^{-1} was observed in the genotype L5 (2.11) which was on par with L3 (3.00), L14 (3.11) and Athulya (3.11). The highest incidence of mites per leaf was recorded in the genotype L11 (6.89) which was on par with L9 (6.33). This was followed by IC284628 (5.00), which was on par with Ujwala (4.89), L4 (4.89), CF3 (4.67), L7 (4.44), CF1 (4.11), IC272868 (4.11), IC342464 (4.11), Jwalamukhi (4.11), L2 (4.00) and L12 (3.89). L12 was also statistically on par with CF2 (3.78), L10 (3.78), L13(3.78), L1 (3.78), IC342426 (3.78), L8 (3.78), Anugraha (3.67), IC312916 (3.67), IC572454 (3.56), L15 (3.56), IC344367 (3.55), L6 (3.33) and IC537657 (3.33).

4.1.1.3 Scirtothrips dorsalis

The mean population of *S. dorsalis* in different chilli genotypes at four different time intervals are depicted in Table 5.

A significant difference was observed in the number of thrips leaf^{-1} among the different genotypes of chilli when the data on the population of *S. dorsalis* was analysed at 20 days after transplanting. The number of thrips leaf^{-1} varied from 1.22 to 5.66 at 20 days after transplanting. Lowest incidence of thrips per leaf was recorded on the

Table 5. Mean population of *Scirtothrips dorsalis* in different chilli genotypes at different time intervals.

Sl. No.	Genotype	No: of thrips leaf^{-1}			
		20 DAT	35 DAT	50 DAT	65 DAT
1.	Anugraha	4.55 (2.13)^{abc}	5.11 (2.26)^{bc}	5.78 (2.4)^{b}	6.44 (2.54)^{b}
2.	Athulya	3.89 (1.97)^{bcde}	4.55 (2.13)^{bcd}	5.44 (2.33)^{bcd}	6.11 (2.47)^{bcd}
3.	L1	3.89 (1.97)^{bcde}	4.56 (2.13)^{bcd}	5.22 (2.28)^{bcd}	5.89 (2.43)^{bcd}
4.	L2	3.56 (1.89)^{bcde}	4.22 (2.06)^{bcd}	4.78 (2.19)^{bcd}	5.33 (2.31)^{bcd}
5.	CF1	4.55 (2.13)^{abc}	4.89 (2.21)^{bcd}	5.55 (2.36)^{bc}	6.22 (2.49)^{bc}
6.	L3	3.11 (1.76)^{de}	3.67 (1.91)^{d}	4.33 (2.08)^{cd}	5.00 (2.24)^{cd}
7.	L4	4.11 (2.03)^{bcde}	4.78 (2.19)^{bcd}	5.22 (2.29)^{bcd}	5.89 (2.43)^{bcd}
8.	L5	1.22 (1.11)^{f}	2.00 (1.42)^{e}	2.55 (1.6)^{e}	3.22 (1.8)^{e}
9.	CF2	3.33 (1.83)^{cde}	3.89 (1.97)^{cd}	4.45 (2.11)^{cd}	5.11 (2.26)^{cd}
10.	L6	4.22 (2.06)^{bcde}	4.78 (2.19)^{bcd}	5.33 (2.31)^{bcd}	6.11 (2.47)^{bcd}
11.	IC272868	4.33 (2.08)^{abcd}	4.67 (2.16)^{bcd}	5.22 (2.28)^{bcd}	6.00 (2.45)^{bcd}

12.	IC284628	4.33 (2.08)^{abcd}	4.89 (2.21)^{bcd}	5.55 (2.36)^{bc}	6.22 (2.49)^{bc}
13.	IC312916	3.56 (1.89)^{bcde}	4.00 (2)^{bcd}	4.67 (2.16)^{bcd}	5.33 (2.31)^{bcd}
14.	IC342426	3.33 (1.83)^{cde}	4.00 (2)^{bcd}	4.67 (2.16)^{bcd}	5.33 (2.31)^{bcd}
15.	IC342464	3.78 (1.94)^{bcde}	4.22 (2.05)^{bcd}	4.89 (2.21)^{bcd}	5.56 (2.36)^{bcd}
16.	IC344367	4.22 (2.06)^{bcde}	4.67 (2.16)^{bcd}	5.33 (2.31)^{bcd}	6.00 (2.45)^{bcd}
17.	IC537657	3.78 (1.94)^{bcde}	4.22 (2.05)^{bcd}	4.78 (2.19)^{bcd}	5.44 (2.33)^{bcd}
18.	IC572454	4.11 (2.03)^{bcde}	4.78 (2.19)^{bcd}	5.55 (2.36)^{bc}	6.22 (2.49)^{bc}
19.	Jwalamukhi	3.67 (1.91)^{bcde}	4.11 (2.03)^{bcd}	4.78 (2.19)^{bcd}	5.45 (2.33)^{bcd}
20.	L7	4.00 (2)^{bcde}	4.67 (2.16)^{bcd}	5.22 (2.28)^{bcd}	5.89 (2.43)^{bcd}
21.	L8	3.89 (1.97)^{bcde}	4.44 (2.11)^{bcd}	5.11 (2.26)^{bcd}	5.78 (2.4)^{bcd}
22.	L9	4.67 (2.16)^{ab}	5.22 (2.29)^{ab}	5.78 (2.4)^{b}	6.45 (2.54)^{b}
23.	L10	4.11 (2.03)^{bcde}	4.78 (2.19)^{bcd}	5.33 (2.31)^{bcd}	6.11 (2.47)^{bcd}
24.	L11	5.66 (2.38)^{a}	6.44 (2.54)^{a}	7.11 (2.67)^{a}	7.78 (2.79)^{a}

25.	Ujwala	3.78 (1.94)^{bcde}	4.33 (2.08)^{bcd}	5.00 (2.24)^{bcd}	5.67 (2.38)^{bcd}
26.	L12	3.33 (1.83)^{cde}	3.89 (1.97)^{cd}	4.56 (2.13)^{bcd}	5.22 (2.29)^{bcd}
27.	L13	3.67 (1.91)^{bcde}	4.11 (2.03)^{bcd}	4.78 (2.19)^{bcd}	5.33 (2.31)^{bcd}
28.	L14	3.00 (1.73)^{e}	3.67 (1.91)^{d}	4.22 (2.05)^{d}	4.89 (2.21)^{d}
29.	CF3	3.55 (1.89)^{bcde}	4.11 (2.03)^{bcd}	4.78 (2.19)^{bcd}	5.44 (2.33)^{bcd}
30.	L15	4.33 (2.08)^{abcd}	4.78 (2.19)^{bcd}	5.33 (2.31)^{bcd}	6.00 (2.45)^{bcd}
	SE m(±)	**0.471**	**0.455**	**0.447**	**0.447**
	CD (0.05)	**(1.333)**	**(1.288)**	**(1.263)**	**(1.265)**

Figures in parentheses are square root transformed values

DAT-Days after transplanting

genotype L5 (1.22), which was significantly different from other genotypes. This was followed by L14 (3.00) which was statistically on par with L3 (3.11), L12 (3.33), IC342426 (3.33), CF2 (3.33), CF3 (3.55), IC312916 (3.56), L2 (3.56), L13(3.67), Jwalamukhi (3.67), Ujwala (3.78), IC537657 (3.78), IC342464 (3.78), L8 (3.89), L1 (3.89), Athulya (3.89), L7 (4.00), IC572454 (4.11), L4 (4.11), L10 (4.11), IC344367 (4.22) and L6 (4.22). The highest number of thrips leaf^{-1} was observed in the genotype L11 (5.66), which was statistically on par with L9 (4.67), Anugraha (4.55), CF1 (4.55), IC272868 (4.33), IC284628 (4.33) and L15 (4.33).

The population of thrips leaf^{-1} varied from 2.00 to 6.44 at 35 days after transplanting. The lowest number of thrips was observed in the genotype L5 (2.00), which was significantly different from other genotypes. This was followed by L14(3.67) which was on par with L3 (3.67), L12 (3.89), CF2 (3.89), IC342426 (4.00), IC312916 (4.00), CF3 (4.11), Jwalamukhi (4.11), L13(4.11), IC537657 (4.22), IC342464 (4.22), L2 (4.22), Ujwala (4.33), L8 (4.44), Athulya (4.55), L1 (4.56), L7 (4.67), IC344367 (4.67), IC272868 (4.67), L15 (4.78), L10 (4.78), L6 (4.78), L4 (4.78), IC572454 (4.78), IC284628 (4.89) and CF1 (4.89). Highest population of thrips leaf^{-1} was observed in the genotype L11 (6.44), which was statistically on par with L9 (5.22). L9 was also statistically on par with Anugraha (5.11).

The number of thrips present leaf^{-1} varied from 2.55 to 7.11 at 50 days after transplanting. Similar trend was observed in the data where the lowest number of thrips leaf^{-1} was observed in the genotype L5 (2.55) which was significantly different from other genotypes. This was followed by L14 (4.22), which was statistically on par with L3 (4.33), CF2 (4.45), L12 (4.56), IC342426 (4.67), IC312916 (4.67), L13(4.78), Jwalamukhi (4.78), L2 (4.78), CF3 (4.78), IC537657 (4.78), IC342464 (4.89), Ujwala (5.00), L8 (5.11), L7 (5.22), IC272868 (5.22), L1 (5.22), L4 (5.22), L15 (5.33), L10 (5.33), IC344367 (5.33), L6 (5.33) and Athulya (5.44). The highest population of thrips leaf^{-1} was recorded in the genotype L11 (7.11) which was significantly different from other genotypes. This was followed by Anugraha (5.78) which was statistically on par with L9 (5.78), CF1(5.55), IC284628 (5.55) and IC 572454 (5.55).

The population of thrips per leaf varied from 3.22 to 7.77 at 65 days after transplanting. The minimum incidence of thrips leaf^{-1} was recorded in the genotype L5

(3.22), which was significantly different from other genotypes. This was followed by L14 (4.89) which was statistically on par with L3 (5.00), CF2 (5.11), L12 (5.22), IC312916 (5.33), L13(5.33), IC342426 (5.33), L2 (5.33), CF3 (5.44), IC537657 (5.44), Jwalamukhi (5.45), IC342464 (5.56), Ujwala (5.67), L8 (5.78), L7 (5.89), L4 (5.89), L1 (5.89), L15 (6.00), IC344367 (6.00), IC272868 (6.00), L10 (6.11), L6 (6.11) and Athulya (6.11). The highest population of thrips leaf^{-1} was recorded in the genotype L11 (7.78) which was significantly different from others. This was followed by L9 (6.45) which was on par with Anugraha (6.44), CF1 (6.22), IC284628 (6.22) and IC572454 (6.22).

4.1.2 Intensity of Damage Caused by Mites

The extent of leaf damage caused by *P. latus* in different chilli genotypes at four different time intervals are given in Table 6.

A significant difference was observed in the per cent leaf damage caused by *P. latus*, among the different genotypes of chilli on all the four observation dates. The leaf damage ranged from 11.33 to 73.00 per cent at 20 days after transplanting. Among the 30 genotypes, the genotype L5 was more tolerant to *P. latus*, with lowest leaf damage of 11.33 per cent. No significant difference in the mean population of *P. latus* was observed in the genotype L14 with a leaf damage of 13.33 per cent and it was statistically on par with L3 (17.33). L3 was on par with L6 (19.67) and Athulya (20.67). L6 was statistically on par with IC312916 with a per cent leaf damage of 23.67 which was on par with IC537657 with a leaf damage of 24.00. IC537657 was on par with IC344367 with a leaf damage of 24.67 per cent, IC342426 (26.67) and IC572454 with a leaf damage of 27.33 per cent. IC572454 was on par with L1 (31.33) and L2 (31.67). L2 was on par with L13(32.67), L10 (34.67), Anugraha (34.67) and CF2 (35.67). CF2 was statistically on par with L12 (36.67), L15 (37.00), L8 (37.67), IC342464 (39.67) and Jwalamukhi (40.00). Jwalamukhi was on par with L7 (40.67), IC272868 (43.67), CF3 (44.67) and CF1 with a leaf damage of 44.67 per cent. The highest leaf damage was observed in the genotype L11 with per cent leaf damage of 73.00 which was significantly different from other genotypes. This was followed by L9 (64.67) which was followed by L4 (58.67). IC284628 (52.67) was significantly different from L4 and was on par with Ujwala (48.67) which was on par with CF1 and CF3.

Table 6. Leaf damage caused by *Polyphagotarsonemus latus* in different chilli genotypes at different time intervals.

Sl. No.	Genotype	Mean leaf damage (%)			
		20 DAT	35 DAT	50 DAT	65 DAT
1.	Anugraha	34.67 (36.1)^{jkl}	40.33 (39.53)^{ijk}	36.00 (36.67)^{kl}	41.67 (40.11)^{hij}
2.	Athulya	20.67 (26.93)^{pqr}	26.00 (30.94)^{op}	21.67 (27.5)^{opq}	27.67 (31.51)^{no}
3.	L1	31.33 (33.8)^{lmn}	36.67 (37.24)^{klm}	33.33 (35.52)^{lm}	38.33 (38.39)^{jkl}
4.	L2	31.67 (34.38)^{lm}	37.00 (37.24)^{kl}	33.33 (35.52)^{lm}	38.67 (38.39)^{jkl}
5.	CF1	44.67 (41.83)^{ef}	50.00 (45.26)^{ef}	46.00 (42.97)^{efg}	50.67 (45.26)^{f}
6.	L3	17.33 (24.64)^{rs}	23.33 (28.65)^{pq}	19.00 (25.78)^{qr}	24.00 (29.22)^{op}
7.	L4	58.67 (49.85)^{c}	64.00 (53.29)^{c}	60.00 (50.99)^{c}	65.33 (53.86)^{cd}
8.	L5	11.33 (19.48)^{t}	17.33 (24.64)^{r}	12.67 (20.63)^{s}	18.33 (25.21)^{q}
9.	CF2	35.67 (36.67)^{ijkl}	41.00 (39.53)^{ijk}	37.00 (37.24)^{jkl}	42.67 (40.68)^{ghij}
10.	L6	19.67 (26.36)^{qr}	25.33 (30.37)^{op}	21.00 (27.5)^{pq}	26.33 (30.94)^{no}
11.	IC272868	43.67 (41.25)^{fg}	49.33 (44.69)^{efg}	45.33 (42.4)^{efgh}	50.33 (45.26)^{f}

12.	IC284628	52.67 (46.41)^{d}	57.67 (49.27)^{d}	54.00 (47.56)^{d}	60.67 (50.99)^{de}
13.	IC312916	23.67 (29.22)^{opq}	29.00 (32.66)^{no}	25.00 (29.79)^{nop}	30.33 (33.23)^{mn}
14.	IC342426	26.67 (30.94)^{no}	32.00 (34.38)^{mn}	28.00 (32.09)^{n}	33.33 (35.52)^{lm}
15.	IC342464	39.67 (38.96)^{ghi}	45.00 (42.4)^{ghi}	41.00 (39.53)^{hij}	46.33 (42.97)^{fgh}
16.	IC344367	24.67 (29.79)^{op}	30.00 (33.23)^{no}	26.33 (30.94)^{no}	31.67 (34.38)^{mn}
17.	IC537657	24.00 (29.22)^{opq}	29.00 (32.66)^{no}	25.00 (29.79)^{nop}	30.67 (33.8)^{mn}
18.	IC572454	27.33 (31.51)^{mno}	33.00 (34.95)^{lmn}	29.00 (32.66)^{mn}	35.00 (36.1)^{klm}
19.	Jwalamukhi	40.00 (38.96)^{fghi}	45.00 (42.4)^{ghi}	41.33 (40.11)^{ghij}	46.33 (42.97)^{fgh}
20.	L7	40.67 (39.53)^{fgh}	46.00 (42.97)^{fgh}	42.00 (40.68)^{fghi}	47.33 (43.54)^{fg}
21.	L8	37.67 (37.82)^{hij}	43.00 (41.25)^{hij}	39.00 (38.39)^{ijk}	44.67 (41.83)^{ghi}
22.	L9	64.67 (53.29)^{b}	70.00 (56.72)^{b}	66.00 (54.43)^{b}	71.67 (57.87)^{b}
23.	L10	34.67 (36.07)^{jkl}	40.00 (39.23)^{jk}	36.00 (36.87)^{kl}	41.33 (40.01)^{ghi}

24.	L11	73.00 (58.44)^{a}	78.33 (62.45)^{a}	74.33 (59.59)^{a}	79.67 (63.03)^{a}
25.	Ujwala	48.67 (44.12)^{de}	54.00 (47.56)^{de}	50.00 (45.26)^{de}	57.33 (49.27)^{e}
26.	L12	36.67 (37.24)^{hijk}	42.00 (40.68)^{hij}	38.00 (37.82)^{ijkl}	43.33 (41.25)^{ghij}
27.	L13	32.67 (34.95)^{kl}	38.33 (38.39)^{jk}	34.00 (35.52)^{l}	39.67 (38.96)^{ijk}
28.	L14	13.33 (21.2)st	19.00 (25.78)^{qr}	15.00 (22.92)^{rs}	20.33 (26.93)^{pq}
29.	CF3	44.67 (41.83)^{ef}	50.00 (45.26)^{ef}	46.33 (42.97)^{ef}	51.67 (45.84)^{f}
30.	L15	37.00 (37.24)^{hijk}	42.00 (40.68)^{hij}	38.00 (37.82)^{ijkl}	43.33 (41.25)^{ghij}
	SEm (±)	**1.763**	**1.742**	**1.761**	**1.973**
	CD (0.05)	**(4.987)**	**(4.927)**	**(4.981)**	**(5.581)**

Figures in parentheses are arcsine transformed values

DAT-Days after transplanting

The per cent of leaf damage caused by *P. latus* varied from 17.33 to 78.33 at 35 days after transplanting. The genotype L5 had the lowest damage with a leaf damage per cent of 17.33 which was statistically on par with genotypes L14 (19.00) which was on par with L3 (23.33). L3 was on par with L6 with a leaf damage per cent of 25.33 and Athulya (26.00). There was no significant difference in the leaf damage by *P.latus* in the genotypes IC537657 (29.00), IC312916 (29.00) and IC344367 (30.00).IC344367 was on par with IC342426 with leaf damage of 32.00 per cent and IC572454 (33.00). IC572454 was on par with L1 (36.67) and L2 (37.00). L2 was statistically on par with L13(38.33), L10 (40.00), Anugraha (40.33) and CF2 (41.00). CF2 was found statistically on par with L15 (42.00), L12 (42.00), L8 (43.00), Jwalamukhi (45.00) and IC342464 with a leaf damage of 45.00 per cent. IC342464 was on par with L7 (46.00) and IC272868 (49.33). The genotype L11 was severely damaged by *P. latus* with a leaf damage per cent of 78.33 which was significantly different from other genotypes. This was followed by L9 with a leaf damage of 70.00 per cent which was followed by L4 (64.00). IC284628 (57.67) was significantly different from L4, but was on par with Ujwala (54.00). Ujwala was on par with CF1 (50.00), CF3 (50.00) and IC272868.

The leaf damage caused by *P. latus* ranged from 12.67 to 74.33 per cent at 50 days after transplanting, where a decrease in the leaf damage was observed when compared to the former observation time. A leaf damage per cent of 12.67 was observed in the genotype L5 which was on par with L14 with a leaf damage of 15.00 per cent which was on par with L3 (19.00). The genotype L3 was on par with L6 (21.00) and Athulya (21.67). Athulya was on par with IC537657(25.00), IC312916 with a leaf damage of 25.00 per cent and IC344367 with a leaf damage of 26.33 per cent. IC344367 was statistically on par with IC342426 (28.00) and IC572454 (29.00). IC572454 was on par with L2 (33.33) and L1 (33.33). L1 was statistically on par with L13with a leaf damage of 34.00 per cent, L10 (36.00), Anugraha (36.00), CF2 (37.00), L15 (38.00) and L12 (38.00). L12 was on par with L8 with a leaf damage per cent of 39.00, IC342464 (41.00), Jwalamukhi (41.33) and L7 (42.00). The highest per cent of leaf damage was recorded in the genotype L11 (74.33), which was significantly different from other genotypes. This was followed by L9 (66.00) which was followed by L4 (60.00). IC284628 (54.00) was significantly different from L4, but was on par with

Ujwala (50.00). Ujwala was on par with CF3 (46.33), CF1 (46.00) and IC272868 (45.33).

The per cent of leaf damage caused by *P. latus* varied from 18.33 to 79.66 at 65 days after transplanting. Here, the per cent of leaf damage was observed to be increased when compared to 50 DAT. The lowest leaf damage was observed in the genotype L5 with 18.33 per cent which was statistically on par with the genotype L14 (20.33) which was again on par with L3 (24.00). L3 was statistically on par with L6 (26.33) and Athulya (27.67). The genotypes IC312916, IC537657 and IC344367 had leaf damage of per cent 30.33, 30.67 and 31.67 respectively, however these genotypes were statistically on par with Athulya. This was followed by IC342426 (33.33) which was on par IC572454 (35.00), L1 (38.33) and L2 (38.67). L2 was statistically on par with L13(39.67), L10 (41.33), Anugraha (41.67), CF2 (42.67), L15 (43.33) and L12 (43.33). L12 was found statistically on par with L8 with a leaf damage of 44.67 per cent, Jwalamukhi (46.33), IC342464 (46.33) and L7 with a leaf damage per cent of 47.33. The genotype L11 was severely damaged by *P. latus* with a leaf damage per cent of 79.67 which was significantly different from other genotypes. This was followed by L9 (71.67) which was followed by L4 (65.33) which was on par with IC284628 (60.67). IC272868 was on par with Ujwala (57.33). CF3 had a leaf damage of 51.67 which was significantly different from Ujwala but was on par with the genotypes CF1 (50.67), IC272868 (50.33), L7, IC342464 and Jwalamukhi.

4.1.2.1 Grouping of Chilli Genotypes Based on Per Cent Leaf Curl Due to *P. latus*

The per cent leaf curl index of chilli genotypes and the grouping of chilli genotypes based on per cent leaf curl index (PLI) is given in Table 7 and Table 8 respectively.

The grouping of chilli genotypes based on per cent leaf curl index showed that the genotypes L5 and L14 were having moderate resistance with per cent leaf curl index value between 11 to 25. Nineteen genotypes namely, Anugraha, Athulya, L1, L2, L3, CF2, L6, IC312916, IC342464, IC344367, IC342426, IC537657, IC572454,

Table 7. Per cent leaf curl index in chilli genotypes due to infestation by *Polyphagotarsonemus latus.*

Sl. No.	Genotypes	20 DAT	35 DAT	50 DAT	65 DAT	MEAN
1.	Anugraha	50.00	50.00	50.00	50.00	50.00
2.	Athulya	25.00	41.67	25.00	41.67	33.34
3.	L1	50.00	50.00	50.00	50.00	50.00
4.	L2	50.00	50.00	50.00	50.00	50.00
5.	CF1	50.00	58.33	50.00	66.67	56.25
6.	L3	25.00	33.33	25.00	33.33	29.17
7.	L4	75.00	75.00	75.00	75.00	75.00
8.	L5	25.00	25.00	25.00	25.00	25.00
9.	CF2	50.00	50.00	50.00	50.00	50.00
10.	L6	25.00	33.33	25.00	41.67	31.25
11.	IC272868	50.00	58.33	50.00	58.33	54.17
12.	IC284628	66.67	75.00	75.00	75.00	72.92
13.	IC312916	33.33	50.00	33.33	50.00	41.67
14.	IC342426	41.67	50.00	41.67	50.00	45.84
15.	IC342464	50.00	50.00	50.00	50.00	50.00

16.	IC344367	33.33	50.00	41.67	50.00	43.75
17.	IC537657	33.33	50.00	33.33	50.00	41.67
18.	IC572454	41.67	50.00	50.00	50.00	47.92
19.	Jwalamukhi	50.00	50.00	50.00	50.00	50.00
20.	L7	50.00	50.00	50.00	58.33	52.08
21.	L8	50.00	50.00	50.00	50.00	50.00
22.	L9	75.00	75.00	75.00	75.00	75.00
23.	L10	50.00	50.00	50.00	50.00	50.00
24.	L11	83.33	100.00	83.33	100.00	91.67
25.	Ujwala	58.33	75.00	58.33	75.00	66.67
26.	L12	50.00	50.00	50.00	50.00	50.00
27.	L13	50.00	50.00	50.00	50.00	50.00
28.	L14	25.00	25.00	25.00	25.00	25.00
29.	CF3	50.00	58.33	50.00	66.67	56.25
30.	L15	50.00	50.00	50.00	50.00	50.00

Table 8. Grouping of chilli genotypes based on per cent leaf curl index

Category	Per cent Leaf Curl Index	Genotypes
Resistant	0-10	
Moderately resistant	11-25	L5, L14
Susceptible	26-50	Anugraha, Athulya, L1, L2, L3, CF2, L6, IC312916, IC342464, IC344367, IC342426, IC537657, IC572454, Jwalamukhi, L8, L10, L12, L13, L15
Highly susceptible	51-100	CF1, L4, IC272868, IC284628, L7, L9, L11, Ujwala, CF3

Jwalamukhi, L8, L10, L12, L13and L15 which had per cent leaf curl index value between 26 to 50 were categorised as susceptible genotypes. Maximum mite infestation was recorded in the genotypes, CF1, L4, IC272868, IC284628, L7, L9, L11, Ujwala and CF3 which showed highest degree of leaf curl index (PLI: 51-100) and categorized as highly susceptible genotypes.

4.1.3 Intensity of Damage Caused by Thrips

The extent of damage caused by *S. dorsalis* in different chilli genotypes at four different time intervals is given in Table 9.

The chilli genotypes differed significantly in per cent leaf damage caused by *S. dorsalis* on all the four observation dates. The leaf damage ranged from 11.67 to 70.67 per cent at 20 days after transplanting. The minimum damage by thrips was observed in the genotype L5 with a leaf damage of 11.67 per cent which was statistically on par with L3 (15.00). L3 was on par with L14 (17.67) which was on par with CF2 (21.00). CF2 was statistically on par with L15 (24.67). L15 was on par with the genotypes IC342426 (26.00) and L7 (28.67). L7 was statistically on par with CF3 (29.67), Ujwala (30.67), IC344367 (31.67) and L12 (32.67). L12 was on par with IC572454 (33.67), L13(34.67), IC 272868 (34.67) and Athulya (36.67). Leaf damage per cent in Athulya was statistically on par with the genotype Jwalamukhi (37.67), IC312916 (38.33), L8 (38.67) and L10 (40.33). L10 was on par with L2 (41.67) and L4 (44.00). The genotype L11 was severely damaged by *S. dorsalis* with a leaf damage of 70.67 per cent which was significantly different from others. This was followed by CF1 (63.67), which was statistically on par with IC284628 (59.67). IC284628 was on par with Anugraha (55.00). L9 (49.67) was significantly different from Anugraha and was on par with IC342464 (46.67), L1 (46.00), L6 (45.67) and IC537657 (45.33).

The per cent of leaf damage caused by *S. dorsalis* varied from 17.00 to 76.00 at 35 days after transplanting. The data revealed a similar trend where the genotype L5 recorded the lowest per cent leaf damage (17.00) which was statistically on par with L3 (20.33). L3 was on par with L14 (23.33), which was again on par with CF2 (26.33). CF2 was statistically on par with L15 (30.00.). L15 was statistically on par with IC342426 (31.33) and L7 (34.33), which was on par with CF3 (35.00), Ujwala (36.00),

Table 9. Leaf damage caused by *Scirtothrips dorsalis* in chilli genotypes at different time intervals.

Sl. No.	Genotype	Mean leaf damage (%)			
		20 DAT	35 DAT	50 DAT	65 DAT
1.	Anugraha	55.00 (48.13)^{c}	60.00 (50.99)^{c}	56.00 (48.47)^{c}	61.33 (51.55)^{cd}
2.	Athulya	36.67 (37.24)^{ijkl}	42.00 (40.68)^{ijkl}	38.00 (38.04)^{hijk}	43.33 (41.17)^{hijkl}
3.	L1	46.00 (42.97)^{def}	51.00 (45.84)^{def}	47.33 (43.49)^{de}	52.33 (46.34)^{ef}
4.	L2	41.67 (40.11)^{fgh}	47.33 (43.54)^{fgh}	43.33 (41.2)^{efg}	48.33 (44.04)^{fgh}
5.	CF1	63.67 (52.71)^{b}	69.33 (56.15)^{b}	65.33 (53.92)^{b}	70.67 (57.21)^{b}
6.	L3	15.00 (22.92)^{tu}	20.33 (26.93)st	16.33 (23.84)^{rs}	21.67 (27.74)^{s}
7.	L4	44.00 (41.83)^{efg}	49.00 (44.69)^{efg}	45.00 (42.11)^{ef}	50.67 (45.38)^{fg}
8.	L5	11.67 (20.05)^{u}	17.00 (24.06)^{t}	13.00 (21.14)^{s}	18.67 (25.6)^{s}
9.	CF2	21.00 (27.5)^{rs}	26.33 (30.94)^{qr}	22.33 (28.19)^{pq}	27.67 (31.74)^{qr}
10.	L6	45.67 (42.4)^{def}	51.00 (45.84)^{def}	47.00 (43.26)^{de}	52.67 (46.53)^{ef}
11.	IC272868	34.67 (36.1)^{jklm}	40.00 (38.96)^{jklm}	35.67 (36.67)^{ijkl}	41.33 (40.01)^{ijklm}

12.	IC284628	59.67 (50.42)^{bc}	65.00 (53.86)^{b}	61.00 (51.34)^{b}	66.67 (54.74)^{bc}
13.	IC312916	38.33 (38.39)^{hijk}	44.00 (41.83)^{hij}	40.00 (39.25)^{ghi}	45.67 (42.52)^{ghij}
14.	IC342426	26.00 (30.94)^{pq}	31.33 (33.8)^{op}	27.33 (31.51)^{no}	32.33 (34.65)^{opq}
15.	IC342464	46.67 (42.97)^{de}	52.67 (46.41)^{de}	48.00 (43.83)^{de}	53.33 (46.91)^{ef}
16.	IC344367	31.67 (34.38)^{mno}	37.00 (37.24)^{mn}	32.67 (34.84)^{lm}	38.33 (38.25)^{lmn}
17.	IC537657	45.33 (42.4)^{def}	51.00 (45.84)^{def}	47.00 (43.26)^{de}	52.67 (46.53)^{ef}
18.	IC572454	33.67 (35.52)^{klmn}	39.00 (38.39)^{klmn}	35.00 (36.27)^{jklm}	40.33 (39.42)^{jklmn}
19.	Jwalamukhi	37.67 (37.82)^{hijk}	43.00 (41.25)^{hijk}	39.00 (38.62)^{ghij}	44.33 (41.74)^{hijk}
20.	L7	28.67 (32.09)^{opq}	34.33 (36.1)^{nop}	30.33 (33.4)^{mno}	35.33 (36.47)^{nop}
21.	L8	38.67 (38.39)^{hij}	44.00 (41.83)^{hij}	39.67 (39.02)^{ghij}	45.33 (42.32)^{ghij}
22.	L9	49.67 (44.69)^{d}	55.33 (48.13)^{cd}	51.00 (45.55)^{d}	56.67 (48.83)^{de}
23.	L10	40.33 (39.53)^{ghi}	45.33 (42.4)^{ghi}	41.00 (39.82)^{fgh}	46.33 (42.9)^{ghi}
24.	L11	70.67 (57.3)^{a}	76.00 (60.73)^{a}	72.33 (58.27)^{a}	77.33 (61.57)^{a}

25.	Ujwala	30.67 (33.8)^{mnop}	36.00 (36.67)^{mno}	32.00 (34.43)^{lmn}	37.67 (37.86)^{lmno}
26.	L12	32.67 (34.95)^{lmno}	38.00 (37.82)^{lmn}	34.00 (35.7)^{klm}	39.33 (38.84)^{klmn}
27.	L13	34.67 (36.1)^{jklm}	40.00 (38.96)^{jklm}	36.00 (36.9)^{ijkl}	41.33 (40.01)^{ijklm}
28.	L14	17.67 (24.64)st	23.33 (28.65)^{rs}	19.00 (25.84)^{qr}	24.33 (29.55)^{rs}
29.	CF3	29.67 (33.23)^{nop}	35.00 (36.1)^{no}	31.33 (34.03)^{lmn}	36.33 (37.07)^{mnop}
30.	L15	24.67 (29.79)^{qr}	30.00 (33.23)^{pq}	26.33 (30.88)^{op}	31.33 (34.04)^{pq}
	SEm (±)	**1.764**	**1.746**	**1.711**	**2.028**
	CD (0.05)	**(4.990)**	**(4.939)**	**(4.839)**	**(5.736)**

Figures in parentheses are arcsine transformed values

DAT-Days after transplanting

IC344367 (37.00), L12 (38.00) and IC572454 (39.00). IC572454 was statistically on par with the genotype L13 (40.00), IC272868 (40.00), Athulya (42.00) and Jwalamukhi (43.00). Jwalamukhi was on par with L8 which showed a leaf damage of 44.00 per cent, IC312916 with a leaf damage of 44.00 per cent, L10 (45.33) and L2 (47.33). L4 (49.00) was on par with the genotypes IC537657 (51.00), L6 (51.00) and L1 (51.00). The highest per cent leaf damage was observed in L11 (76.00) which was significantly different from others. This was followed by CF1 (69.33) which was on par with IC284628 (65.00). The leaf damage in the genotype Anugraha was 60.00 per cent was statistically on par with L9 (55.33). L9 was on par with IC342464 (52.67), L1, L6 and IC537657.

The leaf damage caused by *S. dorsalis* varied from 13.00 to 72.33 per cent at 50 days after transplanting. There was reduction in the leaf damage per cent when compared to 35 DAT. *S. dorsalis* caused a minimum damage in L5 with a leaf damage of 13.00 per cent which was on par with L3 (16.33). L3 was statistically on par with L14 (19.00). CF2 (22.33) was also on par with L14 and L15 (26.33). L15 was found statistically on par with IC342426 (27.33) and L7 (30.33). CF3 showed a leaf damage of 31.33 per cent which was statistically on par with L7, Ujwala (32.00), IC344367 (32.67), L12 (34.00) and IC572454 (35.00). IC572454 was statistically on par with IC272868 (35.67), L13(36.00), Athulya (38.00), Jwalamukhi (39.00) and L8 (39.67). IC312916 showed a leaf damage of 40.00 per cent which was on par with L8, L10 (41.00) and L2 (43.33). L4 (45.00) was on par with L2, L10, IC537657 (47.00), L6 (47.00), L1 (47.33) and IC342464 (48.00). *S. dorsalis* caused severe damage in the genotype L11 with a highest leaf damage of 72.33 per cent which was significantly different from other genotypes. This was followed by CF1 (65.33) which was statistically on par with IC284628 (61.00). Anugraha showed a leaf damage of 56.00 per cent which was significantly different from others. This was followed by L9 (51.00) which was statistically on par with IC342464, L1, L6 and IC537657.

The per cent of leaf damage caused by *S. dorsalis* varied from 18.67 to 77.33 at 65 days after transplanting. The per cent of leaf damage increased, compared to the previous observations taken at 50 DAT. Significantly lower leaf damage of 18.67 per cent was observed in the genotype L5 which was on par with L3 (21.67) and L14

(24.33). This was followed by CF2 (27.67) which was statistically on par with L14. CF2 was on par with L15 (31.33) and IC342426 (32.33). IC342426 was on par with L7 (35.33), CF3 (36.33) and Ujwala (37.67). L7 was also statistically on par with IC344367 (38.33), L12 (39.33) and IC572454 (40.33). IC572454 was on par with L13with a leaf damage of 41.33 per cent, IC272868 (41.33), Athulya (43.33), L8 (45.33) and IC312916 (45.67). L8 was statistically on par with L10 (46.33), L2 (48.33) and L4 (50.67). The genotype L11 was severely damaged by *S. dorsalis* with per cent leaf damage of 77.33 per cent which was significantly different from other genotypes. This was followed by CF1 (70.67), which was on par with IC284628 (66.67). IC284628 was on par with Anugraha (61.33) which was on par with L9 (56.67). L9 was statistically on par with the genotypes IC342464 (53.33), L6 (52.67), IC537657 (52.67) and L1 (52.33).

4.1.3.1 Grouping of Chilli Genotypes Based on Per Cent Leaf Curl Due to *S. dorsalis*

The per cent leaf curl index of chilli genotypes and the grouping of chilli genotypes based on per cent leaf curl index (PLI) is given in Table 10 and Table 11 respectively.

The sorting of chilli genotypes based on per cent leaf curl index showed that the genotypes L3 and L5 were having moderate resistance with leaf curl index value between 11 to 25 per cent. Seventeen genotypes namely, Athulya, CF2, IC342426, IC312916, IC272868, IC344367, IC572454, Jwalamukhi, L7, L8, L10, Ujwala, L12, L13, L14, CF3,and L15 which had leaf curl index value between 26 to 50 per cent were categorised as susceptible genotypes. Maximum mite infestation was recorded in the genotypes, Anugraha, L1, L2, CF1, L4, L6, IC284628, IC342464, IC537657, L9 and L11 which showed highest degree of leaf curling (PLI: 51-100) and categorized as highly susceptible genotypes.

Table 10. Per cent leaf curl index in chilli genotypes due to infestation by *Scirtothrips dorsalis*

Sl. No.	Genotype	20 DAT	35 DAT	50 DAT	65 DAT	MEAN
1.	Anugraha	75.00	75.00	75.00	75.00	75.00
2.	Athulya	50.00	50.00	50.00	50.00	50.00
3.	L1	50.00	66.67	50.00	66.67	58.34
4.	L2	50.00	50.00	50.00	58.33	52.08
5.	CF1	75.00	75.00	75.00	75.00	75.00
6.	L3	25.00	25.00	25.00	25.00	25.00
7.	L4	50.00	58.33	50.00	66.67	56.25
8.	CF2	25.00	41.67	25.00	41.67	33.34
9.	L6	50.00	66.67	50.00	66.67	58.34
10.	L5	25.00	25.00	25.00	25.00	25.00
11.	IC272868	50.00	50.00	50.00	50.00	50.00
12.	IC284628	75.00	75.00	75.00	75.00	75.00
13.	IC312916	50.00	50.00	50.00	50.00	50.00
14.	IC342426	33.33	50.00	41.67	50.00	43.75
15.	IC342464	50.00	75.00	58.33	66.67	62.50

16.	IC344367	50.00	50.00	50.00	50.00	50.00
17.	IC537657	50.00	66.67	50.00	66.67	58.34
18.	IC572454	50.00	50.00	50.00	50.00	50.00
19.	Jwalamukhi	50.00	50.00	50.00	50.00	50.00
20.	L7	50.00	50.00	50.00	50.00	50.00
21.	L8	50.00	50.00	50.00	50.00	50.00
22.	L9	58.33	75.00	66.67	75.00	68.75
23.	L10	50.00	50.00	50.00	50.00	50.00
24.	L11	75.00	91.67	75.00	91.67	83.34
25.	Ujwala	50.00	50.00	50.00	50.00	50.00
26.	L12	50.00	50.00	50.00	50.00	50.00
27.	L13	50.00	50.00	50.00	50.00	50.00
28.	L14	25.00	33.33	25.00	33.33	29.17
29.	CF3	50.00	50.00	50.00	50.00	50.00
30.	L15	33.33	50.00	41.67	50.00	43.75

Table 11. Grouping of chilli genotypes based on per cent leaf curl index

Category	Per cent Leaf Curl Index	Genotypes
Resistant	0-10	
Moderately resistant	11-25	L3, L5
Susceptible	26-50	Athulya, CF2, IC342426, IC312916, IC272868, IC344367 IC572454, Jwalamukhi, L7, L8, L10, Ujwala, L12, L13, L14, CF3, L15
Highly susceptible	51-100	Anugraha, L1, L2, CF1, L4, L6, IC284628, IC342464, IC537657, L9 L11

Principal Component Analysis was carried out based on the population count of sucking pests to find out the tolerant and susceptible genotypes against the sucking pest complex. As per the PCA results, the genotypes L5, L3 and L14 were found as the tolerant and L11 as the susceptible genotype against the sucking pest complex (Plate 3).

The natural enemies were not found in chilli plants in sizeable numbers during the observation period and other pests and diseases were also not noticed.

4.2 Morphological Basis of Resistance in Chilli Genotypes

The morphological characters of the tolerant and susceptible chilli genotypes are presented in Table 12.

4.2.1 Height

Among the four genotypes L3 is the tallest genotype with a height of 51 cm which was on par with L14 (46.7 cm). This was followed by L5 (39.5 cm) and it was statistically on par with L11 having the shortest plant height of 36.7 cm.

4.2.2 Total Number of Leaves Plant^{-1}

Among the four genotypes, the genotype L3 possessed the highest number of leaves plant^{-1} (142.3) which was followed by L14 (106) and L5 (64.7). Lowest number of leaves plant^{-1} was observed in L11 (44.3). All the genotypes were having significant difference from each other in the total number of leaves plant^{-1}.

4.2.3 Number of Branches Plant^{-1}

Among the genotypes, L5 possessed the highest number of branches plant^{-1} (9) which was followed by L3 (8.7) and L14 (7.7). L11 recorded the lowest number of branches plant^{-1} (5.3). The number of branches plant^{-1} were not significantly different in the genotypes.

4.2.4 Leaf Area

The genotype L3 recorded the highest leaf area (32.83 cm^2) which was statistically on par with L14 (21.33 cm^2). L14 was on par with L5 (18.33 cm^2) and L11 (11.83 cm^2). The minimum leaf area was recorded in L11.

A. L5

B. L3

C. L14 D. L11

Plate 3. Tolerant and susceptible chilli genotypes

Table 12. Morphological characters of the tolerant and susceptible genotypes

Genotype	Height(cm)	Total number of leaves plant^{-1}	Number of branches plant^{-1}	Leaf area(cm^2)	Length-width ratio of leaves	Number of trichomes leaf^{-1}
L3	51.00^{a}	142.33^{a}	8.70	32.83^{a}	2.53	24.00^{a}
L14	46.67^{a}	106.00^{b}	7.70	21.33^{ab}	2.67	17.00^{a}
L5	39.50^{b}	64.67^{c}	9.00	18.33^{b}	2.47	27.00^{b}
L11	36.67^{b}	44.33^{d}	5.30	11.83^{b}	2.31	4.00^{c}
SEm (±)	**2.139**	**4.34**	**1.041**	**4.189**	**0.194**	**1.528**
CD (0.05)	**(6.976)**	**(14.153)**	**NS**	**(13.661)**	**NS**	**(4.982)**

4.2.5 Length – width Ratio of Leaves

Length-width ratio of leaves recorded highest in L14 (2.67) which was followed by L3 (2.53) and L5 (2.47). Lowest length-width ratio was observed in L11 (2.31). There was no significant difference in the length-width ratio of leaves in the genotypes.

4.2.6 Number of Trichomes Leaf^{-1}

Number of trichomes leaf^{-1} was observed highest in the genotype L5 (27) which was statistically on par with L3 (24). This was followed by L14 (17) and L11 (4) which were significantly different from others.

4.2.7 Yield (kg plant^{-1})

The yield of different chilli genotypes is presented in Table 13.

On examining the yield obtained from various genotypes, highest yield was recorded from the genotype L3 (0.66kg plant^{-1}) which was statistically on par with L9 (0.60 kg plant^{-1}). L9 was on par with IC572454 (0.45), IC312916 (0.43), IC272868 (0.42), IC342426 (0.41), and Athulya (0.40). The genotype Anugraha recorded a yield of 0.38 kg plant^{-1} which was statistically on par with Jwalamukhi (0.37), L14 (0.37), IC344367 (0.36), L1(0.35), Ujwala (0.35), L7 (0.35), L15 (0.35), L11 (0.34), IC284628 (0.33), L4 (0.32), L8 (0.31), L12 (0.30), L13(0.29), L2 (0.27), L6 (0.27), L10 (0.29), IC342464 (0.26), and IC537657 (0.25). Lowest yield was recorded from CF2 (0.12 kg plant^{-1}), which was statistically on par with L5 (0.13kg plant^{-1}) CF3 (0.14 kg plant^{-1}) and CF1 (0.15 kg plant^{-1}).

Table 13. Yield of different genotypes of chilli

Genotype	Yield (kg plant^{-1})
Anugraha	0.38^{c}
Athulya	0.40^{bc}
L1	0.35^{cd}
L2	0.26^{cdefg}
CF1	0.15^{defg}
L3	0.66^{a}
L4	0.32^{cdefg}
L5	0.13^{fg}
CF2	0.12^{g}
L6	0.26^{cdefg}
IC272868	0.42^{bc}
IC284628	0.33^{cdef}
IC312916	0.43^{bc}
IC342426	0.41^{bc}
IC342464	0.26^{cdefg}

IC344367	0.36^{c}
IC537657	0.25^{cdefg}
IC572454	0.45^{bc}
Jwalamukhi	0.36^{c}
L7	0.35^{cd}
L8	0.31^{cdefg}
L9	0.60^{ab}
L10	0.29^{cdefg}
L11	0.34^{cde}
Ujwala	0.35^{cd}
L12	0.30^{cdefg}
L13	0.29^{cdefg}
L14	0.36^{c}
CF3	0.14^{efg}
L15	0.35^{cd}
SEm (±)	**0.073**
CD (0.05)	**(0.205)**

4.3 Biochemical Basis of Resistance in Chilli Genotypes

The biochemical analysis of the tolerant and susceptible chilli genotypes is given in Table 14.

The total phenol content was highest in the genotype L5 (0.290 mg g^{-1}) which was statistically on par with L14 (0.283 mg g^{-1}). This was followed by L3 (0.234 mg g^{-1}) which was on par with L11 (0.230 mg g^{-1}).

Total protein content was highest in L11 (6.17 mg g^{-1}) which was followed by L5 (5.90 mg g^{-1}) and L3 (5.85 mg g^{-1}) and it was lowest in L14 (5.38 mg g^{-1}). Total protein was significantly different in all the genotypes.

Total sugar content was highest in L11 (0.216 mg g^{-1}) which was followed by L5 (0.198 mg g^{-1}) and L3 (0.122 mg g^{-1}). Total sugar content was lowest in L14 (0.106 mg g^{-1}). There was a significant difference in the total sugar content in all the genotypes.

The capsaicin content was highest in the genotype L5 (0.016 mg g^{-1}). This was followed by the genotype L3 (0.013 mg g^{-1}) and L14 (0.014 mg g^{-1}). Lowest capsaicin content was recorded in the genotype L11 (0.011 mg g^{-1}). The amount of capsaicin was not significantly different in these genotypes.

4.4 Nutrient Analysis of Chilli Genotypes

The amount of total nitrogen, total phosphorus and total potassium in the tolerant and susceptible chilli genotypes are presented in Table 15.

The total nitrogen was higher in genotype L11 (0.18%) which was statistically on par with L5 (0.14 %). Total nitrogen in L14 was 0.16 % which was on par with L3 (0.12%).

The highest total phosphorus content was observed in L11 (0.63%). L14 had a phosphorus content of 0.42% and L5 had a total phosphorus content of 0.30%. Lowest total phosphorus content was observed in the genotype L3 (0.21%). All these were significantly different from each other.

Table 14. Biochemical characters of the tolerant and susceptible genotypes

Genotype	Total phenol (mg g^{-1})	Total protein (mg g^{-1})	Total sugar (mg g^{-1})	Capsaicin (mg g^{-1})
L3	0.2336	5.846	0.122	0.013
L14	0.2827	5.377	0.106	0.014
L5	0.29	5.902	0.198	0.016
L11	0.2309	6.169	0.216	0.011
SEm (±)	**0.006**	**0.001**	**0.001**	**0.001**
CD (0.05)	**(0.019)**	**(0.004)**	**(0.004)**	**NS**

Table 15. Total nitrogen, phosphorus and potassium in the tolerant and susceptible genotypes.

Genotype	Total Nitrogen (%)	Total Phosphorus (%)	Total Potassium (%)
L3	0.12	0.21	0.78
L14	0.16	0.42	1.08
L5	0.14	0.30	0.90
L11	0.18	0.63	0.46
SEm (±)	**0.012**	**0.012**	**0.012**
CD (0.05)	**(0.038)**	**(0.038)**	**(0.038)**

Total potassium was found to be higher in the genotype L14 (1.08%) which was followed by L5 (0.90%) and L3 (0.78%), whereas it was lowest in the genotype L11 (0.46%). Total potassium in all the genotypes were significantly different to each other.

4.6 Correlation between different traits and infestation of *Aphis gossypii, Polyphagotarsonemus latus* and *Scirtothrips dorsalis*.

4.6.1 Aphis gossypii

The details of correlation are presented in Table 16.

Correlation analysis between the infestation of *A.gossypii* and plant height revealed that , there was a significant negative correlation, with a correlation coefficient of -0.678. The total number of leaves plant^{-1} had a negative non-significant correlation with aphid population with a correlation coefficient of -0.727. The number of branches plant^{-1} and leaf area revealed a significant negative correlation with number of *A.gossypii*, with correlation coefficients of -0.658 and -0.648 respectively, whereas the length-width ratio of leaves and trichome density had a non-significant negative correlation having -0.251 and -0.804 as correlation coefficients respectively. The total phenol content in the leaves showed a non-significant negative correlation with the mean population of aphids and the correlation coefficient was -0.421. On the other hand, total protein and sugar revealed a significant strong positive relationship with number of *A.gossypii*, with correlation coefficients of 0.584 and 0.647 respectively. Capsaicin content was having a non-significant negative correlation with population of *A.gossypii* and the correlation coefficient was -0.572. There was a significant positive correlation between total nitrogen and number of *A.gossypii* with a correlation coefficient of 0.619. Total phosphorus revealed a non-significant positive correlation (0.886) and total potassium had a non-significant negative correlation (-0.741) with mean population of *A.gossypii*.

4.6.2 Polyphagotarsonemus latus

Analysis of correlation between the infestation of *P.latus* and plant height revealed that, there was a non-significant negative correlation, with a correlation coefficient of -0.480. The total number of leaves plant^{-1} had a negative non-significant correlation (-0.514) with mite population and the number of branches plant^{-1} revealed a significant negative correlation with number of *P.latus*, with a correlation coefficient of -0.664. Leaf area had a non-significant negative correlation with a correlation coefficient of -0.379 whereas the length-width ratio of leaves and trichome density had a non-significant negative correlation having -0.361 and -0.907 as correlation coefficients respectively. The total phenol content in the leaves expressed a significant negative relationship with the mean population of mites and the correlation coefficient was -0.653. Total protein and total sugar showed a non-significant positive correlation with number of *P.latus*, with correlation coefficients of 0.821 and 0.737 respectively. Capsaicin content showed a non-significant negative correlation (-0.449) with population of *P.latus*. There was a non-significant positive correlation between total nitrogen and number of *P.latus* with a correlation coefficient of 0.524. Total phosphorus revealed a non-significant positive correlation with correlation coefficient 0.759 and total potassium had a non-significant negative correlation with mean population of *P.latus* and the correlation coefficient is -0.942.

4.6.3 Scirtothrips dorsalis

Correlation analysis between the infestation of *S.dorsalis* and plant height revealed that , there was a non-significant negative correlation, with a correlation coefficient of -0.274. The total number of leaves had a negative non-significant correlation with thrips population with a correlation coefficient of -0.308. The number of branches/plant had a significant negative correlation with number of *S.dorsalis*, with a correlation coefficient of -0.654 and leaf area had a non-significant negative correlation with a correlation coefficient of -0.379. The length-width ratio of leaves and trichome density had a non-significant negative correlation having -0.132 and -0.911 as correlation coefficients respectively. The total phenol content in the leaves expressed a significant negative relationship with the mean population of thrips and the correlation coefficient was -0.661. Total protein and total sugar had a non-significant positive

association with number of *S.dorsalis*, with correlation coefficients of 0.916 and 0.783 respectively. Capsaicin content showed a non-significant negative correlation with population of *S.dorsalis* and the correlation coefficient was -0.326. There was a non-significant positive correlation between total nitrogen and number of *S.dorsalis* with a correlation coefficient of 0.291. Total phosphorus showed a significant positive correlation with correlation coefficient 0.576 and total potassium had a non-significant negative correlation with mean population of *S.dorsalis* and the correlation coefficient is -0.968.

Table 16. Correlation between different traits with respect to infestation of *Aphis gossypii, Polyphagotarsonemus latus* and *Scirtothrips dorsalis.*

	A.gossypii	*P.latus*	*S.dorsalis*
Plant height	-0.678*	-0.480	-0.274
Total number of leaves	-0.727	-0.514	-0.308
Number of branches plant^{-1}	-0.658*	-0.664*	-0.654*
Leaf area	-0.648*	-0.379	-0.327
Length-width ratio of leaves	-0.251	-0.361	-0.132
Trichome density	-0.804	-0.907	-0.911
Total phenol	-0.421	-0.653*	-0.661*
Total protein	0.584*	0.821	0.916
Total sugar	0.647*	0.737	0.783
Capsaicin	-0.572	-0.449	-0.326
Total nitrogen	0.619*	0.524	0.291
Total phosphorus	0.886	0.759	0.576*
Total potassium	-0.741	-0.942	-0.968

*** - Correlation is significant at 0.05 level**

Discussion

5. DISCUSSION

Chilli (*Capsicum annuum* L.) is a member of solanaceae family which represents a diverse group of plants. There are various biotic and abiotic factors which are responsible for reduction in the yield of chilli. The infestation by insect pests is considered as the major constraint which in over 25 insects have been observed attacking leaves and fruits of chilli in India. Out of these pests, thrips (*Scirtothrips dorsalis* Hood) (Order- Thysanoptera), aphids (*Aphis gossypii* Glover) (Order- Hemiptera) and mites (*Polyphagotarsonemus latus* Banks) (Order- Trombidiformes) are the important pests (Choudhary and Pandya, 2019) which are characterised by relatively short life cycles, and can complete several generations on a crop.

Although, insecticidal applications bring down the pest damage considerably, it leads to problem of pesticide residues in fruits. Pesticide residues in spices, especially in chillies are one of the major barriers against export to developed countries. Similarly, indiscriminate use of insecticides has led to resistance, pest resurgence, environmental pollution and also upsetting the natural ecosystem (Choudhary and Pandya, 2019).

In this scenario, host plant resistance can be considered as the first and foremost pest management strategy. Plant resistance is in many ways an ideal pest management tactic which is easy to use, inexpensive, effective, and mostly compatible with other pest management strategies (Stout, 2013).

The present study was done to evaluate the field tolerance of chilli genotypes against sucking pest complex.

5.1 FIELD TOLERANCE OF CHILLI GENOTYPES AGAINST SUCKING PEST COMPLEX

The use of insecticides in pest management are often more harmful to non-target organisms or natural enemies than to the pests themselves. Also, many insect pests are maintained in agro-ecosystems at low and non-damaging levels by naturally occurring predators and competitors. When these insecticides negatively affect these natural enemies, secondary pest outbreaks can result. The resistance evolution, pest resurgence, and secondary pest outbreaks reduce the efficacy of insecticides. Reduced efficacy, and

negative effects on environmental and human health, limit the use of chemical insecticides for pest management. As a result, there is an urgent need for environmentally sound and effective alternatives for pest management. Host plant resistance address this need and has become an effective pest management tool (Straub *et al*., 2020). Based on these facts, 30 chilli genotypes were screened for their field tolerance to sucking pest complex including aphids, mites and thrips. Indigenous genotypes of Kerala, KAU released varieties and accessions from NBPGR were included in the present study for identification of tolerant genotypes.

5.1.1 Varietal screening of chilli against *Aphis gossypii*

Among the 30 chilli genotypes tested for their field tolerance against *A. gossypii* based on the population study, the genotype L11 was found most susceptible with a mean population of 23.72 aphids leaf^{-1}. The per cent reduction in the population of *A. gossypii* over the most susceptible genotype was highest in L3 with 88.06 which was followed by L9 (80.57) and L14 (75.76). The least per cent reduction in the population of *A. gossypii* over L11 was recorded in L12 with 26.11 which was followed by with L4 (32.79), IC342464 (34.54) and CF3 (35.60). Similar findings were reported by Kumar *et al.* (2020) who observed that among the 70 genotypes screened against aphids, Pusa Jwala, NT-74, Selection-2010, G-4, GS-15 were found highly resistant to aphids and 2031, 2014, M-2-1, 810-42, Selection-2017, Selection 25-1, 35-30-1, Chaman, Selection-2 (yellow) were highly susceptible.Earlier studies conducted by Kumar *et al*. (2021), reported that out of the ten chilli genotypes screened against *A. gossypii*, minimum infestation was found in the genotype Arka Khyati followed by Arka Sheepal and Arka Lohit and maximum aphid infestation was recorded in genotype Pusa Jwala (Fig 1.).

5.1.2 Varietal screening of chilli against *Polyphagotarsonemus latus*

Infestation of mite was observed in all the genotypes of chilli on four observation dates. The highest mean population of *P. latus* was observed in the genotype L11 (6.30 mites leaf^{-1}). Among the tested genotypes, the per cent reduction

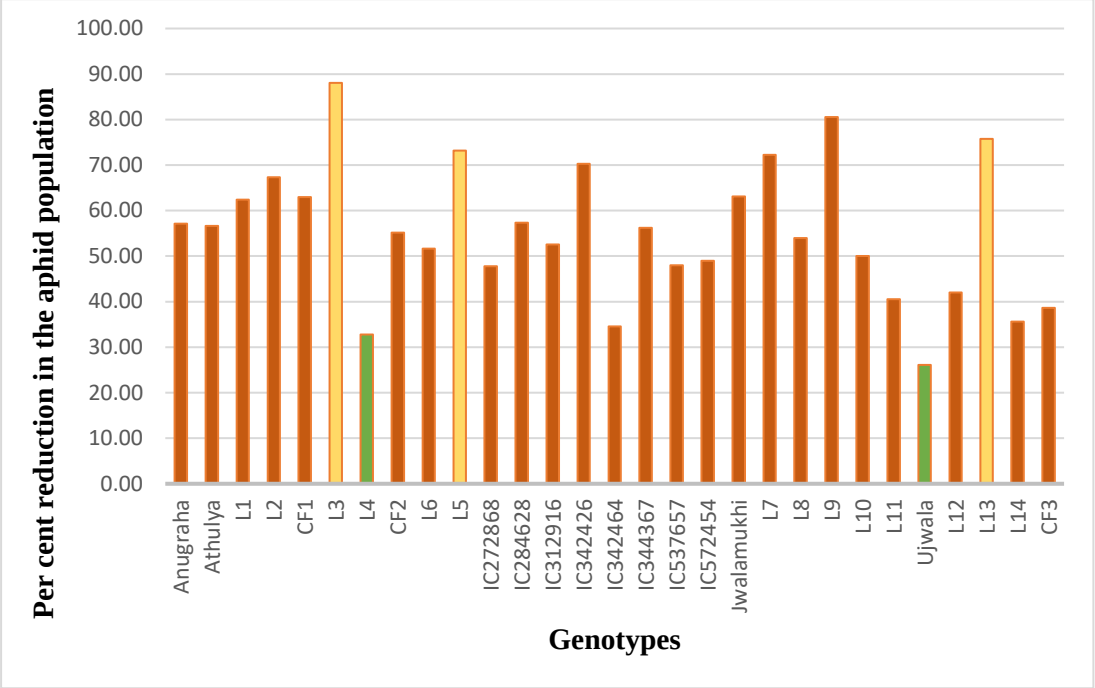


Fig. 1. Comparison of the population of *Aphis gossypii* in chilli genotypes over the most susceptible genotype

in the population of *P. latus* was highest in the genotype L5 (76.66). This was followed by L14 with 62.58 per cent reduction in mite population and L3 (60.37). The per cent reduction in the population of *P. latus* was lowest in the genotype L9 (12.79) when compared with L11. This was followed by L4 (30.87) and IC284628 (34.36). Likewise, Desai *et al.* (2006) observed that out of twenty-one genotypes screened against yellow mite, the genotypes ACG-77, RHRC Erect and Jwala were found to be tolerant whereas PBS 86-1 and G-4 were extremely susceptible against mite infestation. Kaur *et al.* (2010) who screened sixty-three chilli genotypes, observed that none were found resistant and the genotypes MS-12, Hansi-1, Hansi-2, EC 532399, SCM 334, Kashmir Long-1, SH-H-404 and Perennial were highly susceptible. Among the 81 germplasms screened against yellow mite by Satpathy *et al*. (2008), only one line, i.e., PDG-1 (A) did not show any symptom of mite infestation and was rated as resistant and six cultivars, IC-119500, L. Collection, L. Small fruit, IC-14202, EC-391075, VNS-4 (4.34) were found to be highly susceptible among which VNS-4 was most susceptible (Fig 2.).

5.1.3 Varietal screening of chilli against *Scirtothrips dorsalis*

Among the 30 chilli genotypes screened against *S. dorsalis* based on the population study, the maximum mean population of *S. dorsalis* was recorded in the genotype L11. The reduction in the population of *S. dorsalis* when compared to L11 was highest in the genotype L5 with 66.65 per cent which was followed by L14 (41.56) and L3 (40.34). The per cent reduction in the population of *S. dorsalis* over L11 was found minimum in the genotype L9 (18.09) which was followed by Anugraha (18.93) and CF1 (21.40). Similarly, Priyadarshini *et al*. (2019) observed that Bhangar genotype was found tolerant, whereas Mocha was recorded as susceptible against thrips infestation. Megharaj *et al*. (2016) screened 46 chilli genotypes and found that the genotypes Phule jyothi, DCA-106, DCA-139, DCA-140, DCA-142, DCA-205, DCA-232 were found to be with least infestation by *S. dorsalis* population and the genotypes Byadgi Dabbi and Byadgi Kaddi were found highly susceptible. Similar study was conducted by Samota *et al*. (2018), in which ten chilli genotypes were screened and the genotypes Alakhpura Selection, Mathania Local and Pant C-1 were found least

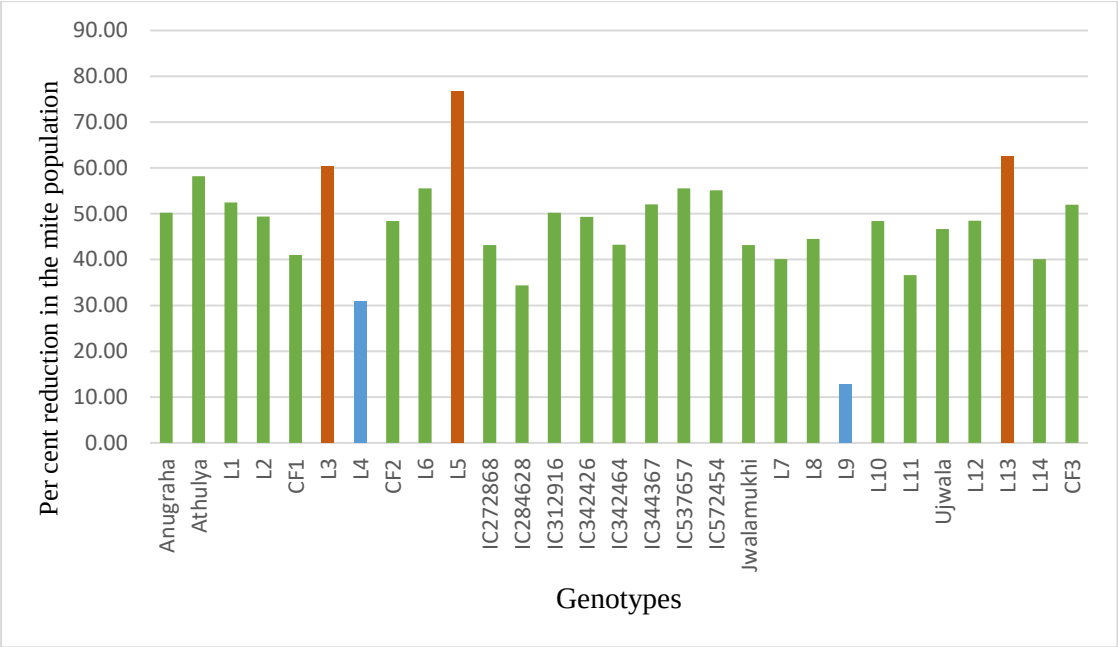


Fig. 2. Comparison of population of *Polyphagotarsonemus latus* in chilli genotypes over the most susceptible genotype

susceptible susceptible to thrips and PS-64 and Pusa Jwala were found to be highly susceptible (Fig 3.).

5.1.4 Leaf damage caused by *Polyphagotarsonemus latus*

Among the thirty chilli genotypes screened, the highest per cent of leaf damage was observed in the genotype L11 (76.33). The least infestation was observed in the genotype L5 (80.46) over L11 which was on par with L14 (77.84) and L3 (72.60). The per cent reduction in the leaf damage was minimum in the genotypes L9 (10.81) and L4 (18.78) when compared to L11. Samanta *et al*. (2017) screened twenty-nine chilli genotypes based on plants infested with visible symptoms due to the damage caused by mites in which the lowest mean per cent of plant infestation with visible symptoms was recorded in the genotype 2012/CHYB-11 due to yellow mites and maximum mean per cent was found on 2011/CHYB-8. Similar screening studies were conducted by Bala *et al*. (2016) and Singh and Pandey (2015) who had screened chilli genotypes against yellow mites based on leaf damage symptoms (Fig 4.).

5.1.5 Leaf damage caused by *Scirtothrips dorsalis*

The highest per cent of leaf damage by *S. dorsalis* among the 30 chilli genotypes tested, was observed in the genotype L11. The highly tolerant genotypes were L5, L3 and L14 with 79.64, 75.26 and 71.54 per cent reduction in the leaf damage over L11 and least per cent reduction in the leaf damage compared with L11 was observed in the genotypes CF1 (9.22), IC284628 (14.85) and Anugraha (21.60). Gopal *et al.* (2019) observed the performance of chilli accessions, assessed them based on thrips population counts and leaf curl symptoms caused by them and found that accessions *viz*., EC-596952, EC-390033 and EC-391082 were least preferred by thrips and EC-599976 and EC-599994 were highly susceptible (Fig 5.).

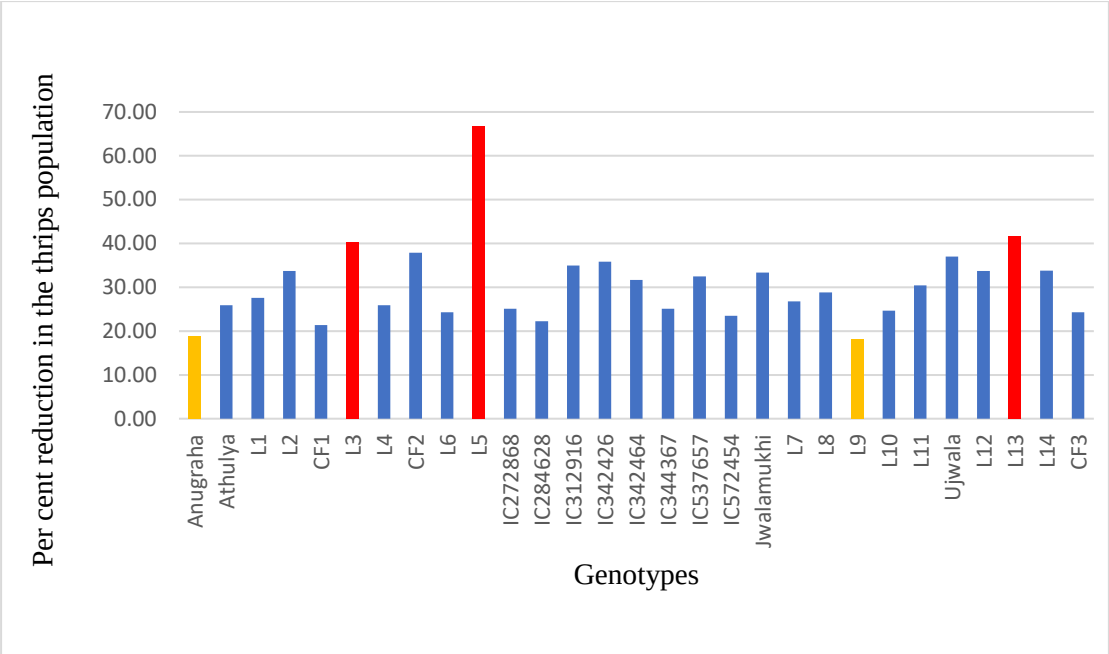


Fig. 3. Comparison of population of *Scirtothrips dorsalis* in chilli genotypes over the most susceptible genotype

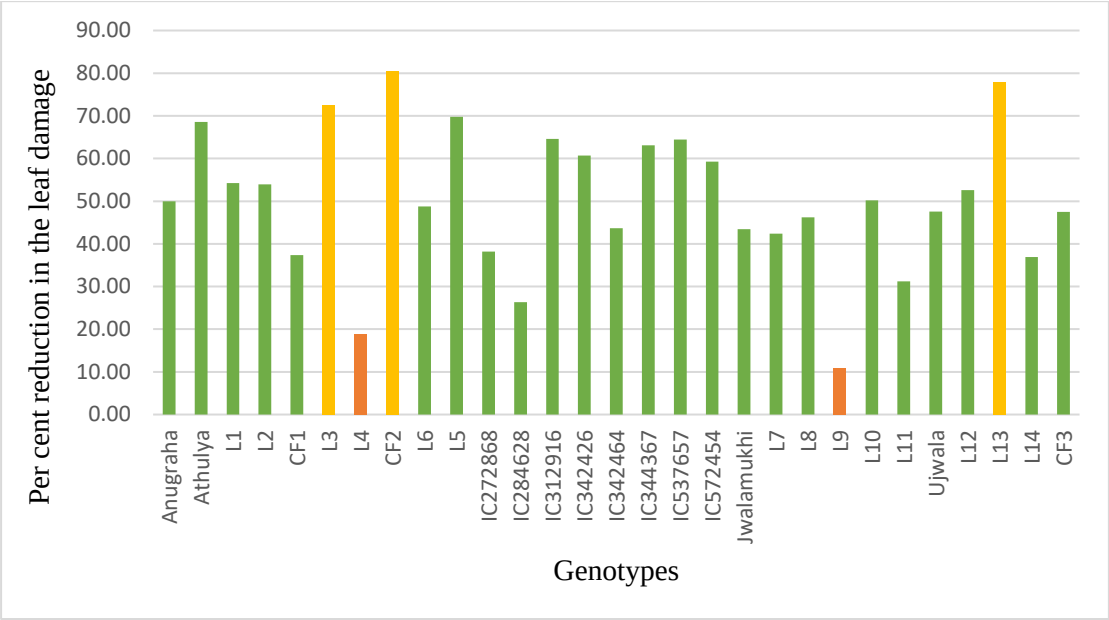


Fig. 4. Comparison of leaf damage caused by *Polyphagotarsonemus latus* in chilli genotypes over the most susceptible genotype

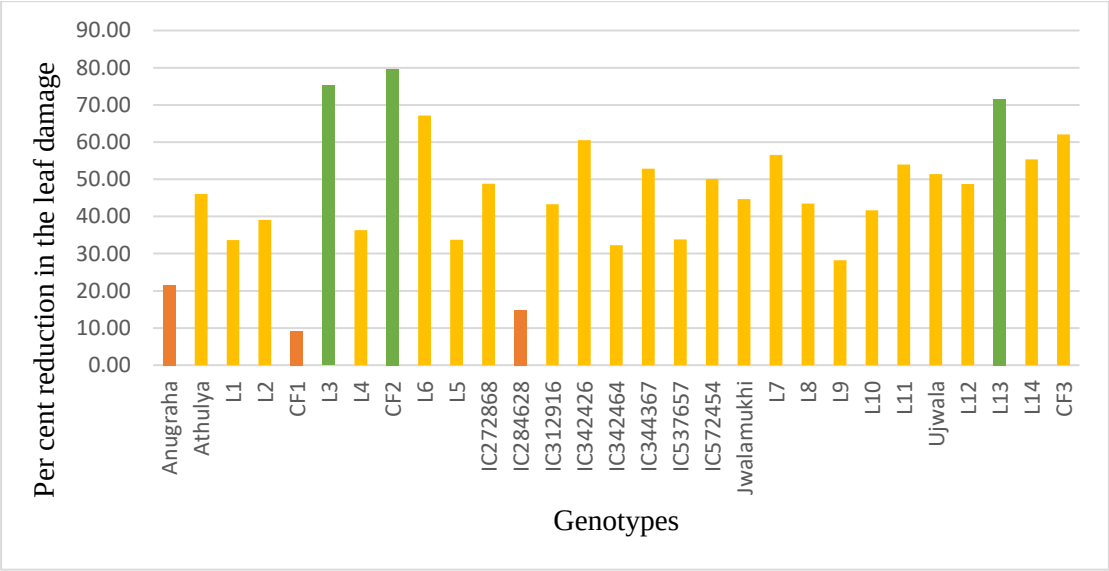


Fig. 5. Comparison of leaf damage caused by *Scirtothrips dorsalis* in chilli genotypes over the most susceptible genotype

Principal Component Analysis (PCA) was performed to find out the tolerant and susceptible genotypes against the sucking pest complex based on the population of *A. gossypii*, *P. latus* and *S. dorsalis*. A PCA biplot was constructed with the variables as aphids, mites and thrips. In this biplot, the genotypes clustered in the direction of aphids, mites and thrips are susceptible to them and those in the opposite quadrant are tolerant. So, it is evident from the PCA results that, the genotypes L5, L3 and L14 were the tolerant and L11 was the susceptible genotype against the sucking pest complex (Fig 6.).

Among the released varieties from KAU, Anugraha, Vellayani Athulya and Jwalamukhi were coming under the susceptible group due to *P. latus* infestation whereas the genotype Ujwala under the highly susceptible group. The genotypes Vellayani Athulya, Jwalamukhi and Ujwala were coming under the susceptible category and Anugraha was included in the highly susceptible group based on the per cent leaf curl index due to infestation by *S. dorsalis*.

Among the genotypes under *Capsicum frutescens*, CF2 was grouped under susceptible category due to infestation by *P. latus* whereas CF1 and CF3 under highly susceptible category. In the case of infestation by *S. dorsalis*, CF2 and CF3 were coming under the susceptible category and CF1 under the highly susceptible category.

Among the accessions from NBPGR, IC312916, IC342464, IC344367, IC342426, IC537657 and IC572454 were included in the susceptible category due to *P. latus* infestation and the accessions IC272868 and IC284628 in the highly susceptible category. Based on the per cent leaf curl index due to infestation by *S. dorsalis*, the accessions IC342426, IC312916, IC272868, IC344367 and IC572454 were grouped under susceptible category and IC284628, IC342464 and IC537657 under highly susceptible category.

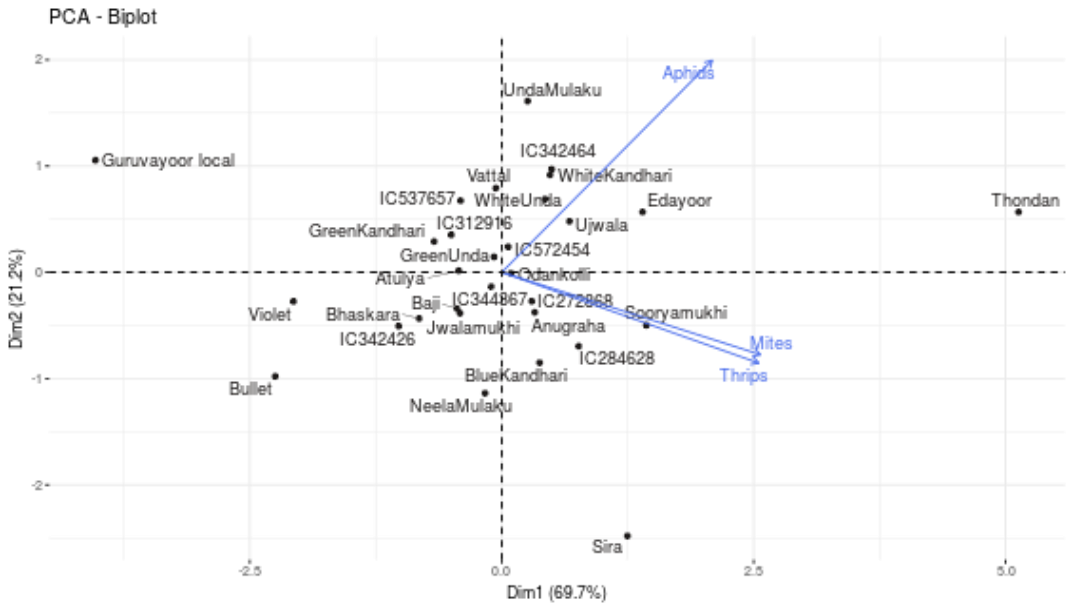


Fig. 6. PCA biplot

5.2 MORPHOLOGICAL BASIS OF RESISTANCE

Various studies have shown that genotypes could differ in their resistance to insect pests due to the difference in the morphological characters (Megharaj *et al*., 2016). The morphological characters such as plant height, total number of leaves plant^{-1}, number of branches plant^{-1}, leaf area and length-width ratio of leaves were negatively correlated with the incidence of aphids, mites and thrips. The plant height was 51.00 cm, 46.70 cm and 39.50 cm in the tolerant cultivars L3, L14 and L5 respectively, whereas the genotype L11 had a plant height of 36.70 cm, which is the susceptible genotype. This might be due to the preference of sucking pests to shorter plants for their survival than taller plants. Rameash *et al*. (2015) reported a negative association between the plant height and susceptibility of chilli genotypes to the thrips, *S. dorsalis*.

Similarly, total number of leaves plant^{-1} were higher in the tolerant genotypes, where the mean number of leaves was 142.3 in the genotype L3, which was followed by L14 and L5. The mean number of leaves in the susceptible genotype L11 was 44.3. This might be due to the high photosynthetic capacity of the plants with large number of leaves which contributes to the mechanism of defense against these pests. Accelerated growth rate could also be a possible mechanism for resistance in chilli plants. Genotypes exhibiting resistance response can produce leaves at a faster rate than leaf damage caused by pests. Also, the number of branches plant^{-1} was higher in the tolerant genotypes L5 (9), L3 and L14, whereas the susceptible genotype L11 had the lowest number of branches plant^{-1} (5.3). This is because more number of branches plant^{-1} results in dense foliage and increased plant spread which affects the movement of pests and results in less damage on plants. This result is in agreement with the screening study conducted by Megharaj *et al*. (2016).

Leaf area was found higher in the genotypes L3 (32.83 cm^2), which was followed by L14 and L5 which were tolerant to the sucking pests. However, leaf area was lower in the susceptible genotype L11 (11.83 cm^2). This might be due to high photosynthetic efficiency due to large leaf area which might contribute to the defense mechanism against these pests. Similarly, in the screening studies conducted by Megharaj *et al*. (2016) it was observed that the leaf area showed negative association with the incidence of thrips. Length-width ratio of leaves showed a negative association

with the pest infestation. As the length-width ratio of leaves increases, the space of feeding and oviposition by the pests decreases. The tolerant genotypes expressed higher length-width ratio of 2.67, 2.53 and 2.47 in the genotypes L14, L3 and L5 respectively, whereas a lower length-width ratio of leaves was observed in the susceptible genotype L11.

Trichome density had a negative association with the incidence of sucking pests in chilli. This indicates the significance of trichomes in confirming the antixenosis type of resistance against leaf curl complex in chilli caused by the sucking pests. The density of trichomes was higher in the genotypes L5 (27), L3 (24) and L14 (17) and it was lower in the susceptible genotype L11 (4). Trichome density in plants is negatively related to the feeding, nutrition, and ovipositional behaviour of insects. Dense trichomes also affect the plant–insect interactions by interfering with the movement of insects and other arthropods on the plant surface, and limiting their access to leaf epidermis. Similar reports were given by Latha and Hanumanthraya (2018) in which the results of correlation between morphological characters of plants such as trichome density, and thrips and mites incidence revealed that thrips and mites population were found negatively correlated. Study conducted by Megharaj *et al*. (2016), revealed that the incidence of sucking pests and morphological characters including leaf area, number of primary branches etc. were negatively correlated.

The tolerance in the genotypes L5, L3 and L14 may also be contributed by other morphological factors such as low midrib thickness, high internodal length, thicker leaves, longer and denser trichomes on leaf lamina, on veins and ventral surface of the leaves etc. This is in agreement with Amin *et al*. (2016), who screened cotton cultivars against aphids and jassids and observed the role of these morphological characters in imparting resistance in cotton plants.

Even though the highest yield was recorded from the tolerant genotype L3 (0.66kg plant^{-1}), no substantial increase in yield was noted in other tolerant genotypes. This might be because different genotypes differ in their fruit weights irrespective of the pest incidence.

5.3 BIOCHEMICAL BASIS OF RESISTANCE

Phenols are secondary metabolites in plants which are involved in the plant defense against insects which either affect insect growth and development or act as oviposition deterrents. The total phenol content was higher in the tolerant genotypes L5 (0.290mg g^{-1}), L14 (0.283mg g^{-1}) and L3 (0.234 mg g^{-1}) and lowest in L11(0.230mg g^{-1}) which is the susceptible genotype. This might be due to the fact that, in resistant genotypes, increase in the levels of total phenol might induce to enhance the synthesis of phenolic precursors and their further oxidation into toxic quinones which prevented the further build-up of pest population as a hypersensitive reaction or induced resistance. Similar reports were observed by Girish *et al*. (2019), in a study conducted for the response of chilli genotypes to yellow mite in which the total phenol content was higher in all the genotypes that were resistant to yellow mite. The findings from the present study are in agreement with Megharaj *et al*. (2016) who also revealed the negative association of total phenol with thrips incidence.

The lowest protein content was noticed in the tolerant genotype L14 (5.38 mg g^{-1}), which was followed by L3 and L5 when compared to the susceptible genotype L11 (6.17mg g^{-1}). Similarly, total sugars were also lower in the tolerant genotypes, i.e., L14 (0.106mg g^{-1}), which was followed by L3 and L5 and higher in L11(0.216mg g^{-1}). This might be due to the fact that total protein as well as higher total sugars imparts more sweetness to leaves which act as a feeding stimulant for sucking pests. These results were in conformity with Girish *et al*. (2019) who observed that total sugars and protein content was high in susceptible genotypes compared to the resistant genotypes. Similarly, Chaudhary and Pandya (2019) reported that chilli genotypes with less total soluble sugar and less protein provided resistance against thrips infestation.

Capsaicin content was higher in the tolerant genotypes L5 (0.016mg g^{-1}), followed by L3 and L14, whereas it was lower in the susceptible genotype L11(0.011mg g^{-1}). This is because capsaicin is an alkaloid which imparts pungency to the chilli plant which makes it unpalatable for the sucking pest. The present results are in confirmation with the findings of Datta and Chakraborty (2013) who reported that chilli genotypes with higher capsaicin content were free from yellow mite and whitefly infestation.

The tolerance in the genotypes L5, L3 and L14 might also be attributed to the high chlorophyll and low proline content in the leaves. Megharaj *et al*. (2016) reported the negative correlation of total chlorophyll with the thrips incidence in chilli and Girish *et al*. (2021) observed that proline content was lower in the resistant chilli genotypes, when screened against *P. latus*.

5.4 NUTRIENT ANALYSIS

Total nitrogen was found to be 0.12%,0.14% and 0.16% in the tolerant genotypes L3, L14 and L5, which was lower when compared to the susceptible genotype L11 (0.18%). This is because nitrogen enhances the vegetative growth of the plants which makes the plant more succulent and attractive for pests. Similarly, Chaudhary and Pandya (2019) reported that chilli genotypes with less nitrogen (%) provided resistance against thrips infestation. Similar trend was also seen in total phosphorus content. It was observed as lower in the genotypes L3 (0.21), L5 (0.30) and L14 (0.42) which were tolerant when compared to L11 (0.63%) which was susceptible. This might be due to the fact that plants experiencing phosphorus deficiency induce the jasmonic acid pathway and enhance their defense against insect herbivory. The results are in agreement with the studies conducted by Megharaj *et al*. (2016) in which nitrogen and phosphorus was higher in the susceptible genotypes.

However, potassium had a negative association with the incidence of pest which act as a resistant factor in plants. The total potassium was higher in the tolerant genotypes L14 (1.08%), L5 (0.90%) and L3 (0.78%), when compared to the susceptible genotype L11 (0.46%). Higher potassium concentrations enable plants to allocate more resources to developing stronger cell walls for preventing insect attack and to obtain more nutrients to be used for plant defense and damage repair. All these results were in conformity with the studies of Megharaj *et al.* (2016) who observed that potassium had a negative correlation with thrips incidence.

A concise analysis of the data generated in the present study revealed that the tolerant genotypes were L5, L3 and L14, whereas the most susceptible genotype was L11 against the sucking pest complex. Among the traits of resistance, the morphological characters like plant height, total number of leaves, number of branches

plant^{-1}, leaf area, length-width ratio of leaves, trichome density etc. and biochemical factors such as capsaicin and higher phenol content as well as high potassium imparted resistance in chilli genotypes against the sucking pest complex. On the other hand, high protein and total sugars, higher nitrogen and phosphorus content were responsible for the susceptibility in chilli.

Summary

6. SUMMARY

Chilli (*Capsicum annuum* L.) is an important spice as well as vegetable crop grown all over India. It is infested by several insect and non-insect pests of which the important sucking pests contributing to decrease in the yield are *P. latus, S. dorsdalis* and *A. gossypii*. The management of chilli pests using insecticides is characterized by high pesticide usage and hence has caused problems of residues in the fruits. It has also resulted in reduction in biodiversity of natural enemies, outbreak of secondary pests, development of resistance to pesticides, pesticides induced resurgence and contamination of food and eco-system. Integrated pest management involves several measures like chemicals, botanicals, use of resistant cultivars, use of bio-control agents, etc. to minimize the losses due to insect pests of which insect resistant genotypes are an important component and suits well in the pest management in chilli.

With this view, the present investigation entitled "Field tolerance of chilli varieties against sucking pest complex" was carried out to evaluate the field tolerance of different chilli genotypes against sucking pest complex and the morphological and biochemical basis of resistance in them. The major findings are summarized below.

- Among the thirty chilli genotypes evaluated against *A. gossypii*, the genotype L3 had the minimum population with 1.66, 2.89,3.22 and 3.56 aphids leaf^{-1} on 20, 35, 50 and 65 days after transplanting respectively, which was followed by L9 (3.77, 4.44, 4.78 and 5.44 aphids leaf^{-1}) and L14 (6.11, 5.33, 5.56 and 5.99 aphids leaf^{1}). The population of *A.gossypii* was highest in L11 (25.89, 22.44, 22.78 and 23.78 aphids leaf^{-1}) on the four observation dates respectively.

- The genotype L5 was least preferred by *P. latus* with a mean population of 0.55, 1.55, 1.67 and 2.11 mites leaf^{-1} on 20, 35, 50 and 65 days after transplanting respectively. This was followed by L14 (1.56, 1.89, 2.89 and 3.11 mites leaf^{-1}) and L3 (1.66, 2.56, 2.78 and 3.00 mites leaf^{-1}) on the four observation dates. The maximum incidence of *P. latus* was observed in the genotype L11 with a mean population of 5.33, 6.33, 6.67

and 6.89 mites leaf^{-1} on 20, 35, 50 and 65 days after transplanting respectively.

- The minimum incidence of *S. dorsalis* was observed in the genotype L5 (1.22, 2.00, 2.55 and 3.22 thrips leaf^{-1}) and was followed by L14 (3.00,3.67, 4.22 and 4.89 thrips leaf^{-1}) and L3 (3.11, 3.67, 4.33 and 5.00 thrips leaf^{-1}) on 20, 35, 50 and 65 days after transplanting. The severe infestation of *S.dorsalis* was found in L11 (5.66, 6.44, 7.11 and 7.78 thrips leaf^{-1}) on the four observation dates respectively.

- The per cent leaf damage was assessed and the genotype L5 was least damaged by *P. latus* with per cent leaf damage of 11.33, 17.33, 12.67 and 18.33 on 20, 35, 50 and 65 days after transplanting respectively. The genotype L11 was severely damaged by *P. latus* with a per cent leaf damage of 73.00, 78.33, 74.33 and 79.67 on the four observation dates respectively.

- The minimum damage by *S. dorsalis* was observed in the genotype L5 with a leaf damage of 11.67, 17.00, 13.00 and 18.67 per cent on 20, 35, 50 and 65 days after transplanting respectively and the damage by *S. dorsalis* was highest in L11 (70.67, 76.00, 72.33 and 77.33 per cent) on the four observation dates.

- Chilli genotypes were classified into various categories based on per cent leaf curl index due to infestation of mites and thrips. The genotypes L5, L3 and L14 were recorded as moderately resistant and the genotypes L11, L4, CF1 and IC284628 were coming under the highly susceptible category.

- The KAU varieties Anugraha, Athulya, Jwalamukhi and Ujwala were coming under the susceptible and highly susceptible category based on per cent leaf curl index due to mites and thrips infestation respectively.

- The NBPGR accessions, IC312916, IC342464, IC344367, IC342426, IC537657 and IC572454 were included in the susceptible category due to *P. latus* infestation and the accessions IC272868 and IC284628 in the highly susceptible category. Based on the per cent leaf curl index due to infestation by *S. dorsalis*, the accessions IC342426, IC312916, IC272868, IC344367 and IC572454 were grouped under susceptible category and IC284628, IC342464 and IC537657 under highly susceptible category.

- The genotypes L5, L3 and L14 were found as tolerant and L11 as susceptible against the sucking pest complex when Principal Component Analysis was carried out based on the population count of sucking pests.

- All the morphological characters *viz*., plant height, total number of leaves plant^{-1}, number of branches plant^{-1}, leaf area, length-width ratio of leaves and trichome density in the tolerant and susceptible genotypes were negatively correlated with the incidence of pests. Plant height and leaf area showed a significant negative correlation with the infestation of *A. gossypii* whereas number of branches plant^{-1} showed a significant negative correlation with the incidence of aphids, mites and thrips. All other morphological traits showed a non-significant negative correlation.

- Among the biochemicals, total phenol and capsaicin content in chilli plants were negatively correlated whereas total protein and total sugar were positively correlated with the population of *A. gossypii, P. latus* and *S. dorsalis*. Total phenol revealed a significant negative correlation with the incidence of *P. latus* and *S. dorsalis* and non-significant negative correlation with *A. gossypii*. Total protein and total sugars had a significant positive association with the infestation of *A. gossypii* whereas a non-significant positive correlation was exhibited with the

incidence of *P. latus* and *S. dorsalis*. Capsaicin had a non-significant negative relationship with the incidence of all the three sucking pests.

- Total nitrogen and total phosphorus had a positive correlation with pest population in which total nitrogen showed a significant positive correlation with the population of *A. gossypii* and total phosphorus exhibited a significant positive correlation with the incidence of *S. dorsalis*. On the other hand, total potassium revealed a non-significant negative association with the infestation of *A. gossypii*, *P. latus* and *S. dorsalis*.

- The results obtained from present study revealed the importance of host plant resistance and utilisation of tolerant cultivars as a tactic in integrated pest management for managing the sucking pest complex in chilli. Based on the mean population of *A. gossypii*, *P. latus* and *S. dorsalis* and the leaf damage caused by them, the genotypes L3, L5 and L14 were observed as the tolerant and L11 as the susceptible genotype to these sucking pest complex.

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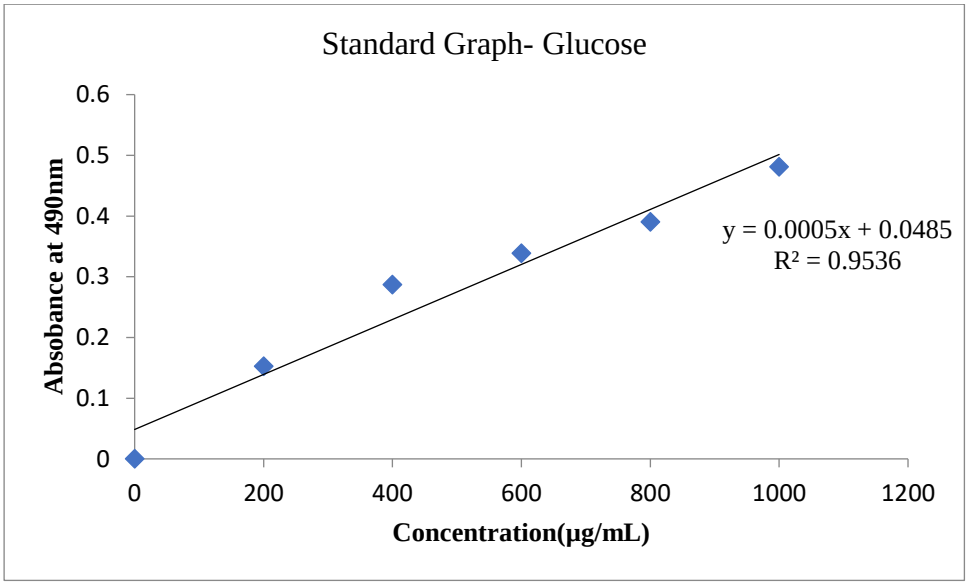
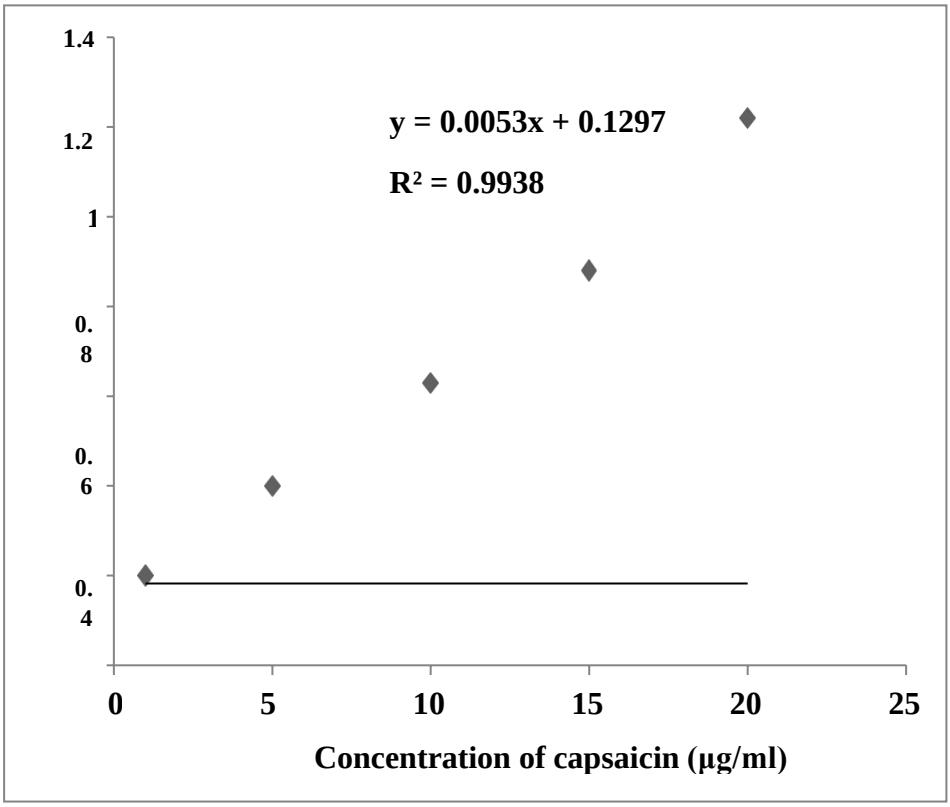
Appendices

APPENDIX I



Standard graph of glucose for estimation of carbohydrates

APPENDIX II



Standard graph of pure capsaicin for estimation of capsaicin

FIELD TOLERANCE OF CHILLI VARIETIES AGAINST SUCKING PEST COMPLEX

by

HARITHA N.K.

(2019-11-132)

ABSTRACT

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Kerala Agricultural University

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM - 695 522

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2021

ABSTRACT

The study on the "Field tolerance of chilli varieties against sucking pest complex"was conducted at Department of Agricultural Entomology, College of Agriculture, Vellayani during 2019-2021 with the objective to evaluate chilli genotypes for field tolerance to sucking pest complex *viz*; *Aphis gossypii* Glover, *Polyphagotarsonemus latus* Banks and *Scirtothrips dorsalis* Hood. A total of 30 genotypes were screened for the field tolerance to the sucking pests, including indigenous genotypes of Kerala, KAU released varieties and accessions from NBPGR.

The mean population count of *A. gossypii*, *P. latus* and *S. dorsalis* on 20, 35, 50 and 65 days after transplanting was recorded and significantly lower mean number of *A. gossypii* was recorded in L3 (2.83 leaf^{-1}), L9 (4.61 leaf^{-1}) and L14 (5.75 leaf^{-1}). The population of *P. latus* was observed least in the genotype L5 with a mean number of 1.47 mites leaf^{-1} which was followed by L14 (2.36 leaf^{-1}) and L3 (2.49 leaf^{-1}). The minimum incidence of *S. dorsalis* was recorded in the genotype L5 which showed a mean population of 2.25 thrips leaf^{-1} and it was followed by L14 (3.94 leaf^{-1}) and L3 (4.03 leaf^{-1}). The genotype L11 was found most susceptible with the highest number of *A. gossypii* (23.72 leaf^{-1}), *P. latus* (6.30 leaf^{-1}) and *S. dorsalis* (6.75 leaf^{-1}).

The damage assessment was done by observing the leaf damage caused by mites and thrips. When the mean leaf damage was recorded on 20, 35, 50 and 65 days after transplanting, *P. latus* showed least preference to the genotype L5 with a per cent leaf damage of 14.92 and this was followed by L14 (16.92) and L3 (20.92). The minimum damage by *S. dorsalis* was observed in the genotype L5 with a leaf damage of 15.08 per cent and was followed by L3 and L14 with a leaf damage of 18.33 and 21.08 per cent respectively. The genotype L11 was severely damaged by *P. latus* and *S. dorsalis* with a per cent leaf damage of 76.33 and 74.08 respectively.

The Per cent Leaf Curl Index (PLI) was calculated based on the leaf damage, for grouping the chilli genotypes into resistant, moderately resistant, susceptible and highly susceptible categories. Based on the mean PLI due to damage by *P. latus* the genotypes, L5 and L14 were grouped under moderately resistant category. The genotypes L5 and L3 were grouped as moderately resistant based on mean PLI due to

damage by *S. dorsalis*. The genotypes L11, L4, CF1 and IC284628 were coming under the highly susceptible category due to infestation of *P. latus* and *S. dorsalis*.

Principal Component Analysis (PCA) was carried out based on the mean population of *A. gossypii, P. latus* and *S. dorsalis* to find out the tolerant and susceptible genotypes against the sucking pest complex. The genotypes L5, L3 and L14 were found as the tolerant and L11 as the susceptible genotype for which the analysis of morphological traits, biochemicals and nutrients were carried out.

Different morphological traits like plant height, total number of leaves plant^{-1} and leaf area were highest in L3. The number of branches plant^{-1} and trichome density was highest in L5 and the length-width ratio of leaves in the genotype L14. However, all these morphological characters were found lowest in the genotype L11. Analysis of biochemicals revealed that the total phenol content and capsaicin content was highest in the genotype L5 (0.290 mg g^{-1} and 0.016mg g^{-1} respectively) and lowest in the genotype L11. Total protein and total sugar were highest in L11 (6.169 mg g^{-1} and 0.216 mg g^{-1} respectively) and lowest in L14. Total nitrogen and total phosphorus were highest in L11 (0.18% and 0.63% respectively) and lowest in L3. Total potassium was highest in L14 (1.08%) and lowest in L11 (0.46%).

Correlation studies were done to find out the relationship between the different traits in chilli genotypes and infestation of *A. gossypii, P. latus* and *S. dorsalis*. Among the morphological characters, plant height and leaf area had a significant negative correlation with the population of *A. gossypii* while number of branches plant^{-1} had a significant negative correlation with the incidence of all the three sucking pests. The total protein and total sugar had a significant positive correlation with the population of *A. gossypii,* whereas total phenol had a significant negative correlation with the incidence of *P. latus* and *S. dorsalis*. Total nitrogen had a significant positive correlation with the population of *A. gossypii* whereas total phosphorus had a significant positive correlation with the population of *S. dorsalis*.

Based on the mean population of *A. gossypii, P. latus* and *S. dorsalis* and the leaf damage caused by them, the genotypes L5, L3 and L14 were observed as the

tolerant whereas the L11 was found as the susceptible genotype to these sucking pest complex.

സംഗ്രഹം

നീരൂറ്റി കുടിക്കുന്ന കീടസമൂഹത്തിനു എതിരെയുള്ള വ്യത്യസ്ത മുളക് ഇനങ്ങളുടെ പ്രതിരോധത്തെപ്പറ്റിയുള്ള പഠനം 2019-2021 കാലയളവിൽ വെള്ളായണിയിലെ കാർഷിക കോളേജിൽ, കീടശാസ്ത്ര വിഭാഗത്തിൽ വെച്ച് നടത്തി. മുഞ്ഞ (എഫിസ് ഗോസ്സിപ്പി), മണ്ഡരി (പോളിഫഗോടാർസൊനീമസ് ലാറ്റസ്), ഇലപ്പേനുകൾ (സിർട്ടോത്രിപ്സ് ഡോർസാലിസ്) എന്നിവ ഉൾപ്പെടുന്ന കീടസമൂഹത്തിനു എതിരെയുള്ള മുളക് ഇനങ്ങളുടെ പ്രതിരോധം പരിശോധിക്കുക എന്ന ഉദ്ദേശത്തോടെയാണ് ഈ പഠനം നടത്തിയത്. കേരളത്തിലെ നാടൻ ഇനങ്ങളും, കേരളാ കാർഷിക സർവകലാശാല പുറത്തിറക്കിയ ഇനങ്ങളും, നാഷണൽ ബ്യൂറോ ഓഫ് പ്ലാന്റ് ജനറ്റിക് റിസോഴ്സ്സിൽ (എൻ ബി പി ജി ആർ) നിന്നും ലഭിച്ച ഇനങ്ങളും അടങ്ങുന്ന 30 ഇനം മുളകുകളാണ് ഈ പഠനത്തിനായി ഉപയോഗിച്ചത് .

പറിച്ചുനടലിനു ശേഷം 20, 35, 50, 65 ദിവസങ്ങളിൽ ഓരോ മുളക് ഇനത്തിലെയും മുഞ്ഞ, മണ്ഡരി, ഇലപ്പേനുകൾ എന്നിവയുടെ എണ്ണം രേഖപ്പെടുത്തി. മുഞ്ഞയുടെ എണ്ണം എൽ 3 (ഒരു ഇലയിൽ 2.83), എൽ 9 (ഒരു ഇലയിൽ 4.61), എൽ 14 (ഒരു ഇലയിൽ 5.75) എന്നീ ഇനങ്ങളിൽ ഗണ്യമായ കുറവാണ് രേഖപ്പെടുത്തിയത്. മണ്ഡരിയുടെ എണ്ണം ഏറ്റവും കുറവ് രേഖപ്പെടുത്തിയത് എൽ 5 (ഒരു ഇലയിൽ 1.47) എന്ന ഇനത്തിലാണ്. കൂടാതെ എൽ 14 (ഒരു ഇലയിൽ 2.36), എൽ 3 (ഒരു ഇലയിൽ 2.49) എന്നീ ഇനങ്ങളിലും മണ്ഡരിയുടെ എണ്ണം കുറവായിരുന്നു. ഇലപ്പേനുകൾ ഗണ്യമായി കുറഞ്ഞു

കാണപ്പെട്ടത് എൽ 5 (ഒരു ഇലയിൽ 2.25), എൽ 14 (ഒരു ഇലയിൽ 3.94), എൽ 3 (ഒരു ഇലയിൽ 4.03) എന്നീ ഇനങ്ങളിലാണ്. മുഞ്ഞയുടെയും (ഒരു ഇലയിൽ 23.72) മണ്ഡരിയുടെയും (ഒരു ഇലയിൽ 6.30) ഇലപ്പേനുകളുടെയും (ഒരു ഇലയിൽ 6.75) എണ്ണം ഏറ്റവും കൂടുതലായി രേഖപ്പെടുത്തിയത് എൽ11 എന്ന ഇനത്തിലാണ്.

മുഞ്ഞ, മണ്ഡരി, ഇലപ്പേനുകൾ എന്നിവ മൂലമുണ്ടാകുന്ന ഇലകളുടെ കേടുപാടുകൾ നിരീക്ഷിച്ചാണ് മുളക് ചെടികളുടെ നാശനഷ്ടം വിലയിരുത്തിയത്. പറിച്ചുനട്ട് 20, 35, 50, 65 ദിവസങ്ങളിൽ ഇലകളുടെ കേടുപാടുകൾ ശതമാനത്തിൽ രേഖപെടുത്തിയപ്പോൾ, മണ്ഡരി മൂലമുണ്ടാകുന്ന ഇലയുടെ കേടുപാടുകൾ ഏറ്റവും കുറവ് എൽ 5 (14.92 %), എൽ 14 (16.92 %), എൽ 3 (20.92 %) എന്നീ ഇനങ്ങളിലായിരുന്നു. ഇലപ്പേനുകൾ ഏറ്റവും കുറഞ്ഞ കേടുപാടുകൾ ഉണ്ടാക്കിയത് എൽ 5 (15.08 %) എന്ന ഇനത്തിലാണ്, തുടർന്ന് എൽ 3, എൽ 14 എന്നീ ഇനങ്ങൾക്ക് യഥാക്രമം 18.33, 21.08 ശതമാനം ഇലയുടെ കേടുപാടുകൾ സംഭവിച്ചു.

മുളക് ഇനങ്ങളെ പ്രതിരോധ ശേഷിയുള്ളതും, മിതമായ പ്രതിരോധ ശേഷിയുള്ളതും, കീടങ്ങളുടെ ആക്രമണത്തിന് സാധ്യതയുള്ളതും, ഉയർന്ന സാധ്യതയുള്ളതുമായ വിഭാഗങ്ങളായി തരം തിരിക്കുന്നതിന് വേണ്ടിയാണ് ഇലകളുടെ കേടുപാടുകൾ അടിസ്ഥാനമാക്കി പെർസെന്റ് ലീഫ് കേൾ ഇൻഡക്സ് (പി എൽ ഐ) കണക്കാക്കിയത്. മണ്ഡരി മൂലമുണ്ടാകുന്ന കേടുപാടുകൾ മൂലമുള്ള ശരാശരി പി എൽ ഐയെ അടിസ്ഥാനമാക്കി എൽ5, എൽ14 എന്നീ ഇനങ്ങളെ

മിതമായ പ്രതിരോധശേഷിയുള്ള വിഭാഗത്തിൽ തരംതിരിച്ചിട്ടുണ്ട്. ഇലപ്പേനുകളുടെ കേടുപാടുകൾ കാരണം ഉണ്ടാകുന്ന ശരാശരി പി എൽ ഐ അടിസ്ഥാനമാക്കി എൽ5, എൽ3 എന്നീ ഇനങ്ങളെ മിതമായ പ്രതിരോധശേഷിയുള്ളവയായി തരംതിരിച്ചിട്ടുണ്ട്. എൽ11, എൽ4, സിഎഫ്1, ഐസി284628 എന്നീ ഇനങ്ങൾ മണ്ഡരി, ഇലപ്പേൻ എന്നിവയുടെ ആക്രമണം മൂലം ഉയർന്ന കീടാക്രമണസാധ്യതയുള്ള വിഭാഗത്തിന്റെ കീഴിലാണ് വരുന്നത്.

മുഞ്ഞ, മണ്ഡരി, ഇലപ്പേനുകൾ എന്നിവയുടെ ശരാശരി എണ്ണത്തെ അടിസ്ഥാനമാക്കിയാണ് പ്രിൻസിപ്പൽ കംപോണന്റ് അനാലിസിസ് (പി സി എ) നടത്തിയത്. എൽ5, എൽ3, എൽ14 എന്നീ ഇനങ്ങൾ പ്രതിരോധശേഷിയുള്ളതും എൽ11 എന്ന ഇനം കീടാക്രമണ സാധ്യതയുള്ളതുമായും കണ്ടെത്തി, അതിനായി രൂപശാസ്ത്രപരമായ സവിഷേതകൾ, ജൈവരാസവസ്തുക്കൾ, പോഷകങ്ങൾ എന്നിവയുടെ വിശകലനം നടത്തി.

ചെടിയുടെ ഉയരം, ഒരു ചെടിയുടെ ആകെ ഇലകളുടെ എണ്ണം, ഇലയുടെ വിസ്തീർണം എന്നിങ്ങനെ വ്യത്യസ്ത രൂപഘടന സവിശേഷതകൾ എൽ3 എന്ന ഇനത്തിൽ ഉയർന്നതായിരുന്നു. ഒരു ചെടിയുടെ ശാഖകളുടെ എണ്ണം, ട്രൈക്കോം സാന്ദ്രത എന്നിവ ഏറ്റവും ഉയർന്നത് എൽ5-ലും, ഇലകളുടെ നീളം-വീതി അനുപാതം എൽ14-ലും ആയിരുന്നു. എന്നിരുന്നാലും ഈ ഘടകങ്ങളെല്ലാം എൽ11 ഇനത്തിൽ ഏറ്റവും താഴ്ന്നതായി കണ്ടെത്തി. ജൈവരാസവസ്തുക്കളുടെ വിശകലനത്തിൽ ഫിനോളും ക്യാപ്സൈസിനും ഏറ്റവും ഉയർന്നത് എൽ5- ലും, ഏറ്റവും കുറവ് എൽ11-ലുമായിരുന്നു.

പ്രോട്ടീനും ഷുഗറും ഏറ്റവും ഉയർന്നത് എൽ11-ലും, ഏറ്റവും കുറവ് എൽ14-ലും ആയിരുന്നു. നൈട്രജനും ഫോസ്ഫറസും എൽ11-ൽ ഉയർന്നതും എൽ3-ൽ ഏറ്റവും താഴ്ന്നതുമായിരുന്നു. പൊട്ടാസിയം ഏറ്റവും കൂടുതൽ എൽ14-ലും കുറവ് എൽ11-ലും ആയിരുന്നു.

മുഞ്ഞ, മണ്ഡരി, ഇലപ്പേൻ എന്നിവയുടെ ശരാശരി എണ്ണത്തെയും അവ മൂലമുണ്ടാകുന്ന ഇലകളുടെ നാശത്തെയും അടിസ്ഥാനമാക്കി എൽ5, എൽ3, എൽ14 എന്നീ മുളക് ഇനങ്ങൾ ഇവയോട് പ്രതിരോധശേഷിയുള്ളവയായി കണ്ടെത്തി. അതേസമയം എൽ11 ഈ കീടങ്ങൾ ബാധിക്കാൻ സാധ്യതയുള്ള ഇനമായും കണ്ടെത്തി.