**Original Research Article**

**Natural and artificial screening of various chilli genotypes to assess resistance for chilli leaf curl virus under south Gujarat conditions**

**ABSTRACT:**

**Aims:** ~~The purpose of this work was~~ This study aimed to evaluate and identify ~~chilli~~ *Capsicum annuum* ~~L.~~ genotypes resistant to Chilli Leaf Curl Virus (ChiLCV) under natural and artificial screening ~~circumstances~~ conditions, with an emphasis on their suitability for cultivation in ~~south~~ South Gujarat.

**Study design:** The investigation used a ~~Randomised~~ Randomized Complete Block Design (RCBD) with 25 chilli genotypes and ~~3~~ three replications.

**Place and Duration of Study:** The research was ~~carried out~~ conducted during the winter season of 2024-2025 at Jarvi Seeds Pvt. Ltd., at Bharadia, Bharuch, Gujarat.

**Methodology:** 25 genotypes were ~~examined~~ evaluated in natural field ~~circumstances~~ conditions and artificially inoculated with virulent whiteflies. Standard rating scales were used to assess disease incidence, severity and reaction. Data were statistically analysed to ~~divide~~ classify the genotypes into resistance categories.

**Results:** The ~~results showed that~~ genotype responses varied significantly. Under natural screening, ~~2~~ Two genotypes ~~–~~ KSP 1234 Mithila and US 730 - were highly resistant, ~~while,~~ 20 genotypes were resistant and ~~3~~ three genotypes were moderately resistant. Under artificial screening, only ~~3~~ three genotypes (KSP 1234 Mithila, US 730 and US 1081) remained resistant, 16 genotypes showed moderate resistance and ~~6~~ six genotypes became ~~vulnerable~~ susceptible. Disease pressure and reaction severity were often higher under artificial settings.

**Conclusion:** KSP 1234 Mithila and US 730 ~~have been discovered~~ were identified as stable and ~~long-lasting resistance sources~~ durable sources of resistance. Artificial screening was more reliable in ~~finding real~~ identifying as resistance, providing useful insights for ~~chilli leaf curl virus resistant~~ ChiLCV-resistant genotypes in Gujarat.

**KEYWORDS:** ~~C~~chilli, ~~D~~disease ~~R~~reaction, ~~D~~disease ~~S~~severity, ~~Leaf Curl Virus~~ ChiLCV and Ppercent ~~D~~disease ~~I~~incidence

**1. INTRODUCTION:**

The farming sector may be threatened by climate-change-driven ~~linked to global warming since~~ pest and disease outbreaks ~~have a significant impact on~~ pose a serious threat to vegetable productivity [1]. ~~Although vegetables constitute an essential component of every dietary plan and are crucial to both food and nutritional security, vegetable crops are a significant pillar of the agricultural industry~~ Vegetables are indispensable to food and nutritional security and form a major pillar of global agriculture. Because they offer vital minerals, vitamins and nutrients required for survival and the health of the human body ~~system~~, vegetables are regarded as protective foods [2]. In addition, the world's population may exceed ~~12~~ 10 billion ~~people~~ by 2050, making it difficult for the farming industry to provide them with food and nutritional security [3].

One of the most important and extensively grown spice crops in India, both for local consumption and ~~for~~ export, is chilli (*Capsicum annuum* L.) [4]. Although the crop is grown in a variety of agroclimatic zones, the main ~~states that produce~~ chilli~~es~~ producing states are Andhra Pradesh, Telangana, Karnataka, Maharashtra and Gujarat. ~~The horticulture economy of~~ Gujarat’s horticulture economy depends heavily on chilli, especially in the southern districts where it is widely ~~farmed~~ cultivated ~~for the markets~~ for dried spices and fresh green~~s~~ markets [5]. A vital source of income for small and marginal farmers, chilli farming ~~is characterized by its~~ offers high commercial value, versatility and ~~ability to create jobs~~ employment opportunities. ~~But~~ However, frequently viral ~~disease~~ outbreaks, particularly those caused by the chilli leaf curl virus (ChiLCV), have become a significant production ~~hindrance~~ constraint, frequently resulting in yield losses of 80-100% in susceptible cultivars [6]. ~~In order to maintain~~ To sustain productivity and profitability in Gujarat's chilli-growing ~~belts~~ regions ~~and throughout the nation~~, it is ~~imperative~~ essential to ~~improve resistance to~~ ~~manage~~ ~~chilli leaf curl virus~~ ChiLCV ~~by identifying and implementing~~ through deployment of resistant genotypes.

~~Aiming to find the most appropriate and resilient genotypes for the area,~~ Accordingly the ~~current~~ present study screened to find 25 chilli genotypes for resistance against the ~~virus~~ ChiLCV under both natural and artificial inoculation conditions ~~in the context of~~. The work focuses on S~~s~~outh Gujarat, ~~taking into account the importance of the~~ where ~~chilli leaf curl virus~~ ChiLCV ~~as~~ is a major constraint in chilli cultivation.

**2. MATERIALS AND METHODS:**

The experiment was carried out ~~throughout the~~ during the winter season of 2024-2025 at Jarvi Seeds ~~Private Limited~~ Pvt. Ltd., in Bharadia, Bharuch, Gujarat. ~~It~~ The study involved evaluating 25 chilli genotypes using a Randomized Complete Block Design (RCBD) with three replications. Seedlings were cultivated in protrays and transplanted at a 60 cm × 45cm spacing after 35 days. The study location and season have historically favoured whitefly ~~population growth~~ proliferation. All recommended agronomic ~~strategies~~ practices were followed during the trial. Virus incidence was ~~measured~~ observed at both the early and grand growth stages.

For artificial screening under mass inoculation ~~circumstances~~ conditions, viruliferous whiteflies were ~~housed~~ maintained on susceptible, symptomatic chilli plants in wooden cages wrapped in nylon netting. Adult whiteflies obtained from these plants were ~~given~~ allowed for 48-hour Acquisition Access Period (AAP) on the chilli genotypes under study. Inoculation was performed at the three-leaf stage, with 10-12 viruliferous whiteflies per seedling ~~and a~~ followed by 48-hour Inoculation Access Period (IAP). Following inoculation, the seedlings were replanted in open fields and disease incidence was ~~reported~~ recoreded.

 Ten plants ~~from every~~ per genotype ~~for each~~ per replication were selected ~~at~~ randomly, tagged and all observations were recorded from the tagged plants ~~throughout~~ during both natural and artificial screening.

**2.1 Chilli Leaf Curl Index**

The chilli leaf curl index was determined for each chilli genotype~~s~~ ~~based on the ratings~~ using the symptom severity scale of Kumar *et al.* (2006) [7].

**Table 1: Indexing of chilli leaf curl virus**

|  |  |  |  |
| --- | --- | --- | --- |
| **Symptom severity grade** | **Symptoms** | **Reaction (%)** | **Category** |
| 0 | No symptoms | 0 | Immune |
| 1 | 0-5% Curling and clearing of upper leaves | 1 - 10 | Highly Resistant |
| 2 | 6-25% Curling, clearing of leaves and swelling of veins | 11 - 25 | Resistant |
| 3 | 26-50% Curling, puckering and yellowing of leaves and swelling of veins | 26 - 40 | Moderately Resistant |
| 4 | 51-75% leaf curling and stunted plant growth and blistering of internodes | 41 - 60 | Susceptible |
| 5 | >75% curling and deformed small leaves, stunted ~~plant~~ growth with small flowers and no or ~~small~~ low fruit set | >60 | Highly Susceptible |

**2.2 Percent Disease Incidence**

The incidence of leaf curl virus was calculated by using the ~~following~~ formula ~~developed~~ described by Kumar *et al.* (2006) [7] and statistically analysed.

|  |  |  |
| --- | --- | --- |
| Percent disease incidence (%) = | Number of diseased plants | × 100 |
| Total number of plants observed |

**2.3 Disease Severity**

The severity of chilli leaf curl virus was calculated by using the ~~following~~ formula ~~developed~~ described by Wheeler (1969) [8] and statistical~~ly~~ analys~~ed~~is.

|  |  |  |
| --- | --- | --- |
| Diversity severity = | Disease class × No. of plants in each class) | × 100 |
| Total number of plants selected × Maximum disease grade |

**2.4 Disease Reaction**

Based on the performance of genotype against leaf curl virus ~~reaction~~, they were categorized into six ~~categories~~ groups by adopting the method of Reddy *et al.* (2001) [9].

**3. RESULTS AND DISCUSSION:**

Significant variation in the responses of 25 chilli genotypes investigated to chilli leaf curl virus (ChiLCV) under both natural and artificial screening conditions ~~is displayed~~ as shown in Tables 2-4.

**3.1 Natural Screening**

With disease severity scores of 9.00% and PDIs of 10.00% and 9.67%, respectively, ~~2~~ two genotypes - US 730 and KSP 1234 - Mithila showed the highest level of resistance under natural screening ~~settings~~ conditions and were classified as highly resistant (HR).

A total of 20 genotypes ~~in all~~ were categorized as resistant (R), with PDI ~~varying~~ ranging between 15.00% and 21.67%. This group's notable genotypes, which maintained low disease severity scores (12.00-18.00%), include US 1081 (17.67%), US 341 (18.00%), US 1003 (20.33%) and NS 2701 (16.00%).

Viraat, Sagar Kalyani and VNR Unnati were the three genotypes that ~~shown~~ showed moderate resistance (MR), with increased disease indices (32.33% to 37.33%) and severity (21.00% to 26.00%). According to Table 3, no genotype was identified as immune (I), sensitive (S), or highly susceptible (HS) in the natural environment.

**3.2 Artificial Screening**

In ~~the majority of instances~~ most cases, a more severe disease response was ~~seen~~ observed under artificial inoculation. US 730 (15.33%), US 1081 (23.33%) and KSP 1234 Mithila (19.00%) were the only ~~3~~ three genotypes that ~~were still~~ remained classified as resistant (R), despite ~~having somewhat~~ showing slightly higher PDI and severity ratings than those ~~obtained~~ observed through ~~spontaneous~~  natural screening.

Mardani 1476, US 1003, US 341, Armour, Kranti and SVHA0786 were among the 16 genotypes classified as moderately resistant (MR). ~~t~~Their PDIs ranged from 19.00% to 42.00% and their disease indices ranged from 26.67% to 41.33%. This shift from resistance to moderate resistance under artificial conditions indicates increased disease pressure in the controlled environment. ~~Increased disease pressure in the controlled environment is indicated by this change from resistance to moderate resistance under artificial conditions.~~

In contrast, ~~6~~ six genotypes - Bangaram, Navtej, Viraat, Sagar Kalyani, SVHA2222 and VNR Unnati were identified as susceptible (S). Their severity ~~ratings~~ scores exceeded 43.00% and their PDIs ranged from 41.00% to 64.33%, ~~showing~~ demonstrating poor tolerance under artificial inoculation ~~conditions~~ (Table 4).

**3.3 Comparative Analysis**

The efficiency of artificial inoculation in identifying minute variations in resistance levels is demonstrated by ~~the fact that, when comparing the two screening techniques~~, disease severity and PDI values were ~~typically~~ generally higher under artificial screening compared to natural conditions. Under artificial pressure, Bangaram and Navtej changed from resistant to susceptible, whereas some genotypes, such US 1003 and US 341, deteriorated from resistant to moderately resistant. KSP 1234 Mithila and US 730, out of all the genotypes, continuously ~~shown~~ showed high resistance under both screening conditions, making them ~~attractive options~~ promising candidates for disease resistance ~~initiatives aimed~~ breeding programs ~~at reducing~~ targeting chilli leaf curl virus (ChiLCV) resistance.

**3.4 Discussion**

In line with earlier observations on diversity in chilli germplasm, the distinct responses of chilli genotypes to the chilli leaf curl virus under both natural and artificial screening ~~circumstances~~ conditions demonstrate the substantial genetic variability in resistance [10, 11]. These results are essential for ~~locating~~ identifying reliable sources of resistance that can be successfully applied in ~~upcoming~~ future disease resistan~~ce~~t ~~initiatives~~ breeding programmes targeted ~~at~~ strategies to control~~ling~~ viral ~~illnesses~~ infections in chillies [12].

About 80% of genotypes showed resistan~~ce~~t to moderately resistant reactions ~~in~~ under natural field ~~circumstances~~ conditions, suggesting that many commercial genotypes might be naturally tolerant of natural inoculum levels [11]. To distinguish genuinely resistant genotypes from those displaying environmental or tolerance-based resistance, however, the artificial screening setup-which applies consistent and high inoculum pressure through whitefly-mediated virus transmission-was more successful [10, 13]. This pattern was also ~~seen~~ observed in previous ~~research~~ findings [12], as evidenced by the ~~continuously~~ consistently higher severity scores and Percent Disease Index (PDI) values obtained under ~~fake~~ artificial screening.

It is noteworthy that KSP 1234 Mithila and US 730 exhibited minimal PDI and severity scores while maintaining high levels of resistance ~~in~~ under both natural and artificial settings. This ~~implies~~ suggests the ~~existence~~ presence of strong and consistent resistance mechanisms ~~that may be connected~~ potentially linked to vector deterrence, hypersensitive responses, or reduction of viral replication [14]. For disease resistance initiatives, these genotypes ~~consequently constitute~~ contributes important genetic resources, particularly in areas like S~~s~~outh Gujarat, where chilli leaf curl virus (ChiLCV) is endemic.

However, after artificial screening, a number of genotypes - including SVHA2222, Bangaram, Navtej and Viraat, that had shown resistance ~~in~~ under natural ~~settings~~ conditions, were ~~demoted~~ reclassified ~~to~~ as susceptible, most likely ~~as a result of~~ due to environment-dependent tolerance rather than actual genetic resistance [15]. The significance of incorporating artificial inoculation techniques during genotype evaluation to guarantee the durability and dependability of disease resistance in pipelines is underscored by this instability under virus assault [16].

**Table 2: Reaction of chilli genotypes screened against chilli leaf curl virus**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sr. No.** | **Genotypes** | **Company/Source** | **Natural screening** | **Artificial screening** |
| **Per cent disease index (%)** | **Disease severity (%)** | **Disease reaction** | **Per cent disease index (%)** | **Disease severity (%)** | **Disease reaction** |
| **1** | US 730  | Numhems Seeds  | 10.00 | 9.00 | HR | 15.33 | 13.00 | R |
| **2** | US 1081 | Numhems Seeds  | 17.67 | 13.00 | R | 23.33 | 21.00 | R |
| **3** | US 341 | Numhems Seeds  | 18.00 | 16.00 | R | 26.67 | 28.00 | MR |
| **4** | US 1003 | Numhems Seeds  | 20.33 | 12.00 | R | 31.33 | 29.00 | MR |
| **5** | US 917 | Numhems Seeds  | 17.33 | 18.00 | R | 27.67 | 31.00 | MR |
| **6** | Armour | Numhems Seeds  | 18.00 | 15.00 | R | 38.67 | 42.00 | MR |
| **7** | Kranti | Numhems Seeds  | 19.00 | 20.00 | R | 33.00 | 45.00 | MR |
| **8** | Viraat | Numhems Seeds  | 32.33 | 21.00 | MR | 41.00 | 48.00 | S |
| **9** | KSP 1234 Mithila  | Kalash Seeds | 9.67 | 9.00 | HR | 19.00 | 23.00 | R |
| **10** | Bangaram | Kalash Seeds | 20.67 | 13.00 | R | 41.33 | 55.00 | S |
| **11** | Mardani 1476 | Kalash Seeds | 15.00 | 14.00 | R | 29.67 | 39.00 | MR |
| **12** | KPS 1483 Albeli | Kalash Seeds | 18.33 | 19.00 | R | 35.67 | 42.00 | MR |
| **13** | Sitara - Seminis | Seminis Seeds | 16.33 | 21.00 | R | 28.00 | 33.00 | MR |
| **14** | SVHA2222 | Seminis Seeds | 36.00 | 24.00 | R | 45.00 | 39.00 | S |
| **15** | SVHA0786 | Seminis Seeds | 18.00 | 14.00 | R | 34.67 | 23.00 | MR |
| **16** | SVHA1049 | Seminis Seeds | 18.33 | 15.00 | R | 35.67 | 28.00 | MR |
| **17** | VNR 305  | VNR Seeds | 17.67 | 14.00 | R | 31.00 | 28.00 | MR |
| **18** | VNR Unnati | VNR Seeds | 37.33 | 25.00 | MR | 62.67 | 60.00 | S |
| **19** | NS 2701  | Namdhari seeds | 16.00 | 12.00 | R | 39.67 | 34.00 | MR |
| **20** | NS 2572 | Namdhari seeds | 18.67 | 12.00 | R | 33.33 | 19.00 | MR |
| **21** | HPH 5531  | Syngenta Seeds | 18.67 | 13.00 | R | 37.33 | 20.00 | MR |
| **22** | KYI 189  | Known You (India) Private Ltd. | 16.67 | 13.00 | R | 29.00 | 19.00 | MR |
| **23** | FB-JWALA  | Farmson Biotech | 17.67 | 15.00 | R | 31.33 | 23.00 | MR |
| **24** | Sagar Kalyani  | Sagar Seeds | 35.00 | 26.00 | MR | 64.33 | 60.00 | S |
| **25** | Navtej  | MAHYCO Seeds | 21.67 | 18.00 | R | 55.33 | 43.00 | S |
|  |  | **S.Em.±** | 2.36 | 2.36 |  | 4.12 | 4.12 |  |
|  |  | **C.D. at 5%** | 6.78 | 6.78 |  | 13.10 | 13.10 |  |

**Table 3: Categorization of chilli genotypes for resistance to chilli leaf curl virus based on virus symptoms under natural condition**

|  |  |  |
| --- | --- | --- |
| **Disease reaction** | **No. of genotypes** | **Genotypes** |
| Immune | 00 | - |
| Highly resistant | 02 | KSP 1234 Mithila and US 730 |
| Resistant | 20 | Mardani 1476, NS 2701, Sitara - Seminis, KYI 189, US 917, US 1081, VNR 305, FB-JWALA, US 341, SVHA0786, Armour, KPS 1483 Albeli, SVHA1049, NS 2572, HPH 5531, Kranti, US 1003, Bangaram, Navtej and SVHA2222 |
| Moderately resistant | 03 | Viraat, Sagar Kalyani and VNR Unnati |
| Susceptible | 00 | - |
| Highly susceptible | 00 | - |

**Table 4: Categorization of chilli genotypes for resistance to chilli leaf curl virus based on virus symptoms under artificial condition**

|  |  |  |
| --- | --- | --- |
| **Disease reaction** | **No. of genotypes** | **Genotypes** |
| Immune | 00 | - |
| Highly resistant | 00 | - |
| Resistant | 03 | KSP 1234 Mithila, US 730 and US 1081 |
| Moderately resistant | 16 | Mardani 1476, NS 2701, Sitara - Seminis, KYI 189, US 917, VNR 305, FB-JWALA, US 341, SVHA0786, Armour, KPS 1483 Albeli, SVHA1049, NS 2572, HPH 5531, Kranti and US 1003,  |
| Susceptible | 06 | Bangaram, Navtej, Viraat, Sagar Kalyani, SVHA2222 and VNR Unnati |
| Highly susceptible | 00 | - |

**CONCLUSION:**

The research revealed significant genetic heterogeneity across 25 chilli genotypes in response to the chilli leaf curl virus (ChiLCV) in both natural and artificial screening conditions. KSP 1234 Mithila and US 730 consistently displayed high resistance in both scenarios. While several genotypes ~~seemed~~ appeared to be resistant in the field, artificial screening ~~revealed~~ uncovers the concealed sensitivity, that highlighting the importance of controlled inoculation in genotype evaluation.

Overall, this work sheds light on the resistance behaviour of commercial chilli genotypes and stresses the need of using stable and long-lasting resistance sources to limit the catastrophic impact of chilli leaf curl virus. ~~This~~ These findings will ~~help~~ aid breeders, pathologists and farmers selecting appropriate genotypes for s chilli production, especially in virus-prone locations like south Gujarat.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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