**Original Research Article**

**FIELD SCREENING FOR LEAF CURL DISEASE RESISTANCE IN SUNFLOWER (*Helianthus annuus* L.*)* GENOTYPES**

# **ABSTRACT**

In India sunflower cultivation faces significant challenges due to leaf curl disease, caused by begomo viruses and transmitted by whiteflies. This study aimed to evaluate the resistance of 48 sunflower genotypes to leaf curl disease during the rabi season of 2024–25 at the Regional Agricultural Research Station, Nandyal. Disease severity was assessed using the Percent Disease Index (PDI) at four different stages viz., 30, 45, 60, and 75 days after sowing (DAS). Significant genotypic differences were observed in disease response at all stages. Analysis of variance revealed that environmental influence on disease expression was minimal, as indicated by higher phenotypic coefficients of variation (PCV) compared to genotypic coefficients (GCV), along with high heritability and genetic advance as a percentage of mean (GAM), suggesting additive gene action in the inheritance of resistance. Disease progression was further analyzed using the apparent infection rate (r) and area under the disease progress curve (AUDPC). The genotype NDLA-2 x NDI-51 exhibited the lowest AUDPC (108.88) and moderate resistance, while the check KBSH-44 recorded the highest AUDPC (822.9), indicating high susceptibility. The study successfully identified genotypes with moderate resistance and highlighted NDLA-2 x NDI-51 as a promising candidate for breeding programs aimed at developing leaf curl-resistant sunflower hybrids.

# **INTRODUCTION**

Sunflower is a significant contributor to global oilseed production, accounting for approximately 9% of the total and 3.85% of contribution to Indian oil seed production. In India, it is a rapidly growing oilseed crop, particularly in states like Karnataka, Andhra Pradesh, and Telangana, where it plays a crucial role in the agricultural economy. In the 2023–24 period, India produced 1.72 lakh tonnes of sunflower from 1.51 lakh hectares, yielding an average of 1144 kg per hectare.

However, sunflower cultivation in Andhra Pradesh faces substantial challenges due to various diseases, including leaf curl, powdery mildew, necrosis disease and Alternaria leaf spot. These diseases can lead to significant yield losses, ranging from 30% to 74% (Prakash *et al*., 2021). Specifically, in Andhra Pradesh, yield losses due to these diseases were reported to be as high as 43% during manifestation trials conducted from 2012 to 2015 under the All India Coordinated Research Project (AICRP) on Sunflower at the Regional Agricultural Research Station (RARS), Nandyal. (Venkataramanamma *et al*., 2016).

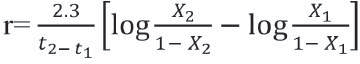
Leaf curl disease in sunflowers is a major problem and is caused by several factors, including viral infections and environmental stressors. Infected plants may exhibit yellowing (chlorosis), mottling, and overall reduced vigor and in severe infections it may lead to significant yield losses. Disease incidence recorded from 24.08 to 56.30%, highest incidence was recorded in Sunbreed-275 hybrid with 56.30% (Harsha Vardhini *et al.* 2023). As of now there is no complete resistance against leaf curl is available in cultivated sunflower or any related germplasm even though the differences in susceptibility exist. Early detection and appropriate management strategies are crucial for minimizing the impact of this disease on sunflower production. Breeding for resistance to leaf curl faces the challenge of a gene pool containing only moderate levels of resistance. There is a strong need to identify genotypes/hybrids resistant to leaf curl disease in sunflower.

# **MATERIAL AND METHODS**

The field experiment was conducted during rabi, 2024-25 at regional agricultural research station in Nandyal, Andhra Pradesh, India. The experimental material consists of 48 genotypes along with susceptible check KBSH -44 and moderately susceptible check NDSH-1012. Each genotype was evaluated in three replications in single row of length 3m with spacing of 60x30 cm. All the recommended agronomical practices were followed throughout the crop growing period. Leaf curl was assessed in each genotype as per the 0– 5 scale proposed by Gururaj Sunkad, *et al.,* (2002) (Table 1). Disease severity was recorded at 15 days interval starting from the appearance of disease symptoms *i.e.*, 30 DAS, 45 DAS (Days After Sowing), 60 DAS and 75 DAS and percent disease index (PDI) was evaluated by using below formula suggested by Vander Plank (1963).



The rate of disease development (r) at different intervals is calculated using the formula outlined by Van der Plank (1963):



Where:

* **r** = Apparent rate of infection or spread
* **X₁** = Percent disease index (PDI) at time t₁
* **X₂** = Percent disease index (PDI) at time t₂
* **t₂ - t₁** = Time interval in days between the consecutive observations

Additionally, the Area Under Disease Progress Curve (AUDPC) values were calculated using the PDI at 45, 60, and 75 days after sowing (DAS) for each genotype, employing the formula recommended by Wilcoxson et al. (1975):



Where:

* **Sᵢ** = Disease severity at the end of time i
* **k** = Number of successive evaluations
* **Tᵢ - Tᵢ-1** = Constant time interval (15 days)

# **RESULTS AND DISCUSSION**

The PDI values calculated at three intervals were utilized to perform an analysis of variance (ANOVA). The ANOVA revealed significant variations among the genotypes concerning their reaction to leaf curl disease at 30, 45, 60, and 75 DAS (Table 2). Phenotypic coefficient of variance (PCV) is observed slightly greater than Genotypic coefficient of variance (GCV). It implies that the influence of environment over the trait response of genotypes is very low. High heritability and genetic advance as a percentage of mean (GAM) indicate additive gene action, implying great potential for advancement through breeding selection. This indicates a substantial genetic diversity in disease resistance among the evaluated sunflower genotypes.

The PDI values at 30, 45, 60, 75 DAS are furnished in Table 3. After 75 DAS the results of the current investigation displayed that out of 48 genotypes, one genotype NDLA-2 x NDI- 51 showed moderate resistance. One genotype CMS 17A showed high susceptibility same as

the high susceptible check KBSH-44. 16 genotypes reported moderate susceptibility and 29 genotypes were found susceptible.

At 30 DAS, the disease symptoms were observed in only some of the evaluated genotypes. NDLA-2 (0.0) and CMS 17A (22.2%) showed lowest and highest PDI values among the female lines, respectively and among the male lines NDI-24, NDI-51, NDI-32, NDI-50, NDI-34 showed lowest PDI of 0.0 and AKSFI-78 showed highest PDI of 15.1%. Among 30 hybrids evaluated the lowest PDI value of 0.0 was observed in 15 hybrids whereas the hybrid CMS 17A x NDI-34 showed the highest PDI of 16.0%. Among checks PHT showed 0.0 PDI value and KBSH-44 exhibited highest PDI of 31.4% indicating susceptibility reaction to disease with score of 4 on 0-5 scale. Among all the genotypes, PDI values ranged from 0.0 to 31.8% with 6.13% mean value. Less PDI of 0.0% was noted in 21 genotypes whereas, highest PDI of 31.8% was noted in KBSH-

44. 25 genotypes demonstrated negative deviation from the mean value. In contrast 23 genotypes showed positive deviation from the mean value.

At 45 DAS, more disease incidence was observed in all entries compared with 30 DAS. NDLA-2 (12.4%) and CMS 17A (44.4%) showed lowest and highest PDI values among the female lines, respectively and among the male lines NDI-50 showed lowest PDI of 5.1% and NDI-49 showed highest PDI of 44.9%. Among 30 hybrids evaluated the lowest PDI value of 4.88% was observed in NDLA-2 x NDI-39 whereas the hybrid CMS 17A x NDI-49 showed the highest PDI of 29.67%. Among checks PHT showed 9.8% PDI and KBSH-44 exhibited highest PDI of 51.2% indicating high susceptibility to disease with score of 5 on 0-5 scale. Among all genotypes, PDI values ranged from 4.88% to 51.2%, with 16.89% mean value. 29 genotypes demonstrated greater negative deviation from the mean value. In contrast 19 genotypes showed positive deviation from the mean value.

At 60 DAS, more disease incidence was observed in all entries compared with 45 DAS. NDLA-2 (22.5%) and CMS 17A (44.4%) showed lowest and highest PDI values among the female lines, respectively and among the male lines NDI-50 showed lowest PDI of 16.3% and NDI-49 showed highest PDI of 44.95%. Among 30 hybrids evaluated the lowest PDI of 8.71% was observed in NDLA-2 x NDI-51 whereas the hybrid CMS 17A x AKSFI-78 showed the highest PDI of 42.27%. Among checks PHT showed 24.1% PDI and KBSH-44 exhibited highest PDI of 61.0% indicating high susceptibility to disease with score of 5 on 0-5 scale. Among all the genotypes evaluated PDI values ranged from 8.7% to 61.0% with 28.54% mean value. 26 genotypes demonstrated negative deviation from the mean value. In contrast

22 genotypes showed greater positive deviation from the mean value.

At 75 DAS, disease was observed in almost all genotypes. NDLA-2 (27.5%) and CMS 17A (55.6%) showed lowest and highest PDI values among the female lines, respectively and among the male lines NDI-50 showed lowest PDI of 16.3% and AKSFI-78 showed highest PDI of 48.5%. Among 30 hybrids evaluated the lowest PDI of 8.71% was observed in NDLA-2 x NDI-51 whereas the hybrid CMS 17A x AKSFI-78 showed the highest PDI of 46.43%. Among checks PHT showed 24.1% PDI and KBSH-44 exhibited highest PDI of 73.1% indicating high susceptibility to disease with score of 5 on 0-5 scale. Among all the genotypes evaluated PDI values ranged from 8.7% to 73.1% with 30.21% average. 28 genotypes showed negative deviation from the mean. In contrast 20 genotypes showed a positive deviation from the mean.

By analyzing the PDI scores obtained, we can conclude that there an increase in disease susceptibility of almost all genotypes from 30 DAS to 75 DAS. The similar results were obtained in the experiment conducted by Deepa *et al.* (2017) where there is an increased susceptibility of genotypes to leaf curl disease from 30 DAS to 90 DAS. Saddam (2016) conducted a study to examine seasonal incidence of leaf curl disease in sunflower and reported that PDI values were reaching up to 80% during the rabi season.

The apparent rate of infection ‘r’ value for leaf curl is summarized in Table 4 for three intervals i.e., between 30-45 DAS, 45-60 DAS and 60-75 DAS along with average rate of infection and AUDPC (Area Under Disease Progress Curve). Between 30-45 days interval among the female parental lines NDLA-2 showed no infection and IMS 265A showed high ‘r’ value of 0.007 and among male parental lines five lines doesn’t showed any infection and NDSI-3 showed high ‘r’ value of 0.009. Among 30 hybrids evaluated, 15 hybrids showed no infection where as nine hybrids showed zero ‘r’ value and hybrid NDLA-2 x NDI-34 showed high ‘r’ value of 0.029. And among checks PHT showed no infection where as TNTSH-1 showed high ‘r’ value of 0.03. Between 45-60 days interval among the female parental lines CMS 17A showed zero ‘r’ value and NDLA-2 showed high ‘r’ value of 0.003 and among 10 male parental lines two lines showed zero ‘r’ value and NDI-50 showed high ‘r’ value of 0.01. Among 30 hybrids evaluated 7 hybrids showed no infection zero ‘r’ value and hybrid NDLA-2 x NDI-39 showed high ‘r’ value of 0.01. And among checks KBSH-44 showed zero ‘r’ value where as PHT showed high ‘r’ value of 0.004. Between 60-75 days interval among the female parental lines IMS 265A and CMS 17A showed zero ‘r’ value whereas NDLA-2 showed high ‘r’ value of 0.001 and among male parental lines nine lines showed zero ‘r’ value and NDSI-3 showed high ‘r’ value of 0.01. Among 30 hybrids evaluated, 28 hybrids showed zero ‘r’ value and hybrids CMS 17A x NDI-24, NDLA-2 x NDI-24 showed high ‘r’ value of 0.001. And all checks showed zero ‘r’ value.

The average ‘r’ values ranged from 0.00 (IMS 265A x NDI-50, CMS 17A x NDI- 32, CMS 17A x NDI-50, NDLA-2 x NDI-51, NDLA-2 x RHA-1055 and NDLA-2 X NDI-50) to 0.011 (NDLA-2 x NDI-34 and TNTSH-1). The genotypes NDI-50, NDLA-2 x

NDI-39 and NDLA-2 x AKSFI-78 exhibited ‘r’ value of 0.005 and NDSI-3 exhibited ‘r’ value of 0.004. Even though these genotypes exhibited higher rate of disease spread, the disease severity was low in contrast to other genotypes lines with lower ‘r’ value and high initial disease infection. In CMS 17A and KBSH-44, high early- stage disease development in combination with low ‘r’ value shows late spread of disease. High early-stage disease infection coupled with higher ‘r’ value is identified in all highly susceptible genotypes. These findings demonstrated that a low apparent infection rate does not always reflect a genotype’s resistance to disease. While the 'r' value alone may not be a reliable indicator of resistance, it can still serve as a useful tool for analyzing disease progression across different genotypes and it was detailed by Wilcoxson *et al.* (1975) he emphasized that while 'r' measures the speed of disease spread, it must not be used alone to declare a genotype resistant. Nargund (1989) reported that apparent infection rate (r) should be integrated with AUDPC for accurate disease progression analysis and Reddy *et al*. (2023) also stated that low 'r' value alone cannot indicate the genotypes resistance to disease in their experiment, field screening of sunflower genotypes for powdery mildew disease resistance.

The AUDPC was derived for each genotype using the PDI values obtained and represented in Table 4. AUDPC values were used to compare the rates of disease progression amongst genotypes. Among female parental lines AUDPC values were in range of 243.04 (NDLA-2) to 638.85 (CMS 17A) and among male parental lines AUDPC values were in range of 148.09 (NDI-50) to 598.43 (NDI-49). Among hybrids the AUDPC values ranged from 108.88 (NDLA-2 x NDI-51) to 504 (CMS 17A x NDI-49). Among checks the AUDPC values ranged from 229.74 (PHT) to 855.9 (KBSH-44). Among all genotypes NDLA-2 x NDI-51 showed least AUDPC value of 108.88 and KBSH- 44 exhibited highest AUDPC value of 822.9. The mean value of AUDPC is 315.45. Genotypes with low AUDPC values develop disease at a slower rate than genotypes with high AUDPC values. So, with the results obtained we can conclude that NDLA-2 x NDI-51 developed disease at slower rate whereas KBSH-44 developed disease at faster rate compared to all other genotypes.

The categorization of genotypes based on DIS (Disease Index Scale) value is summarized in (Table 5), which revealed that there was no clear correlation between Disease Index Scale (DIS) values and the apparent infection rate ('r'), suggesting that relying solely on the 'r' value may not provide an accurate assessment of disease resistance. From the table, we observe that no genotypes fall into the “Highly resistant” (DIS 0) or “Resistant” (DIS 1) categories thus, no ‘r’ values are associated with these categories. A single genotype is categorized as “Moderately resistant” (DIS 2) with an ‘r’ value of 0.00 this also aligns well, as here ‘r’ value is very low. The “Moderately susceptible” (DIS 3) and “Susceptible” (DIS 4) categories show overlapping and indistinguishable ‘r’ value ranges 0.0 – 0.011 and 0.0–0.0107, respectively. This overlap suggests that even as the DIS moves from 3 to 4 (indicating more disease severity), the ‘r’ values do not clearly increase. In the “Highly susceptible” category (DIS 5), the ‘r’ values (0.00033 and 0.00067) are low. These values are lower than many observed in the “Moderately susceptible” and “Susceptible” categories, contradicting the expectation that higher DIS values should correspond to higher ‘r’ values. The similar results were obtained for Reddy *et al*. (2023), in a field experiment conducted to screen powdery mildew disease in sunflower and results obtained showed the variability of AUDPC values and the complex relationship between DIS and 'r' values.

# **CONCLUSION**

The evaluation of sunflower genotypes for resistance to leaf curl disease revealed significant genetic variability in disease reaction. PDI values consistently increased from 30 to 75 DAS, indicating progressive disease development. Among the evaluated genotypes, NDLA-2 x NDI-51 emerged as a moderately resistant hybrid, with the lowest AUDPC and favorable disease progression characteristics. The apparent infection rate (r) was found to be an inconsistent indicator of resistance, reinforcing the need to interpret it alongside PDI and AUDPC values. The moderate heritability and genetic advance estimates suggest that resistance to leaf curl disease is governed by additive gene action, making it amenable to improvement through selection. Genotypes like NDLA-2 x NDI- 51 can serve as valuable donors in breeding programs targeting the development of high-yielding, disease-tolerant sunflower hybrids. The integration of resistant genotypes into cultivation practices is essential for enhancing sunflower productivity and sustainability in.

**REFERENCES**

Deepa & Gururaj Sunkad. (2017). Identification of Resistance Sources for Sunflower Leaf Curl Virus Disease Caused by Begomovirus. *International Journal of Current Microbiology and Applied Sciences,* 6(10), 3226-3230.

Deepa, D., Gururaj Sunkad, G.S., Govindappa, M.R., Naik, M.K. & Suresh, S.R. (2015). Estimation of yield loss in sunflower due to new sunflower leaf curl virus disease at different stages of crop growth. *International Journal of Plant Protection*, 8, 138-141.

Deepa, M., Anjanappa, M., & Bindu, J.S. (2015). Assessment of crop losses due to sunflower leaf curl virus (SuLCV) disease. *Journal of Oilseeds Research*, 32(2), 123–127.

Deepa, M., Anjanappa, M., & Bindu, J.S. (2017). Biochemical changes in sunflower hybrids infected with leaf curl virus. *Journal of Oilseeds Research*, 34(2), 142–145.

Deepa, M., Anjanappa, M., & Bindu, J.S. (2017). Screening of sunflower hybrids for resistance to sunflower leaf curl virus. *Journal of Oilseeds Research*, 34(1), 75–79.

Ghante, V.N., Sunkad, G., & Naik, M.I. (2020). Population dynamics of whiteflies in sunflower and their correlation with weather parameters. *Karnataka Journal of Agricultural Sciences*, 33(4), 519–523.

Govindappa, M.R., Sunkad, G., & Sreenivas, A.G. (2011). First report of sunflower leaf curl virus in Karnataka, India. *Indian Phytopathology*, 64(3), 342–343.

Gururaj Sunkad, G., Naik, M.I., & Patil, M.S. (2002). Development of scale for disease incidence of sunflower leaf curl virus. *Karnataka Journal of Agricultural Sciences*, 15(2), 221–223.

Harsha Vardhini, B., Venkataramanamma, M., & Sreenivasulu, K. (2023). Survey on sunflower leaf curl virus disease in Andhra Pradesh and Karnataka. *Journal of Oilseeds Research*, 40(1), 65–70.

Kulkarni, R., Venkataramanamma, M., & Basavarajappa, R. (2023). Assessment of sunflower leaf curl disease severity in selected districts of North Eastern Karnataka. *Karnataka Journal of Agricultural Sciences*, 36(1), 101–106.

Nargund, V. B. (1989). Epidemology & control of leaf rust of wheat caused by Puccinia recondite f. Sp. tritici Rob. Ex. Desm. Ph.D. Thesis submitted to University of Agricultural Sciences, Dharwad, Karnataka.

Prakash, V., Gaur, A & Chauhan, A. (2021). Sunflower: head rot, rust and powdery mildew.Diseases of Nationally Important Field Crops, 30(100), 491-500.

Reddy, Y.P.K., Reddy, B.V.R.P., Ramanamma, K.V & Shanthi, P. (2024). Field screening for powdery mildew disease resistance in sunflower (*Helianthus annuus* L.) genotypes. *The Journal of Research ANGRAU,* 52(2), 148-153.

Saddam, H. 2016. Seasonal Incidence and Transmission of Leaf Curl Virus by Whitefly, *Bemisia tabaci* in Sunflowe*r* (*Doctoral dissertation, University of Agricultural Sciences, Raichur*).

Saddam, M. (2016). Studies on seasonal incidence of whitefly and sunflower leaf curl virus transmission. *M.Sc. Thesis*, University of Agricultural Sciences, Raichur.

Sudha, P. (2018). Study On Diversity of Leaf Curl Viruses and Their Vectors in Major Crops (*Doctoral dissertation, University of Agricultural Sciences, Raichur*).

Sunkad, G., Govindappa, M.R & Naik, M.K. (2014). Management of new sunflower leaf curl virus disease caused by Begomovirus. *Trends in Biosciences*, *7*(16), 2127-2131.

Sunkad, G., Patil, R. B., & Nadaf, H. L. (2002). Reaction of sunflower genotypes to sunflower leaf curl virus disease. *Helia*, 25(36), 135–140.

Vanitha, P. (2013). Incidence and distribution of sunflower leaf curl virus in Karnataka. *M.Sc. Thesis*, University of Agricultural Sciences, Raichur.

Venkaramanamma, K & Sujatha, M. (2023). Survey for Sunflower Leaf Curl Disease Incidence in Andhra Pradesh and Karnataka. *Andhra Pradesh Journal of Agricultural Sciences,* 9(3), 214-218.

Venkataramanamma, K & Prabhakar, K. (2020). Field evaluation of coordinated entries of sunflower for important diseases. *Andhra Pradesh Journal of Agricultural Sciences*, 6(2), 106-110.

Venkataramanamma, K., Neelima, S., Prabhakar, K. & Lakshmi Kalyani, D. (2022). Management of leaf curl disease of sunflower under field conditions. *Agricultural Research Journal*, *59*(3), 447-52.

Venkataramanamma, K., Venkataravanappa, V., Prabhakar, K., Reddy, B.R.P., Sri, P.A. & Venkateswarlu, N. (2024). Survey and molecular characterization of begomovirus, and assessment of yield losses caused by leaf curl disease of sunflower (*Helianthus annuus*). *The Indian Journal of Agricultural Sciences*, *94*(11), 1226-1233.

Venkataramanamma, M., Harsha Vardhini, B., & Bindu, J.S. (2022). Management of whitefly transmitted leaf curl virus in sunflower using seed and foliar insecticide treatments. *Journal of Oilseeds Research*, 39(1), 63–68.

Venkataramanamma, M., Harsha Vardhini, B., & Vindyashree, R. (2024). Incidence and molecular identification of sunflower leaf curl virus in Andhra Pradesh. *Indian Journal of Virology*, 34(1), 34–41.

Venkataramanamma, M., Naik, M.I., & Sunkad, G. (2020). Screening of sunflower lines for resistance to sunflower leaf curl virus. *International Journal of Plant Protection*, 13(1), 78–81.

Vidhyashree, R., Naik, M.I., & Sunkad, G. (2016). Field survey of sunflower leaf curl disease in North Eastern Karnataka. *Plant Disease Research*, 31(2), 179–181.

Vindyashree, M., Govindappa, M.R. & Aswathanarayana, D.S. (2018). Virus-vector relationship of sunflower Leaf Curl Virus (SuLCV) in relation to disease spread. *International Journal of Innovative Research and Advanced Studies, 5*, 21-25.

Vindyashree, R., Naik, M.I., & Sunkad, G. (2018). Transmission dynamics of sunflower leaf curl virus by whitefly. *Indian Journal of Plant Protection*, 46(1), 52–56.

Wilcoxson, R.D., Skovmand, B & Atif, A.A. 1975. Evaluation of wheat cultivars for the ability to retard development of stem rust. *Annals of Applied Biology*, 80, 275–287.

**Table 1. Based on disease incidence, the entries were categorized by following 0-5 scale (Gururaj Sunkad, et al., 2002)**

|  |  |  |
| --- | --- | --- |
| **Score** | **Disease reaction** | **Disease incidence (% average)** |
| 0 | I/HR (Immune/Highly resistant) | No infection or 0% to 1% |
| 1 | R (Resistant) | 1.1 to 5% |
| 2 | MR (Moderately susceptible) | 5.1 to 10% |
| 3 | MS (Moderately susceptible) | 10.1 to 25% |
| 4 | S (Susceptible) | 25.1 to 50% |
| 5 | HS (Highly susceptible) | Above 50% |

**Table 2. Analysis of variance for PDI at different stages**

**PDI at**

**different growth Mean Sum SE CD Heritability**

**stages of Squares Mean CV (m) (5%) (bs) PCV GCV GAM**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Treatment** | **Error** |  | | | | | | | |
| **PDI@30 DAS** | 111.13\*\* | 0.71 | 6.13 | 13.73 | 0.59 | 1.69 | 0.99 | 121.5 | 121.2 | 248.80 |
| **PDI@45 DAS** | 226.78\*\* | 3.41 | 16.89 | 10.93 | 1.29 | 3.71 | 0.99 | 63.10 | 62.59 | 127.96 |
| **PDI@60 DAS** | 247.86\*\* | 8.28 | 28.54 | 10.08 | 2.01 | 5.79 | 0.97 | 39.01 | 38.35 | 77.68 |
| **PDI@75 DAS** | 332.02\*\* | 9.12 | 30.21 | 10.00 | 2.1 | 6.08 | 0.97 | 42.65 | 42.06 | 85.45 |

\* and \*\* significant at 5% and 1% LOS, respectively. bs= broad sense.

**Table 3. Percent disease index of Leaf curl disease at different growth stages**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sl.**  **No.** | **Genotypes** | **30 days** | | | **45 days** | | | **60 days** | | | **75 days** | | |
| **PDI** | **Score on 0-5 scale** | **Host Reacti on** | **PDI** | **Score on 0-5 scale** | **Host React ion** | **PDI** | **Score on 0-5 scale** | **Host Reacti on** | **PDI** | **Score on 0-5 scale** | **Host Reacti on** |
|  | **Female parents** |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | IMS 265 A | 6.85 | 2 | MR | 21.83 | 3 | MS | 28.20 | 4 | S | 28.20 | 4 | S |
| 2 | CMS 17 A | 22.22 | 3 | MS | 44.44 | 4 | S | 44.40 | 4 | S | 55.60 | 5 | HS |
| 3 | NDLA 2 | 0.00 | 0 | HR | 12.37 | 3 | MS | 22.50 | 3 | MS | 27.50 | 4 | S |
|  | **Male parents** |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | NDI-24 | 0.00 | 0 | HR | 19.09 | 3 | MS | 28.60 | 4 | S | 28.60 | 4 | S |
| 2 | NDSI-3 | 5.57 | 2 | MR | 16.72 | 3 | MS | 24.90 | 3 | MS | 30.50 | 4 | S |
| 3 | NDI-39 | 11.69 | 3 | MS | 27.92 | 4 | S | 44.20 | 4 | S | 44.20 | 4 | S |
| 4 | NDI-51 | 0.00 | 0 | HR | 9.43 | 2 | MR | 18.90 | 3 | MS | 18.90 | 3 | MS |
| 5 | NDI-49 | 14.65 | 3 | MS | 44.95 | 4 | S | 44.90 | 4 | S | 44.90 | 4 | S |
| 6 | RHA-1055 | 12.13 | 3 | MS | 23.61 | 3 | MS | 33.50 | 4 | S | 42.50 | 4 | S |
| 7 | NDI-32 | 0.00 | 0 | HR | 21.54 | 3 | MS | 39.20 | 4 | S | 39.20 | 4 | S |
| 8 | NDI-50 | 0.00 | 0 | HR | 5.13 | 2 | MR | 16.30 | 3 | MS | 16.30 | 3 | MS |
| 9 | AKSFI-78 | 15.08 | 3 | MS | 33.27 | 4 | S | 42.50 | 4 | S | 48.50 | 4 | S |
| 10 | NDI-34 | 0.00 | 0 | HR | 14.36 | 3 | MS | 28.70 | 4 | S | 28.70 | 4 | S |
|  | **Crosses** |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | IMS 265A X NDI-24 | 0.00 | 0 | HR | 15.48 | 3 | MS | 28.18 | 4 | S | 28.18 | 4 | S |
| 2 | IMS 265A X NDSI-3 | 6.93 | 2 | MR | 6.93 | 1 | R | 25.54 | 4 | S | 25.54 | 4 | S |
| 3 | IMS 265A X NDI-39 | 6.46 | 2 | MR | 6.46 | 1 | R | 33.48 | 4 | S | 33.48 | 4 | S |
| 4 | IMS 265A X NDI-51 | 0.00 | 0 | HR | 8.33 | 2 | MR | 16.67 | 3 | MS | 16.67 | 3 | MS |
| 5 | IMS 265A X NDI-49 | 10.80 | 3 | MS | 10.80 | 3 | MS | 36.93 | 4 | S | 36.93 | 4 | S |
| 6 | IMS 265A X RHA-1055 | 8.83 | 2 | MR | 8.83 | 1 | R | 33.65 | 4 | S | 33.65 | 4 | S |
| 7 | IMS 265A X NDI-32 | 0.00 | 0 | HR | 17.42 | 3 | MS | 20.63 | 3 | MS | 20.63 | 3 | MS |
| 8 | IMS 265A X NDI-50 | 0.00 | 0 | HR | 13.39 | 3 | MS | 13.39 | 3 | MS | 13.39 | 3 | MS |
| 9 | IMS 265A X AKSFI-78 | 9.43 | 2 | MR | 9.43 | 2 | MR | 25.66 | 4 | S | 25.66 | 4 | S |
| 10 | IMS 265A X NDI-34 | 6.35 | 2 | MR | 6.35 | 2 | MR | 28.18 | 4 | S | 29.18 | 4 | S |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 11 | CMS 17A X NDI-24 | 6.27 | 2 | MR | 20.86 | 3 | MS | 30.99 | 4 | S | 40.59 | 4 | S |
| 12 | CMS 17A X NDSI-3 | 0.00 | 0 | HR | 9.09 | 2 | MR | 33.57 | 4 | S | 33.57 | 4 | S |
| 13 | CMS 17A X NDI-39 | 10.05 | 2 | MR | 10.05 | 2 | MR | 41.43 | 4 | S | 41.43 | 4 | S |
| 14 | CMS 17A X NDI-51 | 0.00 | 0 | HR | 14.58 | 3 | MS | 21.83 | 3 | MS | 21.83 | 3 | MS |
| 15 | CMS 17A X NDI-49 | 15.48 | 3 | MS | 29.67 | 4 | S | 42.26 | 4 | S | 42.26 | 4 | S |
| 16 | CMS 17A X RHA-1055 | 14.36 | 3 | MS | 14.36 | 2 | MR | 34.85 | 4 | S | 34.85 | 4 | S |
| 17 | CMS 17A X NDI-32 | 0.00 | 0 | HR | 21.11 | 3 | MS | 21.11 | 3 | MS | 21.11 | 3 | MS |
| 18 | CMS 17A X NDI-50 | 0.00 | 0 | HR | 28.57 | 4 | S | 28.57 | 4 | S | 28.57 | 4 | S |
| 19 | CMS 17A X AKSFI-78 | 15.50 | 3 | MS | 25.83 | 4 | S | 42.27 | 4 | S | 46.43 | 4 | S |
| 20 | CMS 17A X NDI-34 | 16.02 | 3 | MS | 16.02 | 3 | MS | 40.07 | 4 | S | 40.07 | 4 | S |
| 21 | NDLA-2 X NDI-24 | 0.00 | 0 | HR | 11.58 | 3 | MS | 16.24 | 3 | MS | 23.27 | 3 | MS |
| 22 | NDLA-2 X NDSI-3 | 0.00 | 0 | HR | 7.12 | 2 | MR | 12.08 | 3 | MS | 12.08 | 3 | MS |
| 23 | NDLA-2 X NDI-39 | 0.00 | 0 | HR | 4.88 | 1 | R | 13.40 | 3 | MS | 13.40 | 3 | MS |
| 24 | NDLA-2 X NDI-51 | 0.00 | 0 | HR | 8.71 | 2 | MR | 8.71 | 2 | MR | 8.71 | 2 | MR |
| 25 | NDLA-2 X NDI-49 | 7.18 | 2 | MR | 9.31 | 2 | MR | 26.80 | 3 | MS | 26.80 | 4 | S |
| 26 | NDLA-2 X RHA-1055 | 0.00 | 0 | HR | 14.17 | 3 | MS | 14.17 | 3 | MS | 14.17 | 3 | MS |
| 27 | NDLA-2 X NDI-32 | 6.79 | 2 | MR | 17.15 | 3 | MS | 17.15 | 3 | MS | 17.15 | 3 | MS |
| 28 | NDLA-2 X NDI-50 | 0.00 | 0 | HR | 16.73 | 3 | MS | 18.86 | 3 | MS | 18.86 | 3 | MS |
| 29 | NDLA-2 X AKSFI-78 | 0.00 | 0 | HR | 5.21 | 2 | MR | 14.17 | 3 | MS | 14.17 | 3 | MS |
| 30 | NDLA-2 X NDI-34 | 2.38 | 1 | R | 9.17 | 2 | MR | 24.41 | 3 | MS | 24.41 | 3 | MS |
|  | **Checks** |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 | NDSH-1012 | 20.89 | 3 | MS | 28.6 | 4 | S | 41.9 | 4 | S | 48.8 | 4 | S |
| 2 | KBSH-44 | 31.79 | 4 | S | 51.2 | 5 | HS | 61.0 | 5 | HS | 73.1 | 5 | HS |
| 3 | KBSH-78 | 8.25 | 2 | MR | 12.9 | 3 | MS | 35.8 | 4 | S | 35.8 | 4 | S |
| 4 | TNTSH-1 | 2.50 | 1 | R | 15.8 | 3 | MS | 25.0 | 3 | MS | 27.5 | 4 | S |
| 5 | PHT | 0.00 | 0 | HR | 9.8 | 2 | MR | 24.1 | 3 | MS | 24.1 | 3 | MS |

HR= highly resistant, R= resistant, MR= moderately resistant, S= susceptible, HS=highly susceptible

**Table 4. Apparent rate of infection “r” values and AUDPC values for leaf curl resistance in sunflower genotypes**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Sl.**  **No.** | **Genotypes** | **30 to 45 days** | **45 to 60 days ‘r’** | **60 to 75 days ‘r’** | **Average ‘r’** | **AUDPC** |
|  | **Female parents** |  |  |  |  |  |
| 1 | IMS 265 A | 0.007 | 0.001 | 0.000 | 0.002667 | 337.56 |
| 2 | CMS 17 A | 0.002 | 0.000 | 0.000 | 0.000667 | 638.85 |
| 3 | NDLA 2 | - | 0.003 | 0.001 | 0.002000 | 243.04 |
|  | **Male parents** |  |  |  |  |  |
| 1 | NDI-24 | - | 0.001 | 0.000 | 0.000500 | 310.21 |
| 2 | NDSI-3 | 0.009 | 0.001 | 0.001 | 0.003667 | 298.4 |
| 3 | NDI-39 | 0.004 | 0.001 | 0.000 | 0.001667 | 499.99 |
| 4 | NDI-51 | - | 0.004 | 0.000 | 0.002000 | 188.58 |
| 5 | NDI-49 | 0.003 | 0.000 | 0.000 | 0.001000 | 598.43 |
| 6 | RHA-1055 | 0.003 | 0.001 | 0.000 | 0.001333 | 421.81 |
| 7 | NDI-32 | - | 0.001 | 0.000 | 0.000500 | 401.9 |
| 8 | NDI-50 | - | 0.010 | 0.000 | 0.005000 | 148.09 |
| 9 | AKSFI-78 | 0.003 | 0.000 | 0.000 | 0.001000 | 537.68 |
| 10 | NDI-34 | - | 0.002 | 0.000 | 0.001000 | 287.18 |
|  | **Crosses** |  |  |  |  |  |
| 1 | IMS 265A X NDI-24 | - | 0.002 | 0.000 | 0.001000 | 288.71 |
| 2 | IMS 265A X NDSI-3 | 0.000 | 0.008 | 0.000 | 0.002667 | 243.49 |
| 3 | IMS 265A X NDI-39 | 0.000 | 0.009 | 0.000 | 0.003000 | 299.55 |
| 4 | IMS 265A X NDI-51 | - | 0.004 | 0.000 | 0.002000 | 166.68 |
| 5 | IMS 265A X NDI-49 | 0.000 | 0.005 | 0.000 | 0.001667 | 357.94 |
| 6 | IMS 265A X RHA-1055 | 0.000 | 0.006 | 0.000 | 0.002000 | 318.56 |
| 7 | IMS 265A X NDI-32 | - | 0.001 | 0.000 | 0.000500 | 241.83 |
| 8 | IMS 265A X NDI-50 | - | 0.000 | 0.000 | 0.000000 | 167.38 |
| 9 | IMS 265A X AKSFI-78 | 0.000 | 0.005 | 0.000 | 0.001667 | 263.14 |
| 10 | IMS 265A X NDI-34 | 0.000 | 0.009 | 0.000 | 0.003000 | 261.44 |
| 11 | CMS 17A X NDI-24 | 0.008 | 0.001 | 0.001 | 0.003333 | 376.35 |
| 12 | CMS 17A X NDSI-3 | - | 0.006 | 0.000 | 0.003000 | 297.19 |
| 13 | CMS 17A X NDI-39 | 0.000 | 0.005 | 0.000 | 0.001667 | 386.03 |
| 14 | CMS 17A X NDI-51 | - | 0.002 | 0.000 | 0.001000 | 236.59 |
| 15 | CMS 17A X NDI-49 | 0.002 | 0.001 | 0.000 | 0.001000 | 504 |
| 16 | CMS 17A X RHA-1055 | 0.000 | 0.003 | 0.000 | 0.001000 | 369 |
| 17 | CMS 17A X NDI-32 | - | 0.000 | 0.000 | 0.000000 | 263.88 |
| 18 | CMS 17A X NDI-50 | - | 0.000 | 0.000 | 0.000000 | 357.13 |
| 19 | CMS 17A X AKSFI-78 | 0.002 | 0.001 | 0.000 | 0.001000 | 495.29 |
| 20 | CMS 17A X NDI-34 | 0.000 | 0.003 | 0.000 | 0.001000 | 420.64 |
| 21 | NDLA-2 X NDI-24 | - | 0.002 | 0.001 | 0.001500 | 197.23 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 22 | NDLA-2 X NDSI-3 | - | 0.004 | 0.000 | 0.002000 | 126.16 |
| 23 | NDLA-2 X NDI-39 | - | 0.010 | 0.000 | 0.005000 | 124.86 |
| 24 | NDLA-2 X NDI-51 | - | 0.000 | 0.000 | 0.000000 | 108.88 |
| 25 | NDLA-2 X NDI-49 | 0.002 | 0.005 | 0.000 | 0.002333 | 265.43 |
| 26 | NDLA-2 X RHA-1055 | - | 0.000 | 0.000 | 0.000000 | 177.06 |
| 27 | NDLA-2 X NDI-32 | 0.007 | 0.000 | 0.000 | 0.002333 | 231.34 |
| 28 | NDLA-2 X NDI-50 | - | 0.000 | 0.000 | 0.000000 | 225.08 |
| 29 | NDLA-2 X AKSFI-78 | - | 0.009 | 0.000 | 0.004500 | 132.29 |
| 30 | NDLA-2 X NDI-34 | 0.029 | 0.005 | 0.000 | 0.011333 | 234.81 |
|  | **Checks** |  |  |  |  |  |
| 1 | NDSH-1012 | 0.001 | 0.001 | 0.000 | 0.000667 | 526.88 |
| 2 | KBSH-44 | 0.001 | 0.000 | 0.000 | 0.000333 | 822.9 |
| 3 | KBSH-78 | 0.003 | 0.003 | 0.000 | 0.002000 | 353.89 |
| 4 | TNTSH-1 | 0.030 | 0.002 | 0.000 | 0.010667 | 279.15 |
| 5 | PHT | - | 0.004 | 0.000 | 0.002000 | 229.74 |

**Table 5. Categorization of the sunflower genotypes for leaf curl resistance.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Disease Reaction** | **Disease Index Scale** | **No. of genotypes** | **Range of ‘r’ values** |
| Highly resistant | 0 | Nil | - |
| Resistant | 1 | Nil | - |
| Moderately resistant | 2 | 1 | 0.00 |
| Moderately susceptible | 3 | 16 | 0.0-0.011 |
| Susceptible | 4 | 29 | 0.0-0.0107 |
| Highly susceptible | 5 | 2 | 0.00033 & 0.00067 |