Original Research Article

Simultaneous Selection in Groundnut Genotypes

**Simultaneous selection for stable disease resistant high yielding groundnut genotypes**

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**Novelty statement**

This is the first attempt for simultaneous selection for mean performance, yield stability and leaf spot disease resistance in groundnut. The study revealed the role of weather parameters in the expression of leaf spot disease. Pod yield and disease score showed significant GEI effects in groundnut. K 1789, Kadiri 9 and TCGS 1097 were identified with maximum stable pod yield and less disease under high rainfall areas.

**ABSTRACT**

This is the first attempt in groundnut to study simultaneously the role of weather, AMMI stability for pod yield and disease resistance. Thirteen best performing genotypes were evaluated for yield, leaf spot resistance and other agronomic traits during three consecutive years. This study helped in understanding the role of temperature and relative humidity in the increased expression of leaf spots and in turn reduction in pod yields. It also revealed that genotypes were highly influenced by the environment for pod yields while genotypes contributed more variation for disease score. Genotype Environment Interaction (GEI) had a significant role for both pod yield and disease score. Simultaneous selection for high yield, yield stability, disease resistance and disease stability was best achieved when more weights were assigned to pod yield and diseasescore followed by yield stability and least weight to disease stability in the selection index. The best performing groundnut genotypes identified in the present study for high rainfall areas were K 1789, Kadiri 9 and TCGS 1097.

**Key words:** AMMI, Groundnut, Leaf spot, Selection index, Simultaneous selection, Stability.

**Introduction**

Groundnut (*Arachis hypogaea* L.) is the predominant oil seed crop grown in Southern India. The area under this crop is fluctuating since cost of cultivation is high and yields are unpredictable especially in the areas which receive high rainfall. Hence, farmers are slowly shifting to other remunerative crops like maize leading decreased area under groundnut cultivation in high rainfall areas like North Coastal Andhra Pradesh, India. The low pod yields of groundnut in high rainfall areas may be because of basal stem elongation. Pegs formed at basal node have more chances of penetration into the soil and thus forming fully matured pods compared to those at other nodes. When the basal stem itself elongates, the distance from the soil to the pegs formed at basal stem also increase and thus resulting in reduced pod yields in groundnut. Further, high rainfall leads to increased humidity which is much congenial for the occurrence of tikka leaf spot which in turn reduces yields upto 50% (Khedikar *et al*. 2010). Development of genotypes suitable for *Kharif* or summer-rainy season in high rainfall areas is a major challenging task and so far all the varieties released in India are mostly suited for *Rabi* or dryseason in medium to high rainfall areas. Identification of high yielding, disease resistant and stable genotypes for high rainfall areas plays a crucial role in sustaining the groundnut cultivation in high rainfall areas receiving more than 1000mm annual rainfall.

**Materials and Methods**

The best performing thirteen groundnut entries which proved to be promising at other research stations were collected for re-evaluation at Agricultural Research Station, Vizianagaram, Andhra Pradesh, India to find out the suitability and adaptability to the region which receives an annual rainfall of 1100mm. This location witnesses both, early leaf spot caused by *Cercospora arachidicola* and late leaf spot caused by *Cercosporidium personatum* regularly during *kharif* season. The experiment was conducted during three consecutive *kharif* seasons (rainy season of 2015, 2016 and 2017).Genotypes were grown in six rows of five meter length in a randomized complete block design with three replications. All standard practices were followed except for control of leaf spot disease so that the role of the environment on natural occurrence of disease and in turn its effect on yield can be studied. All the weather parameters were recorded in the station. Disease score for early and late leaf spot were calculated at 60 and 90 days after sowing as percent disease index (PDI).

$$PDI=\frac{Number of diseased plants}{Total Number of plants}$$

Association analysis was performed using SPSS (v16). Combined analysis was performed in RStudio (RStudio, 2020) after testing the error variance for homogeneity. AMMI stability analysis, AMMI Stability Values (ASV) and simultaneous selection for high yield, yield stability, disease resistance and disease stability were calculated using R (Onofriand [Ciriciofolo](https://www.researchgate.net/scientific-contributions/E-Ciriciofolo-2092672663?_sg%5B0%5D=-Uz1SnmHzZNmL5KRFadj9lhD13UiiYPIKX8-0LDwQbZxZDtzf1hXRUMkfQ3QXFZMM7t5d_0.4sBym8OZEnUH8uUDseiafNa0xQ6GyD3wRLHqxsrIZVhzEcE8lvA3BZYOrgNLnF4m5vDUalw1441Vc2KUzOMoCQ&_sg%5B1%5D=2mYWa6FRXcuBj9b8Qo5xuOaG7aT8-2R4ij2Qgj_HgWoGWo1nu_wt3ShBkyiQLVicdRYfz3M.rS4eUw3_NkXNY2uQbS4krWrZZv7Rh4VwB3JDFR-W3TuyRPGL5QGg-hlwV6oLRX5-3TgN3CZj1m1snWWLmJn1eg)*,*Ciriciofolo, 2007) with little modification for simultaneous selection. Though disease score was recorded for both early and late leaf spot, the later was considered to assess the role of genotype-by-environment interaction (GEI) for disease occurrence and stability in expression of resistance or susceptibility by different genotypes. In general early and late leaf spots are highly correlated and late leaf spot is considered to be more aggressive than early leaf spot causing heavy defoliation of leaves leading to losses in pod yield(http://osufacts.okstate. edu). The AMMI analysis was conducted only after observing more than 70% GEI signal for both traits in the pooled ANOVA, since the interpretation of AMMI results holds good only when there is a strong signal for GE interaction otherwise noise may be misunderstood as signal which leads to wrong interpretations (Gauch, 2013).

Stability for yield indicates consistent performance of genotypes, whether the genotype may be high yielding or low yielding similarly for disease, stability for disease implies consistent reaction of a genotype towards a virulent pathogen. It may show resistant or susceptible reaction but always the same. ASV was considered for calculation of simultaneous selection index because the model obtained was AMMI2 and ASV gives weighted values to principal components (PCs) based on their contribution to GEI (Purchase *et al.* 2000). The extended formula of (Rao and Prabhakaran, 2005) including disease score and stability for disease was used to identify better performing groundnut genotypes for high rainfall areas. The criteria is that a desirable genotype is the one which has high pod bearing ability along with high stability for yield, strong resistant reaction towards the disease and high stability for low/no disease.

$$I\_{i}=α\frac{\overbar{PY\_{i...}}}{\overbar{PY}…}+β\frac{\frac{1}{ASV\_{PY\_{i}}}}{\frac{1}{g}\sum\_{1}^{g}\frac{1}{ASV\_{PY\_{i}}}}+γ\frac{\frac{1}{\overline{DS\_{i...}}}}{\frac{1}{\overline{DS\_{...}}}}+δ\frac{\frac{1}{ASV\_{DS\_{i}}}}{\frac{1}{g}\sum\_{1}^{g}\frac{1}{ASV\_{DS\_{i}}}}$$

Where

Ii= Index of the *ith* genotype.

$\overline{PY\_{i...}}$ = is the average pod yield of the *ith* genotype during three years of testing

$\overbar{PY}…$*=* the overall mean of pod yield,

$ASV\_{PY\_{i}}$ *=*AMMI Stability Value of *ith*genotype for Pod Yield

*g=* Number of genotypes

$\overline{DS\_{i...}}$*=* is the average disease score of the *ith* genotype during three years of testing

$\overline{DS\_{...}}$*=* the overall mean of disease score

$ASV\_{DS\_{i}}$*=* AMMI Stability Value *of ith*genotype for Disease

α, β, ϒ and δ are the weights attached to pod yield, pod yield stability, disease score and disease score stability to arrive at an index of a genotype. Ranking of genotypes was based on the index score it attained among 13 genotypes studied.

Simultaneous selection analysis was conducted using different combinations giving different weights to different parameters, starting from equal weight to biased weight and even giving no importance to particular trait like disease stability or disease occurrence, so that best genotypes can be identified. Various combinations of weights tried were:

|  |  |  |
| --- | --- | --- |
| **I1:** α=25, β=25, ϒ=25 & δ=25 | **I6:** α=40, β=15, ϒ=40 & δ=5 | **I11:** α=50, β=50, ϒ=0 & δ=0 |
| **I2:** α=40, β=20, ϒ=20 & δ=20 | **I7:** α=50, β=20, ϒ=30 & δ=0 | **I12:** α=60, β=40, ϒ=0 & δ=0 |
| **I3:** α=50, β=20, ϒ=20 & δ=10 | **I8:** α=50, β=10, ϒ=40 & δ=0 | **I13:** α=70, β=30, ϒ=0 & δ=0 |
| **I4:** α=50, β=20, ϒ=25 & δ=5 | **I9:** α=33, β=33, ϒ=33 & δ =0 | **I14:** α=80, β=20, ϒ=0 & δ=0 |
| **I5:** α=50, β=15, ϒ=30 & δ =5 | **I10:** α=40, β=30, ϒ=30 & δ=0 | **I15:** α=90, β=10, ϒ=0 & δ=0 |

**Results**

**Role of weather on pod yield and disease occurrence:**

The amount of rainfall received during 2016 (Table 1) was more compared to other two years which might have resulted in higher plant height (Table 2) during that year. In order to have a better understanding on the influence of weather parameters on yield and other related traits, correlations were studied and results revealed few significant associations (Table 3). Plant height as was assumed had significant positive association with rainfall while shelling percent had significant negative association with rainfall and plant height indicating that increase in plant height due to increased rainfall led to the production of ill filled pods. Days to 50% flowering was not at all effected by the weather. Early leaf spot did not show any significant relationship with the weather parameters. However late leaf spot recorded significant positive association with number of rainy days and relative humidity recorded at afternoon time as well as significant negative association with minimum temperature.

**AMMI Analysis:**

To understand the role of environment on the expression of yield and disease occurrence among various genotypes, AMMI analysis was conducted (Table 4) and results revealed that genotype, environment and GE interaction were highly significant (at least P<0.01) for both pod yield and disease occurrence. It was observed that for pod yield, the role of environment was high (43.1%) followed by genotypes (22.7%) and GE interaction (21.4%) while for disease resistance the proportion of variation explained by genotypes (40.2%) and GEI (37.3%) was much more than that of environmental variation (14.7%). To include the stability parameter for yield, (Rao and Prabhakaran, 2005) suggested a model which was extended in the present study to include disease resistance and stability for disease and consequently simultaneous selection index was calculated.

**Selection Index**

When only mean yield was considered for ranking, K 1789, TCGS 1097 and K 1801 ranked the best while highly stable genotypes were ICGV 03057, KadiriHarithandhra and TCGS 1097 (Table 5). When disease resistance was given main criterion for ranking, K 1789, Kadiri 9 and K 1805 were having least score. Since direct selection is not advisable selection index was developed with various combinations and analysed. Most of the combinations of weights assigned to α, β, ϒ and δ have resulted into similar results *i.e* first best three genotypes were same and hence to avoid redundancy, combinations with similar results were discussed as group. Only one sample from each group was presented in the Table 5.

**I1**&**I2**: When equal weights were assigned to all factors or importance was given even to disease resistance stability and pod stability, K 1789 with 21.0 q average pod yield and 4.2% disease score ranked first, followed by Dharani with 14.7 q pod yield and 40.1% disease score which in turn was followed by ICGV 03057 with 13.7 q pod yield and 40% disease score. K 1789 with high pod yield and low disease score along with moderate yield stability is very much of interest. Though Dharani and ICGV 03057 were nearer to or less than mean pod yield with high disease score, the undue weight given to stability for disease and stability for yield marked them as best genotypes. But in practicality they cannot be selected as they possess high disease score with below average yield. The selection of genotypes based on equal weight to all the components cannot hold good practically.

**I3**&**I4**: When the weightage for pod yield increased and weightage for disease stability was reduced but still giving importance to pod yield stability and disease resistance, here also K 1789 stood as the best genotype which is followed by Dharani and Kadiri 9. Though Kadiri 9 had more pod yield (15.0 q/ha) and very less disease score (11.0%) than Dharani (13.7q/ha & 40% pod yield & disease score respectively), it ranked only after Dharani because pod yield stability and disease resistance were given almost equal importance. Hence, this may not be the good index for selection.

**I5 to I10:** Very meager weight or no weight was assigned to disease stability and equal importance to all other components or slight increased weight to grain yield and disease resistance, as usual K 1789 had highest index score followed by Kadiri 9 (15.3 q/ha & 11% podrespectively). In this case, though TCGS 1097 was having higher mean pod yield compared to Kadiri 9, less disease score of the later played an important role in ranking it as the second best genotype. Along with pod yield, disease resistance also plays a vital role, Hence these results can be relied upon for selection of best genotypes. If the genotype shows resistant reaction during two years and breaks in one year then the average score may be lesser leaving an impression that it is moderately resistant to the disease but there is every chance to get the disease in future, hence at least little importance should be given to disease stability also. In the present results, there were no such top ranking genotypes with very less stability for disease, Hence a meager weight given or no weight given to disease stability did not effect the top three ranking genotypes. But, if anyone wishes to select a resistant genotype for inclusion in crossing programme then it is far more important to consider stability in expression of a genotype for disease resistance along with the less/no disease score.

**I11:** It is like many previous studies where there was no mention of disease except considering yield and stability for yield. When yield and yield stability were given equal importance, TCGS 1097, ICGV 03057 and KadiriHarithandra ranked the top three positions. Except TCGS 1097, ICGV 03057 and KadiriHarithandra (11.6 q/ha) were lower than the average yield but were highly stable in their yield expression during the three periods of testing. Hence, they got best index score while K 1789 was no more in the scene though it had highest yield with moderate stability because of giving undue importance to stability when only two parameters are considered.

**I12& I13**: When only yield and its stability are under consideration, giving little more weight to yield compared to yield stability will choose stable genotypes along with high yielding ability as like in the present condition. TCGS 1097 was the best one which was a high yielder with considerable stability. K 1789 appeared as one among the best three but still ICGV 03057 which was a below average yielder is in the picture because of its high stability.

**I14& I15**: Even when very less weight is assigned to yield stability, ICGV 03057 had better index score and ranked third position indicating that comparative yield difference between ICGV 03057 (13.7 q/ha) and high yielding genotypes (K 1805, Kadiri 6, Kadiri 9 & K 1801 -15.4, 14.7, 15.3 & 15.7 q/ha respectively) was less compared to the stability score difference. Hence, if we are to consider only yield and stability then ICGV 03057 is considered to be better than K 1805, Kadiri 6, Kadiri 9 & K 1801, while TCGS 1097 is much better than ICGV 03057.

**Discussion**

The results showed that environment plays an important role in deciding the crop yield as well as disease occurrence. Hence, in the present study the role of weather parameters on pod yield and disease occurrence were also referred based on previous studies. Higher plant height includes increased basal stem elongation there bymaking it difficult for the gynophores to reach the soil and hence leading to reduced pod yield compared to other two years.Indirect selection for lesser plant height may sometimes be beneficial. But, it may be partially true in this study because the number of pods were lesser in 2016 compared to the year 2015 but were more than that in the year 2017.The lower yields in 2016 can befurther attributed to higher occurrence of late leaf spot disease which might have resulted in ill filling of pods. It is evident from low shelling percent recorded during 2016. Poor filling of pods may be because of decreased photosynthate production due to leaf spot disease. During 2016, maximum temperature was below 34°C and minimum temperature was nearer to 22°C with morning and afternoon relative humidity reaching more than 82% and near to 78% respectively. Favourable weather parameters like more than 70% relative humidity recorded twice a day, high maximum temperature during the crop growth period in the year, 2016 might have favoured the causal organism. It is in consonance with forewarning of tikka disease occurrence given by (Samui*et al*. 2005).

The results obtained from the association studies were further supporting the findings of (Samui*et al*. 2005) that decrease in minimum temperature and increase in relative humidity are the most important weather parameters to anticipate the occurrence of the leaf spot disease. The positive significant association of late leaf spot with number of rainy days may not be direct. It may be that increased number of rainy days led to the increase in relative humidity as observed from their significant positive association which in turn enhanced the disease. The increase in disease in turn reduced pod yields significantly. Pod yields in this study did not show any significant association with rainfall rather it had a significant positive association with minimum temperature. It may be because groundnut requires warm temperature for proper growth and also decrease in minimum temperature increases leaf spot disease. Minimum temperature and relative humidity effected pod yields directly or indirectly through the disease occurrence. Disease can be forecasted based on the weather and preventive measures can be taken up but weather cannot be changed easily to get higher yields all the time. Therefore, it is better to select high yielding genotypes which perform consistently under varied situations. Selection of a better genotype is challenging since yields fluctuate from year to year even at a single location. This variation can be attributed to differences in factors like vegetative growth and/or disease occurrence.

High amount of genotypic variation for disease resistance indicates that resistant genotypes can be developed through simple breeding techniques while the greater role of environment on pod yield indicates that stable high yielding groundnut genotypes are to be developed to withstand the vagaries of weather. Both pod yield and disease resistance emphasize the importance of the GEI. Similar results for pod yield were obtained by (Badigannavar*et al.* 2007, Kebede and Getahun 2017) suggesting that pod yields are sensitive to weather fluctuations and there is a prerequisite to breed varieties for distinct regions since GEI was substantial. Dissection of GEI indicated that the first two interaction components in the ANOVA of AMMI2 model detailed 100% of the interaction variation leaving no residual (Table 4). This is in confirmation with (Anuradha *et al*. 2017), which means that the first two interaction components could elucidate the interaction variation sufficiently and AMMI 2 model holds well (Gauch, 2013).

AMMI analysis showed the sizeable role of GEI for both pod yield and disease resistance indicates that genotypes cannot be selected *per se* and stability analysis component should be considered while selecting a better genotype. Selection of a genotype based on the mean performance and encouraging its cultivation in farmers fields may lead to greater risk as the genotype may not perform consistently. At present it is not possible to predict the changes in weather accurately and select genotypes accordingly to suit the weather. The only alternative is to have a stable high yielding genotype with no/little compromise in yield for stability.

Simultaneous selection of genotypes for yield and yield stability were used in several crops by earlier researchers (Mekbib, 2002 and Kumar *et al.* 2018) for identifying consistently better performing genotypes while inclusion of disease resistance and its stability in selection index is first of its kind. Careful selection of a model is very important. If one is having only yield and stability for yield then it is better to give more weight to yield rather giving equal importance as it may lead to loosing of high yielding genotypes like K 1789. Here we need to remember one thing, for yield ranking of genotypes may hold good but for stability the comparativeness between genotypes is (ASV value to be low) but rank is not important.

High yielding genotypes along with high to moderate stability can be selectedwith some sacrifice of yield stability as like in the selection indices, I12 to I15. Whenever there is a possibility of having disease resistance data along with yield, it is more important to give due importance to disease reaction and some importance to stability in disease resistance along with more emphasis on yield and to some extent on yield stability as like in I5 to I10.

This study helped in understanding the role of temperature and relative humidity in the expression of leaf spots and pod yields of groundnut. Results revealed that increased plant height and occurrence of early and late leaf spots during the high rainfall years seems to be the prime cause for reduction in yields. Temperature and relative humidity played a significant role on disease occurrence and in turn on pod yields. AMMI analysis revealed that pod yield was very much influenced by the environmental fluctuations with considerable GEI while disease score was influenced equally by genotypes and GEI. Simultaneous selection index analysed with 15 different combinations of weights assigned to pod yield, yield stability, disease score and disease stability and best scoring genotypes, K 1789, TCGS 1097 and Kadiri 9 were identified from best combination of weights.

**Conclusion**

This study helped in understanding the role of temperature and relative humidity in the expression of leaf spots and pod yields of groundnut. It also revealed that genotypes were highly influenced by the environment for pod yields while genotypes contributed more variation for disease score. Genotype Environment Interaction had a significant role for both pod yield and disease score. Simultaneous selection for high yield, yield stability, disease resistance and disease stability was best achieved when the more weights were assigned to pod yield and disease score followed by yield stability and least weight for disease stability in the selection index (**I5** to **I10)**. The best groundnut genotypes identified in the present study for high rainfall areas were K 1789, Kadiri 9 and TCGS 1097.

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**Author contributions**

NA designed, planned and executed the experiments, NA and AS interpreted the results, made the original draft of manuscript and made the write up, TSSKP supervised the experiments and reviewed the manuscript and YSR and UT engaged with yield trials and phenotypic data analyses.

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**Table 1: Weather parameters during the groundnut crop growth period during *Kharif* 2015, 2016 and 2017**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Month** | **RF** | **RD** | **Tmax** | **Tmin** | **RHM** | **RHA** |
| 1 | **2015** | 477.1 | 19 | 30.4 | 26.8 | 85.3 | 63.2 |
| 2 | **2016** | 965.2 | 48 | 30.5 | 24.0 | 87.0 | 72.9 |
| 3 | **2017** | 580.6 | 29 | 30.3 | 25.3 | 86.7 | 67.6 |
| **Mean** | **674.3** | **32.0** | **30.4** | **25.4** | **86.3** | **67.9** |

where RF: Total rain fall received; RD: Total number of rainy days; Tmax: Mean maximum temperature; Tmin: Mean minimum temperature; RHM&A : Relative humidity recorded during morning and afternoon.

**Table 2: Mean performance ofthirteen groundnut genotypes evaluatedduring *Kharif* 2015, 2016 and 2017**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Year** | **DFF** | **PH** | **NPD** | **NBR** | **PY** | **SP** | **KY** | **ELS** | **LLS** |
| 1 | 2015 | 31.7 | 62.8 | 19.9 | 6.1 | 19.6 | 70.8 | 14.0 | 11.4 | 23.2 |
| 2 | 2016 | 32.1 | 102.2 | 16.5 | 8.0 | 10.8 | 68.1 | 7.4 | 17.0 | 37.8 |
| 3 | 2017 | 25.2 | 67.6 | 11.1 | 4.7 | 13.1 | 70.9 | 9.1 | 20.7 | 30.6 |
| **Mean** | **29.7** | **77.5** | **15.8** | **6.3** | **14.5** | **69.9** | **10.2** | **16.4** | **30.5** |

DFF: Days to 50% flowering; PH: Plant height in cm; NPD: Number of Pods per plant; NBR: Number of branches per plant; PY: Pod yield (q/ha); SP: Shelling percent (%); KY: Kernel yield (q/ha), ELS: Early leaf spot (%) and LLS: Late leaf spot (%)

**Table 3: Correlation of weather parameters with pod yield, disease score and other traits of 13 groundnut genotypes tested during *Kharif* 2015, 2016 and 2017**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Trait** | **RF** | **RD** | **Tmax** | **Tmin** | **RHM** | **RHA** | **DFF** | **PH** | **NPD** | **NBR** | **PY** | **SP** | **KY** | **ELS** |
| **RD** | 0.990\* |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Tmax** | 0.748 | 0.645 |  |  |  |  |  |  |  |  |  |  |  |  |
| **Tmin** | -0.935 | -0.976\* | -0.464 |  |  |  |  |  |  |  |  |  |  |  |
| **RHM** | 0.778 | 0.860 | 0.165 | -0.950\* |  |  |  |  |  |  |  |  |  |  |
| **RHA** | 0.964\* | .992\*\* | 0.546 | -0.995\*\* | 0.916 |  |  |  |  |  |  |  |  |  |
| **DFF** | 0.364 | 0.227 | 0.891 | -0.010 | -0.301 | 0.105 |  |  |  |  |  |  |  |  |
| **PH** | 0.996\*\* | 0.973\* | 0.805 | -0.899 | 0.718 | 0.937 | 0.447 |  |  |  |  |  |  |  |
| **NPD** | -0.072 | -0.214 | 0.608 | 0.421 | -0.682 | -0.333 | 0.903 | 0.019 |  |  |  |  |  |  |
| **NBR** | 0.803 | 0.709 | 0.996\*\* | -0.539 | 0.250 | 0.617 | 0.848 | 0.853 | 0.537 |  |  |  |  |  |
| **PY** | -0.831 | -0.902 | -0.252 | 0.974\* | -0.996\*\* | -0.948 | 0.216 | -0.777 | 0.615 | -0.335 |  |  |  |  |
| **SP** | -0.973\* | -0.929 | -0.881 | 0.827 | -0.611 | -0.877 | -0.570 | -0.990\* | -0.161 | -0.919 | 0.679 |  |  |  |
| **KY** | -0.829 | -0.900 | -0.248 | 0.973\* | -0.996\*\* | -0.947 | 0.220 | -0.775 | 0.618 | -0.331 | 0.999\*\* | 0.676 |  |  |
| **ELS** | 0.315 | 0.447 | -0.395 | -0.630 | 0.840 | 0.554 | -0.770 | 0.227 | -0.969\* | -0.313 | -0.789 | -0.086 | -0.792 |  |
| **LLS** | 0.946 | 0.983\* | 0.493 | -0.999\*\* | 0.939 | 0.998\*\* | 0.044 | 0.913 | -0.390 | 0.567 | -0.966\* | -0.846 | -0.965\* | 0.604 |

RF: Total rain fall received; RD: Total number of rainy days; Tmax: Mean maximum temperature; Tmin: Mean minimum temperature; RHM&A : Relative humidity recorded during morning and afternoon. DFF: Days to 50% flowering; PH: Plant height in cm; NPD: Number of Pods per plant; NBR: Number of branches per plant; PY: Pod yield (q/ha); SP: Shelling percent (%); KY: Kernel yield (q/ha), ELS: Early leaf spot (%) and LLS: Late leaf spot (%).

**Table 4: Pooled ANOVA and AMMI ANOVA for groundnut yield and disease occurrenceduring *Kharif* 2015, 2016 and 2017**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Source** | **Pod yield (q/ha)** | **% Variation explained** | **Disease score (%)** | **% Variation explained** |
| **Df** | **MSS** |  | **MSS** |  |
| **Total** | **116** | **32.3** |  | **296.0** |  |
| **Treatment Design** | **38** | **86.1** |  | **833.4** |  |
| Genotype | 12 | 71.1\*\*\* | 22.7% of Total variation | 1149.02\*\*\* | 40.2% of Total variation |
| Environment | 2 | 809.0\*\*\* | 43.1% of Total variation | 2528.2\*\* | 14.7% of Total variation |
| GE Interaction | 24 | 33.4\*\*\* | 21.4% of Total variation | 534.36\*\*\* | 37.3% of Total variation |
| IPC1 | 13 | 47.9\*\*\* | 77.6 of GE Interaction | 882.37\*\*\* | 89.4 of GE Interaction |
| IPC2 | 11 | 16.3\*\* | 22.4 of GE Interaction | 123.07\*\*\* | 10.6 of GE Interaction |
| **Experimental Design** | **78** | **6.13** |  | **34.2** |  |
| Blocks within Environment | 6 | 6.9 |  | 132.1 |  |
| Error | 72 | 6.1 |  | 26.1 |  |

Df, degree of freedom; MSS, mean sum of squares

\*\*\*, significant at 0.1% (p<0.001)

**Table 5: Ranking of groundnut genotypes based on pod yield, yield stability, disease resistance and index based ranking.**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Genotype** | **PY** | **ASVPY** | **DS** | **ASVDS** | **Index Score** | **YBR** | **YSBR** | **DSBR** | **Index based Rank** |
| **I1** | **I3** | **I7** | **I11** | **I13** | **I14** | **I1** | **I3** | **I7** | **I11** | **I13** | **I14** |
| 1 | K 1805 | 15.4 | 3.6 | 18.9 | 11.6 | 1.3 | 1.2 | 1.2 | 1.0 | 1.0 | 1.0 | 4 | 10 | 3 | 8 | 7 | 4 | 10 | 9 | 6 |
| 2 | Kadiri 6 | 14.7 | 7.4 | 36.7 | 42.5 | 0.7 | 0.8 | 0.9 | 0.7 | 0.8 | 1.0 | 6 | 12 | 9 | 12 | 12 | 12 | 12 | 12 | 9 |
| 3 | Dharani | 12.1 | 1.7 | 40.1 | 02.1 | 2.7 | 1.7 | 1.0 | 1.3 | 1.1 | 0.9 | 11 | 4 | 10 | 2 | 2 | 9 | 5 | 6 | 11 |
| 4 | K 1725 | 13.3 | 2.8 | 32.9 | 06.1 | 1.4 | 1.1 | 1.0 | 1.0 | 1.0 | 0.9 | 10 | 9 | 8 | 7 | 8 | 10 | 9 | 11 | 12 |
| 5 | Kadiri 9 | 15.3 | 2.3 | 11.0 | 20.8 | 1.6 | 1.5 | 1.7 | 1.2 | 1.2 | 1.1 | 5 | 6 | 2 | 4 | 3 | 2 | 6 | 5 | 4 |
| 6 | TCGS 1097 | 17.9 | 1.4 | 26.4 | 11.0 | 1.5 | 1.5 | 1.5 | 1.7 | 1.5 | 1.3 | 2 | 3 | 4 | 5 | 4 | 3 | 1 | 1 | 2 |
| 7 | K 1789 | 21.0 | 2.5 | 4.2 | 06.9 | 3.2 | 2.8 | 3.4 | 1.4 | 1.4 | 1.4 | 1 | 7 | 1 | 1 | 1 | 1 | 4 | 2 | 1 |
| 8 | KadiriHarithandra | 11.6 | 1.4 | 30.0 | 07.8 | 1.5 | 1.3 | 1.2 | 1.5 | 1.2 | 0.9 | 12 | 2 | 6 | 6 | 6 | 6 | 3 | 4 | 10 |
| 9 | TCGS 1156 | 10.0 | 7.7 | 50.9 | 20.0 | 0.6 | 0.6 | 0.6 | 0.5 | 0.6 | 0.7 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 |
| 10 | K 1801 | 15.7 | 3.8 | 30.0 | 25.1 | 0.9 | 1.0 | 1.0 | 0.9 | 1.0 | 1.1 | 3 | 11 | 7 | 10 | 10 | 8 | 11 | 10 | 5 |
| 11 | Anantha | 13.9 | 2.6 | 45.9 | 23.9 | 0.9 | 0.9 | 0.9 | 1.1 | 1.0 | 1.0 | 7 | 8 | 12 | 11 | 11 | 11 | 8 | 8 | 7 |
| 12 | TCGS 1157 | 13.5 | 2.3 | 29.9 | 13.6 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 9 | 5 | 5 | 9 | 9 | 7 | 7 | 7 | 8 |
| 13 | ICGV 03057 | 13.7 | 1.3 | 40.1 | 05.6 | 1.7 | 1.4 | 1.2 | 1.7 | 1.4 | 1.1 | 8 | 1 | 11 | 3 | 5 | 5 | 2 | 3 | 3 |

where PY: Pod yield (q/ha); ASVPY: AMMI stability value for pod yield; DS: Late leaf spot disease score(%); ASVDS: AMMI stability value for disease score, YBR: Yield based rank; YSBR: Yield stability based rank; DRBR: Disease score based rank .

**Index scores: I1:** α=25, β=25, ϒ=25 & δ=25; **I3:** α=50, β=20, ϒ=20 & δ=10; **I7:** α=50, β=20, ϒ=30 & δ=0; **I11:** α=50, β=50, ϒ=0 & δ=0; **I13:** α=70, β=30, ϒ=0 & δ=0; **I14:** α=80, β=20, ϒ=0 & δ=0

1. [↑](#footnote-ref-1)