MATERIAL AND METHODS

The present investigations on "Integrated approach for the control of Chilo partellus (Swinhoe), a major pest of sorghum" were conducted at the Indian Agricultural Research Institute, New Delhi, as well as at Sorghum Research Station, Parbhani (Maharashtra) and Gujarat Agricultural University, Navsari Campus (Gujarat).

A LAYOUT AND DESIGN OF FIELD TRIALS

Field trials were laid out in randomized complete block as well as in split plot designs with varying number of treatments for different trials, each treatment was replicated three/four times depending on the area available for the trial. A sub-plot consisted of single/five rows, each row being three metres long. The row to row distance was maintained at 75 cm and plant to plant distance in a row was kept at 15 cm. Twenty plants were maintained per row thinning out the excess plants after one week of germination.

B GENERAL METHODS

B-1 Agronomic practices:

Sowings of various trials were done generally in the first week of July each year. The normal tillage and interculture operations, as recommended for improved sorghum varieties/hybrids, were given. The sowings were done on
ridges. A basal dose of fertilizers at the rate of 40 kg N and 40 Kg P₂O₅ per hectare was applied before sowing. Two side dressings of N at the rate of 30 Kg each per hectare were applied on 25th day after germination and again at boot leaf stage.

B-2 Chemical control of other pests:

Sorghum crop suffers heavy damage from shoot fly, stem borer and midge. Since the present studies were undertaken to observe damage by stem borer, it was essential to effectively protect the entire crop (including control) from damage by shoot fly and midge. Carbosulfan seed treatment was given for shoot fly control by using 10 parts of 50 per cent S.P. of carbosulfan per 100 parts of seed (5% a.i.) and endosulfan 35 EC at the rate of 1 litre in 600 litres of water per hectare was used against midge.

B-3 Parameters for assessing stem borer damage:

The parameters used for assessing borer damage were leaf injury and stem tunnelling.

C Investigations carried out

The present investigations on integrated approach for the control of Chilo partellus (Swinhoe) were carried out in the following stages.

C-1 Biology of sorghum stem borer:

Biology of stem borer was studied on natural diet by growing hybrid CSR-1 in the field. Freshly laid eggs
collected were kept in glass vials (5 cm x 2.5 cm) at a controlled temperature of 27°C ± 2°C, relative humidity ranged from 70 to 90 per cent and a fluorescent light of 40 watts intensity was provided. Newly hatched larvae were transferred to fresh leaf whorls of young plants (25 to 35 days old) brought from field and from 2nd instar onwards the larvae were reared on stem pieces, kept inside glass jars (15 cm x 10 cm). Food was changed on every alternate day. Pupae developed from these larvae were kept in separate glass jars (15 cm x 10 cm) for emergence of adults. The freshly emerged adults were separated according to sex and a pair was kept in one glass jar, with a layer of moist sand (2-3 cm thick) at bottom which was covered with a round piece of white butter paper.

The inner surfaces of glass jars were also covered with white butter paper. Five such jars were maintained for egg laying. Observations were recorded on longevity of male and female, average number of eggs per female, percentage viability, incubation period, larval and pupal period, sex-ratio and total developmental period from egg to adult.

C-2 Host plant resistance:

Systematic work on screening of germplasm consisting of over 10,000 lines was initiated under the All India Coordinated Sorghum Improvement Project. This programme resulted in the identification of 26 lines exhibiting
resistance to stem borer but none of these is immune to stem borer attack nor high yielding. Some of these sources like BP53, M35-1, K-Local were utilized in breeding programme for developing high yielding stem borer resistant cultivars. A part of the available material was screened in different trials for stem borer resistance.

G-2.1 **Screening of selected cultivars:**

Over 450 cultivars developed from the breeding programme combining high yield with moderate level of resistance were selected by screening a large number of derivatives. Out of these cultivars, twelve cultivars were further selected for various studies. The pedigrees of these cultivars are given in table-1.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Cultivar</th>
<th>Selection</th>
<th>Pedigree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>E 601</td>
<td>DU 98</td>
<td>IS 2954 x BP53</td>
</tr>
<tr>
<td>2</td>
<td>E 602</td>
<td>DU 245</td>
<td>IS 2954 x BP53</td>
</tr>
<tr>
<td>3</td>
<td>E 603</td>
<td>DU 19</td>
<td>IS 550 x M35-1</td>
</tr>
<tr>
<td>4</td>
<td>E 604</td>
<td>U 783</td>
<td>IS 3922 x Asipuri</td>
</tr>
<tr>
<td>5</td>
<td>E 605</td>
<td>U 83</td>
<td>IS 531 x M35-1</td>
</tr>
<tr>
<td>6</td>
<td>E 606</td>
<td>U 121</td>
<td>CK 608 x BP53</td>
</tr>
<tr>
<td>7</td>
<td>E 607</td>
<td>U 329</td>
<td>IS 506 x Karad Local</td>
</tr>
<tr>
<td>8</td>
<td>E 608</td>
<td>U 111</td>
<td>IS 3691 x BP53</td>
</tr>
<tr>
<td>9</td>
<td>E 609</td>
<td>U 104</td>
<td>IS 3922 x Asipuri</td>
</tr>
<tr>
<td>10</td>
<td>E 610</td>
<td>DU 135</td>
<td>IS 2954 x BP53</td>
</tr>
<tr>
<td>11</td>
<td>E 611</td>
<td>U 218</td>
<td>CK 608 x BP53</td>
</tr>
<tr>
<td>12</td>
<td>E 612</td>
<td>U 152</td>
<td>IS 3691 x BP53</td>
</tr>
</tbody>
</table>
C-2.1(a) Screening of selected cultivars for resistance to stem borer under natural infestation conditions:

Twelve selected cultivars were grown along with high yielding but susceptible released hybrid GBH-1 to investigate their relative resistance to stem borer and extent of damage caused by it under natural conditions, during Bharat 1975 to 1976 at the Indian Agricultural Research Institute, New Delhi and during summer 1976 at Parbhani (Maharashtra) and Bharat 1978 at Navsari (Gujarat). The cultivars were sown in single row plots each replicated three times during 1975 and 1976 at Delhi and in 1976 at Parbhani and Navsari and in five row plots, each replicated three times during 1977 to 1979 at Delhi. Yield data were also recorded at Delhi from 1977 to 1979.

C-2.1(b) Stability of stem borer resistance in selected cultivars of sorghum:

The stability resistance was worked out by following the model of Saperlart and Russel (1966). The means of various cultivars were calculated and regression coefficients (b) were tested against unity to locate most adaptable cultivar for borer damage.

C-2.1(c) Screening of selected cultivars for resistance to stem borer under artificial infestation conditions:

The same selected twelve cultivars were subjected to more intensive screening by conducting the trial under artificial infestation conditions in 1978. Sowing was
done in randomized block design. Each entry was sown in single row plot, replicated three times. CSN-1 was included as susceptible check. Five healthy plants were selected at random and tagged in each row and each plant was infested with 5 newly hatched larvae of stem borer on 25th day after germination. Observations were recorded for leaf injury and stem tunnelling.

C-2.1(d) Multiple regression for effect on grain yield of stem tunnelling and leaf injury in selected cultivars:

Simple correlation analysis was done for leaf injury, stem tunnelling and grain yield. As the regression for both leaf injury and stem tunnelling was found to be negatively correlated with yield, the multiple regression analysis was also carried out for these factors.

C-2.2 Screening of high yielding sorghum varieties for stem borer resistance:

In another set of trials 260 varieties (SPV entries) developed by sorghum breeders from exotic x Indian crosses combining high yield and other desirable agronomic characters with borer resistance were screened. Twenty three varieties were selected as promising after initial screening. These varieties were grown for three years from 1977 to 1979 in single row plot, each replicated three times along with CSN-1 to study their reaction to stem borer attack under field conditions.
Breeding for resistance:

These studies were planned to incorporate the known sources of stem borer resistance in breeding programmes to generate material having desirable agronomic characters with satisfactory level of resistance to stem borer.

Various crosses were made at Delhi over the years starting from 1975 and the $F_1$ seeds were collected for further testing. Individual plant selections were made in $F_2$ generation. Four trials of selected plants were sown in single rows, each replicated three times from $F_2$ onwards and the plants showing borer resistance as well as desirable agronomic characters were selected for testing in advance generations. First trial of six crosses of which $F_1$ seed was advanced by one generation at Hyderabad in summer 1976 consisting of 699 x 772; 699 x GS 3541; 699 x IS 4664; 772 x IS 2146; 772 x IS 4664 and R 147 x IS 4664 was sown during Kharif 1976 to 1979, second trial again of six crosses viz., E 303 x P 37; Swarna x E 303; E 302 x E 303; P 37 x E 303; E 303 x IS 5490 and DU 258 x P 37 sown in Kharif 1977 to 1979, third trial of two crosses viz., SPV 100 x P 151 and SPV 115 x P 151 (seven selections from each cross) sown in Kharif 1978 and 1979 and fourth trial of three crosses viz., SPV 105 x IS 5490 (five selections), SPV 100 x IS 5490 (three selections) and E 302 x SPV 104 (seven selections) in Kharif 1978 and 1979.
Chemical control:

An effective and economical insecticidal control method is an indispensable component of any integrated control programme. It has particular relevance in the case of control of sorghum stem borer as none of the other methods available at present can ensure timely and satisfactory suppression of stem borer population. Following chemical control trials were carried out with this objective over the period of four years (Kharif 1976 to 1979). Hybrid GM-5 was used for these studies. Each treatment was sown in five row plots, each replicated four times.

C-4.1 Relative efficacy of different granular insecticides for the control of sorghum stem borer:

Nine insecticides available in granular form viz., endosulfan 4 per cent, phenthoate 2 per cent, carbofuran 3 per cent, quinolphos 3 per cent, fenitrothion 5 per cent, lepithoros 3 per cent and chlorpyrifos 10 per cent were evaluated against stem borer during Kharif 1976 and compared with control (no treatment). Granules of different insecticides were applied in leaf whorls at three different periods viz., on 20th, 30th and 40th day after germination at the rate of 8, 10 and 12 kg per hectare, respectively.
C-4.2 Relative efficacy of dust formulation of promising insecticides against stem borer when applied in leaf whorls-

This trial was conducted in 1977 with the main objective of developing a chemical method of control for the stem borer which should be effective as well as economical. To achieve this objective, dust formulation, which is cheaper, was substituted for more expensive granular formulation. Dusts of four promising insecticides tested earlier i.e., endosulfan 4 per cent, phenthoate 2 per cent, carbaryl 5 per cent and malathion 5 per cent were evaluated along with BHC 10 per cent dust and control (no treatment). There were two and three application schedules for each insecticidal dust, which were applied in 'leaf whorls' with the help of perforated tin applicators. In two application schedule, dusts were applied at the rate of 5.0 and 7.5 Kg per hectare on 25th and 35th day after germination and in three application schedule, the dusts were applied at the recommended rates of 8, 10 and 12 kg/ha on 30th, 35th and 40th day after germination respectively.

C-4.3 Relative efficacy of different formulations of promising insecticides for the control of stem borer-

To collect more data on relative efficacy of different formulations, insecticides, a modified trial was conducted in Kharif 1978 and 1979 seasons. Three highly effective insecticides (endosulfan, phenthoate and carbaryl) were tested as granular, dust and spray formulations. Granules were applied at the rate of 8, 10 and 12 kg per
hectare on 20th, 30th and 40th day after germination respectively as per recommendation of All India Coordinated Sorghum Improvement Project. Dusts were applied at the rate of 5 and 7.5 Kg per hectare on 25th and 35th day after germination while 0.05 per cent sprays of the three insecticides were given on 25th and 35th day after germination using 500 and 600 litres of the spray liquid per hectare for the two applications respectively.

4.4 Studies on efficacy of different insecticidal schedules

This trial was planned to study the suitable time and number of applications of insecticide necessary for effective control of stem borer. The trial was conducted for two years during Kharif 1978 and 1979 using susceptible hybrid CS-1. The crop was sown in 5 row plots each replicated four times. The treatments were: application of endosulfan dust on (i) 20th day at the rate of 5 Kg/ha, (ii) 25th day at the rate of 5 Kg/ha, (iii) 20th + 30th day at the rate of 5 and 7.5 Kg/ha respectively, (iv) 30th day at the rate of 7.5 Kg/ha, (v) 35th day at the rate of 7.5 Kg/ha, (vi) 20th + 30th + 40th day at the rate of 5, 7.5 and 10 Kg/ha respectively, (vii) 25th + 35th day at the rate of 5 and 7.5 Kg/ha respectively, (viii) 40th day at the rate of 10 Kg/ha and (ix) control (no application). Observations were recorded on borer damage and grain yield.
C-5 Management of stem borer through integration of host plant resistance and chemical control.

Twelve cultivars, selected as promising for stem borer resistance in the present studies, were further evaluated under field conditions in Kharif 1978 and 1979 to determine whether damage by stem borer can be appreciably reduced by integrating with chemical control. This was considered to necessary as the level of resistance in these cultivars is moderate and there is some borer damage depending on the intensity of infestation. The cultivars were grown in five row plots in two sets, one set protected for borer damage and other set under unprotected conditions, each replicated thrice. Endosulfan (4%) dust was used for the borer control in two application schedule at the rate of 5 and 7.5 kg per hectare on 25th and 35th day after germination respectively.

C-6 Cultural control:

C-6.1 Studies on stem borer larvae in stumps, peduncles and stubbles at the time of harvest:

It is reported that stubbles and harvested stems harbour diapausing larvae and these form major sources of carry over of stem borer from one season to other. Field studies were conducted in 1978 and 1979 to record number of borer larvae and infestation in stubbles left in the field after harvest as well as in harvested stem and peduncles.
C-6.2 Survival of the hibernating larvae kept in stem pieces:

Percentage of emergence of adults, time of emergence and mortality of larvae were calculated from a culture of 400 larvae kept in stem pieces at room temperature in laboratory during November to July of 1978 and 1979.

C-6.3 Effect of planting geometry (row and plant spacings) on the damage by stem borer:

This trial was conducted in Kharif 1978 and 1979 to collect data on the effect of different row and plant spacings on the incidence and damage by stem borer. The following row and plant spacings were studied: 30 cm x 18 cm, 45 cm x 12 cm, 60 cm x 9 cm, 75 cm x 7 cm and 90 cm x 6 cm. Each treatment (spacing) consisted of 5 rows and was replicated 4 times. Hybrid GSH-5 was used for these studies during both the years.

C-6.4 Effect of nitrogen fertilization on the incidence of stem borer:

High yielding varieties and hybrids are very responsive to high doses of fertilizers, particularly nitrogen. Six cultivars viz., E 601, E 602, E 603, E 604, E 605 and E 606 were sown in Kharif 1978 to study the effect of different levels of N on the borer incidence. The experiment was sown in split-plot design taking different doses of nitrogen as main treatments and varieties as sub-treatments. Four levels of nitrogen
Viz. 0, 30, 40 and 60 kg/ha were applied in the form of ammonium sulphate as basal dose. Each entry was seen in four row plot replicated four times. Stem tunnelling was taken as the parameter for assessing borer damage.

C-7  Studies on Natural Enemies:

C-7.1  Incidence of Stictoidea flavipes Ben. on stem borers larvar-

Stictoidea flavipes is a major parasite of stem borer. Data were recorded at fortnightly interval on the extent of parasitisation of stem borers by this parasite in the field by collecting larvae from the stems in 1976 and 1977.

C-7.2  Record of parasitism of stem borer-

Stem borer infested material was brought to laboratory from field and kept in rearing glass jars and maintained at a constant temperature of 27°C ± 2°C and relative humidity ranging from 70 to 80 per cent. The parasites which emerged from the larvae were collected and sent to British Museum for identification.

C-7.3  Control of Chilo partellus (Hawtree) with Bacillus thuringiensis-

Efficacy of a new virulent strain of Bacillus thuringiensis (marketed as Bipel) was studied for the control of stem borer, and its compatibility with endosulfan was also studied in trials conducted during 1976 and 1977. The objective was to determine whether effective control of stem borer can be obtained by
replacing the toxic and relatively expensive insecticides. B.t. was used in the form of granules as well as spray. Two and four per cent granules were prepared as per procedure described by Jotevani et al., 1977.

C.7.3(a) Efficacy of B. thuringiensis against stem borer and its compatibility with endosulfan (1978):

This trial was conducted in 1978 with six treatments, each replicated thrice. Seed of GSH-1 was used. The treatments included application of 2 per cent and 4 per cent granules of Bacillus thuringiensis (B. t.) alone at the rate of 8, 10, and 12 Kg/ha on 20th, 30th and 40th day after germination, 0.05 per cent (16000IU/mg) spray of B. t. on 20th, 30th and 40th day after germination, endosulfan 4 per cent granules followed by second application of B. t. 4 per cent granules and the third of endosulfan 4 per cent granules at the rate of 8, 10 and 12 Kg/ha on 20th, 30th and 40th day after germination respectively. These applications were compared with endosulfan granules at the rate of 8, 10 and 12 Kg/ha on 20th, 30th and 40th day after germination and control where no treatment was given.

C.7.3(b) Efficacy of B. thuringiensis against stem borer and its compatibility with endosulfan (1979):

The trial in 1979 was conducted in split-plot design using GSH-1 and GSH-5 as sub-treatments. There were eleven treatments each replicated thrice. In all three applications were given, one each on 20th, 30th and
40th day after germination. The rate of application of granules was 0, 10 and 1.2 kg/ha for 1st, 2nd, and 3rd applications respectively. The treatments were (i) endosulfan 4 per cent granules - 3 applications, (ii) S.t. 4 per cent granules - 3 applications, (iii) S.t. + S.t. + endosulfan, (iv) S.t. + endosulfan + S.t., (v) endosulfan + S.t. + S.t., (vi) S.t. + endosulfan + endosulfan, (vii) endosulfan + S.t. + endosulfan, (viii) S.t. spray at the rate of 0.25 per cent (16000IU/mg) on Xth, X+1th and 40th day after germination, (ix) B.t. spray at the rate of 0.1 per cent (16000IU/mg) on Xth, X+1th and 40th day after germination, (x) B.t. spray at the rate of 0.2 per cent (16000IU/mg) on Xth, X+1th and 40th day after germination and (xi) Control (no treatment).

APPLICATION OF DIFFERENT FERTILIZERS
FOR INCREASED YIELD UNDER FIELD

The granules were applied in leaf shears, using special applicators which were fabricated from glass specimen tubes of 10 x 2 cm size. Tubes were fitted with corks having control slits running its whole length at intervals of sides. Each applicator was suitably marked to indicate the quantity of insecticide to be used per row. Dusts were applied in leaf shears like granules. A glass specimen tube covered with fine mesh was used to apply dust. Each tube was marked for quantity of dust to be used per row. The spray formulation was applied by mainly directing the spray on leaf shears and upper leaves.
This provided proper coverage of the area where newly emerged larvae congregate. Marut foot-sprayer was used for applying the insecticides. The quantity of spray formulation used was 500 to 600 litres per hectare depending on the age of plants.

E

OBSERVATIONS RECORDED

E-1 Observations on leaf injury due to stem borer:

The number of plants per plot showing leaf injury due to borer and number of healthy plants were counted on 25th and 35th day after germination. Percentage of plants showing leaf injury was calculated from total number of plants per plot and the number of plants showing leaf injury.

In host plant resistance and breeding for resistance studies, the various entries were first visually graded according to intensity of leaf injury on 25th and 35th day after germination. Zero to 9 scale (0 for no leaf injury and 9 for very severe leaf injury including dead hearts) was adopted for this purpose. Grading 1 to 3 was given to those plants showing low intensity of leaf injury, 4 to 6 for medium (intermediate) leaf injury and 7 to 9 for high intensity of leaf injury respectively. This grading was converted into per cent leaf injury by taking 1 grade as 10 per cent.

E-2 Observations on stem tunnelling due to stem borer:

At the time of harvest, 10 plants were selected at random from each plot and were cut in halves lengthwise.
Observations were taken on total stem length and stem length tunneled by the stem borer larvae. The average percentage stem tunnelling was worked out by taking the total stem length of 10 plants and total length tunneled.

\[
\text{Av. stem tunnelling} = \frac{SD\ 10 \times 100}{SL\ 10}
\]

(\(SD\ 10 = \) Total length of damaged stems of 10 plants, 
\(SL\ 10 = \) Total stem length of 10 plants)

**YIELDS OF GRAIN AND FODDER**

For determining the efficacy of any treatment, the most important criterion is the extent to which it protects the crop from pest damage. This is assessed by comparing yields from treated plots with those from untreated plots. Thus by recording yields from all treatments the relative efficacy of different insecticides was finally assessed.

The trials were harvested on maturity of the grain. The earheads were cut from stems and were dried by exposing to sun for about a week. The dried heads were then threshed, and the grains were cleaned and weighed plotwise. The yield obtained per plot was converted into yield per hectare.

Similarly the harvested stems and leaves from each plot were weighed in the field by using spring balance. The fodder yield recorded plotwise was converted to yield per hectare.
ESTIMATION OF AVOIDABLE LOSSES AND INCREASE IN GRAIN YIELD

The percentage avoidable loss and percentage increase in grain yield in various treatments were calculated as per formulae suggested by Pradhan (1969a).

\[
\text{Percentage avoidable loss} = \left( \frac{\text{Highest yield in treated plot} - \text{Yield in treated plot}}{\text{Highest yield in treated plot}} \right) \times 100
\]

\[
\text{Percentage increase in yield} = \left( \frac{\text{Yield in treated plot} - \text{Yield in untreated plot}}{\text{Yield in untreated plot}} \right) \times 100
\]

II

STATISTICAL ANALYSIS

II-1 General analysis:

The data obtained in various experiments were compiled and statistically analysed by the standard procedures (analysis of variance, multiple regression analysis, split-plot analysis) described by Cochran and Cox (1963). The percentages only were converted to arc sin values before analysis and various tables represent the same converted values.

II-2 Stability analysis:

Stability of stem borer resistance in selected cultivars was worked out by following the model of Eberhart and Russel (1966). The mathematical model used for analysis was as follows:

\[
Y_{ij} = \mu_i + \beta_i I_j + \epsilon_{ij}
\]

where \(Y_{ij}\) is the variety mean of the \(i^{th}\) variety at the \(j^{th}\) environment \((i = 1, 2, \ldots, v; j = 1, 2, \ldots, n)\), \(\mu_i\) is the \(i^{th}\) variety mean over all environments, \(\beta_i\) is the regression coefficient that measures the response of \(i^{th}\) variety to varying environments, \(\epsilon_{ij}\) is the deviation from regression of the \(i^{th}\) variety at the \(j^{th}\) environment, and \(I_j\) is the environmental index.
\[ I_j = \left( \frac{\tilde{x}}{1} \frac{y_{1j}}{v_{1}} \right) - \left( \frac{\tilde{x}}{1} \frac{y_{1j}}{v_{1j}} \right), \quad \tilde{x} I_j = 0 \]

With this model the sum of squares due to Environments and Variety x Environments are partitioned into Environments (linear), Varieties x Environments (linear) and Deviations from the regression model.

Analysis of variance for stability parameters is given below.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>S.S.</th>
<th>M.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>(nv - 1)</td>
<td>(\sum_{i=1}^{s} \sum_{j=1}^{n} y_{ij}^2 - \text{C.F.})</td>
<td>(\text{M.S}_1)</td>
</tr>
<tr>
<td>Varieties (V)</td>
<td>(v - 1)</td>
<td>(\frac{1}{n} \sum_{i=1}^{s} \sum_{j=1}^{n} y_{ij}^2 - \text{C.F.})</td>
<td>(\text{M.S}_1)</td>
</tr>
<tr>
<td>Environments (Env.)</td>
<td>(n - 1)</td>
<td>(\frac{1}{(v-1)(n-1)} \sum_{i=1}^{s} \sum_{j=1}^{n} y_{ij}^2 - \frac{Y^2}{n})</td>
<td>(\text{M.S}_2)</td>
</tr>
<tr>
<td>V x Env. (linear)</td>
<td>(v(n-1))</td>
<td>(\frac{1}{v} \sum_{j=1}^{v} \left( \sum_{i=1}^{s} y_{ij}^2 \right) / \frac{1}{v} I_j^2)</td>
<td>(\text{M.S}_2)</td>
</tr>
<tr>
<td>Pooled Deviations</td>
<td>(v(n-2))</td>
<td>(\sum_{i=1}^{s} \sum_{j=1}^{n} \frac{y_{ij}^2}{n} - \text{Env. (lin.))} )</td>
<td>(\text{M.S}_3)</td>
</tr>
<tr>
<td>Variety-1</td>
<td>(n-2)</td>
<td>(\frac{s}{i=1} \frac{y_{ij}^2}{n} - \frac{(y_{ij})^2}{n} )</td>
<td>(\text{M.S}_3)</td>
</tr>
<tr>
<td>Variety-(v)</td>
<td>(n-2)</td>
<td>(\frac{s}{i=1} \frac{y_{ij}^2}{n} - \frac{(y_{ij})^2}{n} )</td>
<td>(\text{M.S}_3)</td>
</tr>
<tr>
<td>Pooled Error</td>
<td>(n(v-1))</td>
<td>(\frac{1}{v-1} \sum_{j=1}^{v} \frac{y_{ij}^2}{n} - \frac{(\bar{y}<em>{ij})^2}{\bar{y}</em>{ij}})</td>
<td>(\text{M.S}_3)</td>
</tr>
</tbody>
</table>

(i) Mean: Mean of a variety overall the environments.

(ii) Regression coefficient \((b_1)\): The regression coefficient of the varietal mean on "environmental index was estimated for each genotype in the experiments as follows:

\[ b_1 = \frac{s}{i=1} \frac{y_{ij} I_j}{\frac{1}{j} I_j^2} \]

(iii) Deviation from linearity \((\sigma^2)\): The deviation from linearity was calculated for each individual genotype as the deviation of regression S.S. from S.S. due to genotype over environments as given below:

Deviation \(S_S^d = \frac{\frac{1}{j} \sum_{i=1}^{s} y_{ij}^2 - \frac{y_{ij}}{n}}{\frac{s}{i=1} \frac{y_{ij}^2}{n} - \frac{(y_{ij})^2}{n}}\)
\( \sigma^2_{1j} \) = Deviation S.S./(n-2) for the \( i \)th variety

Test of significance:

The significance of differences among variety means

\( H_0: \mu_1 = \mu_2 = \ldots = \mu_v \) can be tested approximately by the

F-test, \( F = MS_1/MS_3 \) with homogenous deviation mean squares

since \( MS_3 \) is the pooled deviation. If there are no differences among regression coefficients \( (\beta_1 = \beta_2 = \ldots = \beta_v) \), the F-test will be approximately the same as \( F = MS_1/MS \)

(Variety x Environments) on the standard analysis of variance.

The hypothesis that there are no genetic differences among varieties for their regression on the environmental index. \( H_0 = \beta_1 + \beta_2 \ldots + \beta_v \) can also be tested approximately by F-tests, \( F = MS_1/MS_3 \). Thus all linear variances were tested against pooled deviations mean squares \( (MS_3) \). An approximate test of the deviations from regression for each variety can be obtained,

\( F = \frac{\hat{\sigma}^2_{1j}}{\bar{y}} \) for pooled error. The test of significance carried for the stability parameters \( s.a. \) for mean and regression coefficients are as follows:

\[
\text{S.E.} = \sqrt{\frac{\text{Error M.S.}}{\text{Reps}}}
\]

\[
t = (\bar{x}i - \mu)/\text{S.E.}
\]

Thus L.S.E. for mean is equal to S.E. \( \times t.05 \).

The hypothesis that any regression coefficient does not differ from unity can also be tested by the approximate, t-test. The S.E. and \( t \) for regression coefficient were calculated as follows:

\[
\text{S.E. (b)} = \sqrt{\frac{\text{Deviation of MS}}{\text{Reps}}} I_{1j}^2 = b - 1/\text{S.E. (b)}
\]

Thus L.S.E. for \( (b-1) \) is equal to S.E.(b) \( \times t.05 \).