STUDIES OF VARIATION, HERITABILITY AND CORRELATION OF COMPONENTS OF YIELD IN RAGI

(*Eleusine coracana*, Gaertn.)

By

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C E R T I F I C A T E

Certified that this thesis entitled "Studies of Variation, Heritability and Correlation of Components of yield in Ragi (*Eleusine coracana*, Gaertn.)" submitted to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment for the degree of Master of Science in Agriculture, embodies the results of a piece of bonafide research work carried out by Shri G. P. Ranga Rao under my guidance and supervision.

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(G. P. Ranga Rao)

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CHAPTER I

INTRODUCTION

A judicious and successful breeding programme often requires atleast three distinct types of information. Firstly, it is desirable for the breeder to have a sufficient knowledge of the nature and magnitude of variation in the available collection, so as to ensure proper choice of the initial material. In case, ample variation does not exist in the collection at hand, it is but futile to attempt any improvement by selection before enhancing variability by some means or further enriching the collection. Secondly, since variation in any character (s) may be due to both genetic and non-genetic or environmental factors, it is further necessary to assess the contribution of genetic factors and thus determine that part, which is amenable to selection. Thirdly, a knowledge of the association of characters is often helpful and at times imperative.

The ultimate aim of a plant breeder is to obtain high yield. But yield is a very complex character depending upon (1) interaction among several quantitative characters within a plant as well as (2) interaction of the genotype with the environment in which the plant grows. Direct methods to evaluate or select this character is often very difficult and therefore, selection may be facilitated by determining the existence of association of less variable characters with yield.

Accordingly, numerous investigations in this country and abroad have sought to provide such information as aids to breeding of various crops. No attempt has yet been made in this direction in Ragi (Elensine coracana, Gaertn) - an important millet crop of India. Hence, the present investigation was undertaken to obtain such basic information regarding quantitative characters, supposed to have direct or indirect bearing on yield, in Ragi varieties of Orissa and neighbouring States. The specific objects may be stated as follows:-

(1) to estimate the magnitude of genetic variance in the collection of Ragi varieties, (2) to determine heritability of different characters, and phenotypic, genotypic and environmental correlations between pairs of characters and (3) to select certain characters as indicators of high yield in this crop.

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CHAPTER II

REVIEW OF LITERATURE

I. VARIATION AND HERITABILITY:

The quantitative and analytical study of factors concerned in variation owes its origin to Johannson (1909), who demonstrated that both heritable and non-heritable factors contributed to variation in segregating populations and that variation in pure lines was entirely environmental. This observation was subsequently confirmed by Nilsson-Ehle (1909) and East (1916) and thus provided the first method for estimating the magnitude of relative contribution of environment and genotype to the total variation.

Since then several workers (Powers, 1936 and 1942; Hutchinson, Panse and Govande, 1938; Charles and Smith, 1939; Panse, 1940; and Hutchinson, 1940) have tried to assess as precisely as possible the nature and magnitude of the genetic and non-genetic components of variation in different plant species and to further resolve the genetic part of variance into other components. The amount of variation is usually measured and expressed as the variance, which is the mean of squared values of individual deviations from the population mean. Denoting the phenotypic, genotypic and environmental variances by the symbols V_p , V_g & V_e respectively, the relationship among these variances can be expressed as $V_p = V_g + V_e$.

As early as 1918, Fisher suggested that the genetic variance (V_G) itself was contributed by three distinct components: (1) that due to additive effects of genes, (2) the deviation from the additive scheme due to dominance and (3) another part of the deviation from the additive scheme attributable to inter-allelic interaction.

Methods for estimation of the relative magnitude of these components of genetic variance have been further elaborated by Fisher, Immer & Tedin (1932), Hutchinson, Panse and Govande (1938), Panse (1940), Hutchinson (1940), Lush (1948), Mather(1949) and others.

Using the symbols V_A , V_D and V_I to denote the additive dominance and interaction components of genetic variance respectively, the total variance may be expressed as the sum of the components as follows:

$$V_P = (V_A + V_D + V_I) + V_e$$

However, the relationship of the total variance to its components is not so straightforward as indicated by the above equation. Falconer (1960) points out that certain factors like genotypic - environment correlations and interactions between genotype and environment as well as between pairs of components of genotypic variance not only render the relationship shown above more complex, but also complicate the precise and unbiased estimation of the components of variance. This would explain the discrepancy that is often observed among the estimates of component(s) of variance of a particular trait either obtained by different methods or worked out by different investigators.

One of the main objectives of partitioning of total variance into components is to know that part which is heritable and hence amenable to selection. Much of the work on variation of metric or quantitative traits of direct or indirect economic value is in fact aimed in this direction i.e. the determination of heritability of economic traits. In a broader sense, the formula V_G/V_P or V_G/ V_G+V_e has been taken to denote heritability (Burton and Devane, 1953).

However, as proposed by Lush and Panse the ratio of additive genetic variance to total variance is a true measure of heritability. Robinson, Comstock and Harvey (1949) used a method involving estimates of components of variance through a study of biparental progenies to measure heritability in corn. Warner (1952) presented another method of estimating heritability from the variances of three segregating populations. The method has the advantage of not requiring an estimate of environmental or of total genetic variance. Heritability estimates were also calculated by many plant and animal breeders in order to improve the efficiency of selection of superior genotypes (Panse, 1940; Lush, 1949; Robinson et. al., 1949; Mahmud and Kramer, 1951; Burton, 1951; Burton and Devane, 1953; Webel, 1956; and others).

Robinson, Comstock and Harvey (1949) calculated heritability values for different characters in corn and obtained high heritability values for plant height, ear height, husk extension and husk score and low values for number of ears per plant, ear length, ear diameter and yield. Low heritability was obtained by Burton (1951) in Pearl millet for effective tillers, plant height and number of leaves, while high values of heritability were obtained for stem diameter, head length, maturity date and leaf width. In rice, high heritability values have been estimated for plant height, panicle length and flowering period (Nei and Syakudo, 1957; Syakudo and Kobori, 1957; and Toriyama and Futsuhura, 1958). Sakai and Niles (1957) however, obtained a high heritability value for plant height but a low value for panicle length.

Heritability estimates for different characters in wheat were calculated by Sikka and Jain (1958). They observed low heritability for grain yield and number of ears per plant and high values for characters like number of grains per ear, 1000-grain weight and earing date. Murthy and Sethi (1961) in their studies on variability in Barley recorded higher values of heritability for 250-grain weight, ear length, number of days taken for ear-emergence and plant height. Low heritability estimates were recorded for number of ears per plant and yield. Low heritability values for yield were also obtained in case of many other crop plants (in wheat by Davis et. al., 1961; in soybean by Weber and Moorthy, 1952).

In Sorghum, Vishnu Swarup and Chaugale (1962) obtained lower heritability estimates for stem diameter, panicle weight, grain yield, sugar content and reaction to stem borer. Yields of grain and fodder were found to have a high heritability, but the values were lower than those for some other characters like plant height, leaf number, length of peduncle, length of panicle and HCN-content.

Apart from the use of partitioning of total variance of a metric trait in plant breeding, the other aspects of variation like its range of variability and genetic coefficient of variation have also been studied as an aid to the planning of breeding programmes of different crop plants (Wallan, et.al., 1955; Frey, 1959; Philipp, 1960 and Vishnu Swarup and Chaugale, 1962).

II. CORRELATIONS:

The association between two or more variables is usually determined by calculating the correlation coefficients. Phenotypic and genotypic correlations are useful in planning and evaluating breeding programmes.

Several workers in India and abroad have calculated the correlations for different pairs of characters in different crops. Some pertinent reports relating to the correlations of the characters studied under the present investigation are given below:

Number of days for panicle emergence and other plant characters:-

Working with rice, Vibar (1920) noted that flowering duration was positively correlated with the yield of grain. From his extensive studies at the Central Rice Research Institute, Cuttack, Katwe (1958) found that duration is feebly correlated with yield, ear bearing tillers and sterility. But Bollich(1957) obtained a negative correlation between flowering duration and grain yield.

Goulden and Elders (1926), from a study of characters of wheat varieties influencing yield found that the date of heading was most highly correlated with yield. A positive correlation has also been reported in wheat by Hayes, Aamodt and Stevenson (1927), Immer and Ausemus (1931), Bridgford and Hayes (1931) and Moussouros and Papadopoulos (1935). However, in the same crop, Tan (1945) failed to find any correlation between duration and yield while Chinoy (1947) reported a negative correlation between the two characters. In an attempt to determine suitable index as an aid to breeding for high yield in aestivum wheat, Sikka and Jain (1958) observed a low and non-significant correlation between earing date and grain yield. The correlations obtained between earing date and ear number, and earing date and 1000-grain weight were negative and non-significant.

Positive correlations between duration and yield were also recorded by Immer and Stevenson (1928) in oats and Fiuzat and Atkins (1953) in Barley. In Sorghum, Rangaswami Ayyangar et. al. (1935) found that duration was highly negatively correlated with yield. Similar results were also obtained by Joshi, Ramanujam and Sisodia (1961) in Linseed and Murthy and Sethi (1961) in Barley.

The correlations between duration and other plant characters have been reported by several workers. Ramiah (1933) in a few cases of rice found a positive correlation between duration and height, while in other cases negative correlations were obtained. Syakudo and Kobori (1958) reported positive correlation between these two characters. In wheat, a negative correlation was obtained by Bridgford and Hayes (1931). Burton (1951) in Pearl millet found that heading date was positively correlated with leaf number and negatively correlated with plant height. The correlation calculated with the length of internode was of a low order. Vishnu Swarup and Chaugale (1962), from their studies on genetic variability in sorghum found the number of days for panicle emergence to be positively correlated with plant height, stalk diameter, number of leaves, seed weight and fodder yield.

Height of plant and other characters :-

Studying correlation of characters in wheat, Love (1912) and Hayes, Immer and Stevenson (1927) reported a positive correlation between plant height and yield of grain. But Immer and Stevenson (1928) did not find any relation between these two characters. Stewart (1931) found that the height of culms and number of culms were correlated but the value was not significant. Tan (1945) obtained a highly significant correlation of height with the length of earhead and grain yield.

Ganguli and Sen (1941) found height to be significantly correlated with panicle length in rice. Ramiah (1953) also obtained a positive correlation between plant height and yield; and height and ear length.

Whitecomb (1913) and Robertson and Koonce (1936) observed positive correlation between height and yield in barley. But studies by Kiesselbach and Webster (1940) did not indicate any association between the two characters, while a negative and significant correlation was obtained by Choubey (1952).

Positive correlations between plant height and yield of grain have also been reported in Sorghum by Patel (1923), Patel and Patel (1928), Kottur and Chavan (1927, 1928), Martin (1928), Kulkarni (1932), Venkatraman and Subramanyam (1933) and Kolhe (1951); and in Soybean by Weatherspoon and Wentz (1931) and Weber and Moorthy (1952). An appreciable positive association was also recorded by Robinson, Comstock and Harvey (1951) in Corn; Burton (1951) in Pearl millet; Murthy and Roy (1957) in maize; Khem Singh Gill and Gursham Singh (1958) in linseed, and Vishnu Swarup and Chaugale (1962) in Sorghum.

Vishnu Swarup and Chaugale (1962) have also found height to be correlated with other characters like stalk diameter, number of leaves, seed weight and fodder yield in sorghum.

Tiller number and other characters:-

Number of tillers is one of the most important factors in determining yield. In rice, Jacobson (1916) reported that varieties with profuse tillering produced more grains per plant than poor tillering ones. Findings of Copeland (1924), Mahalonobis (1934), Rao (1937), Grant (1941), Ganguli and Sen (1947), Ramiah (1953), Brown (1953), Alim (1957) and Katwe(1957) are in confirmity with the above observation. Ting (1936) concluded from his investigations in rice that tillering capacity was the most important yield component and average panicle weight which seemed to be composed of length of ear and number of seeds per panicle, was next to it. Rao (1937) and Ramiah (1953) obtained negative correlation between tillering and panicle size. Alim and Sen (1957) found that the yield of the spring paddy was positively correlated with the number of tillers. A feeble correlation between the two characters has also been reported by Katwe (1957).

Smith (1925), who studied a series of wheat varieties over a number of years did not find any consistent correlation between number of ears per plant and yield. He, however, found a close relationship between tillering and yield in some years. Smith (1937), working on vulgare wheats found that the number of ears and grain weight were highly correlated. Simlote (1947) found that the number of tillers at harvest was closely correlated with number of ears and weight of straw and positively, but not significantly correlated with 100-grain weight. Csukly (1954) and Sikka and Maini (1962) report that ear number and ear weight have greater influence on yield than the number of tillers.

In Oats, significant negative correlation between tillers per plant and yield per panicle was obtained by Fore and Woodworth (1933). However, a high and significant positive correlation between tillering and yield has been recorded in barley by Choubey (1952), Sandfaer (1953), and Murthy and Sethi (1961); and in corn by Robinson, Comstock and Harvey (1951).

From a preliminary study on the relationship of population and yield in Ragi, Samathuvam (1961) observed increased yield with a wide spacing and attributed it to a greater number of tillers produced by a plant. Thus he indicated the existence of a possible correlation between yield and tillering. Khem Singh Gill and Gursham Singh (1958) and Joshi, Ramanujam and Sisodia (1961) also obtained positive correlation between these two characters in linseed.

Grain yield and other characters :-

Yield is the ultimate criterion which a plant breeder keeps in view in order to evolve improved varieties of crop plants. The association of different quantitative characters with grain yield in cereals, millets and other crops has been studied by several workers. The correlation of yield with duration and height of plant has already been reviewed above.

In rice, Rao (1945) found that the weight of grains per plant was positively and significantly correlated with weight and density of panicle but no significant correlation was obtained with coleoptile length, length of peduncle and number of grains per head. Alim and Sen (1957) working with spring paddy found that number of tillers, length of the panicle and number of grains per panicle were collectively associated with yield.

Waldron (1929) working on wheat observed a significant positive correlation between yield and most of the important economic ancillary characters. Tan (1945) found significant positive correlation of yield with weight of heads, kernel number, leaf width and plant height. Sikka and Jain (1958) noted that the grain yield of wheat was positively correlated with number of ears, number of grains per ear and 1000-grain weight. Beaven (1947) and Murthy and Sethi (1961) from extensive studies in barley found that number of ears, kernel weight and ear weight were also positively related to yield.

In Sorghum, Kottur and Chavan (1927, 1928) determined the correlation between yield and seven other characters and found that the correlations are positive and significant in five cases, viz. height of plant, number of leaves, length of rachis, breadth and weight of the ripe ears, and small and unreliable in two cases, viz. length of peduncle and size of the grain. Patel and Patel (1927, 1928) working on Surat Jowars arrived at the same conclusion. Martin (1928) concluded that the yield of grain sorghums was more closely associated with the number of heads per acre than with the size of head or weight of grain per head. High positive correlations between grain yield of Sorghum with diameter of peduncle, weight, length and thickness of earhead and straw weight were obtained by Rangaswami Ayyangar et. al. (1935). Burton (1951) observed positive correlation with stem number, stem diameter, plant height and leaf width in Pearl millet. Murthy and Roy (1957) obtained high total correlation coefficients between yield of maize and weight of the ear, length of the ear, leaf area and 1000-grain weight and moderate correlation between yield and girth of the ear.

1000-grain weight and other characters:-

From his studies in wheat, Quisenberry (1928) concluded that 1000-grain weight was not as important a factor in determining yield as number of kernels per head and size of head. But significant positive correlation between 1000-grain weight and yield was determined by Waldron (1929) and Bridgford and Hayes (1931). Sikka and Jain (1958) showed positive correlation of 1000-grain weight with ear number and negative correlation with grain number, the value being nonsignificant in both the cases. Simlote (1941) found no correlation between 100-grain weight and weight of straw. Sikka and Maini (1962) obtained a positive correlation between 100-grain weight and grain yield. Rangaswami Ayyangar et. al. (1935) found that 100-grain weight was significantly correlated with yield in sorghum.

Fodder yield and other characters:-

As early as 1908, Scherffius and Woosley from their study in wheat concluded that there was absolutely no relationship between yield of straw and grain, but generally higher yields of straw were associated with the lower yields of grain under normal conditions. In oats, Love (1914) and Leighty (1914) found a direct association between the yield of grain and straw.

But Musgrave (1925) showed the general association of large grain yields with low straw yields in oats; whereas in barley no significant relationship was apparent. Positive correlation between these two characters has also been reported by Martin (1928), Kolhe (1951), Ahmed and Bhatti (1954) in sorghum; and Shafer and Wiggans (1941) in maize.

Vishnu Swarup and Chaugale (1962) working with sorghum found that the yield of fodder was positively correlated with days for panicle emergence, plant height, stalk diameter, number of leaves, and 1000-grain weight but negatively correlated with grain yield.

Earhead length and other characters:-

Correlation between panicle length and yield was reported by different workers . In rice, Ramiah (1953), Alim (1957) and Katwe (1958) have reported positive correlation between panicle length and yield. But Ramiah has noted that there was negative correlation between panicle length and number of tillers. Alim and Sen (1957) reported that length of panicle was positively correlated with number of grains per panicle. In barley, Leasure et. al. (1948) and Choubey (1952) found significant positive correlation between ear length and yield. Venkatraman and Subramanyam (1933) also obtained positive correlation between ear length and grain yield in sorghum. Robinson, Comstock and Harvey (1951) from correlation studies in corn found that ear length and ear diameter bore relatively low positive or negative correlations with each of the characters like plant height, ear height, husk extension, husk score, ears per plant and yield.

Leaf number and other characters :-

In sorghum, Kottur and Chavan (1928), Patel and Patel (1928), Patel (1932) and Kolhe (1951) reported that the number of internodes was positively correlated with yield. Weatherspoon and Wentz (1933) also found significant correlation with yield. Burton (1951) in Pearl millet found leaf number was positively, though not significantly, correlated with internode length. In sorghum, Vishnu Swarup and Chaugale (1962) also obtained significant positive correlation between number of leaves and seed weight.

Leaf area and other characters :-

The relationship existing between leaf area and yield has also been studied by several workers. Davis (1940) from his work on field bean obtained a positive correlation between leaf area and yield. Later on Swanson (1941) studied the relation of leaf area to grain yield in sorghum. He observed that abundant rainfall stimulated leaf development and found that less leaf area was required to produce a bushel of grain in dry year than in a wet year, but the highest yields were obtained in seasons of abundant rainfall. Positive correlation was also reported in groundnut by Mishra (1958) who found that the seed size was significantly correlated with each of the leaf characters, namely leaf length, leaf breadth , length: breadth ratio and product.

Correlation between other characters :-

Venkatraman and Subramanyam (1933) obtained a positive correlation, between peduncle diameter and yield in sorghum.

Rangaswami Ayyangar et al. (1935) observed that the length of peduncle was either not correlated or was negatively correlated with yield. In case of Italian millet, Rangaswami Ayyangar and Hariharan (1937) found that the internodes and heads of the tall plants were longer and hence had a correspondingly greater number and weight of grains, thus showing a positive correlation between internode length and grain yield.

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CHAPTER III

MATERIALS AND METHODS

I. MATERIALS:

A set of twenty seven varieties of Ragi (*Eleusine coracana*, Gaertn.) were used in the present study. The varieties, listed below, mostly represent local types grown in Orissa and some improved types grown in other parts of South India. The investigation was conducted during the Kharif season in 1962-63 in the experimental plot of the Economic Botanist II section, Bhubaneswar.

The varieties used in the present investigation are given below:

1. 55-136-2
2. Bistuguda-1
3. Bistuguda-2
4. Black Ragi
5. Jalantri Ragi
6. Sikiri -I
7. Bhodei Ragi
8. A.K.P.-7
9. Kara Ragi
10. V.Z.M.I
11. 55-98-4
12. N.R.124
13. Co.6
14. Paluria
15. Gauntia
16. Aska
17. Red Ragi
18. A.K.P.6
19. Co.5
20. Padar Ragi
21. Deogaon
22. Prunagunpur
23. P.No.1
24. Punnadi Ragi
25. A.K.P. 3
26. Sodangi
27. Kakeri Ragi

The materials for this study were obtained from the Economic Botanist II Section, Bhubaneswar.

Seeds were sown in nursery beds on the 20th June, 1962 and seedlings were transplanted in the field on the 18th July, 1962. The layout adopted for the experiment was randomised block design with four replications and with a total area of 9.25 cents. The area of each replication was 30'3" x 24'6", i.e. 1.701 cents. Each variety in a replication was grown in a plot containing three rows, each being 7'6" long and 9" apart from the other and consisting of fifteen plants. The distance between plants in a row was 6 inches and only one plant was transplanted per hill. The spacing given between replications was 3 feet and between varieties was 1' 3".

Normal cultural operations such as manuring, weeding, irrigation etc. were conducted in time.

II. EXPERIMENTAL OBSERVATIONS:-

For collecting data on various characters, five plants of each variety in each replication were selected at random. The selected plants were tagged and properly labelled. The average of the five plants per replication for each character observed was used for statistical analysis.

Data on individual plants were recorded on the following eighteen characters:

1. Height of plant :- Plant height was measured at maturity in centimetres from the ground level to the tip of the panicle of the main axis.

2. Duration or Number of days taken for panicle emergence:- The date of emergence of tip of the first panicle of each selected plant was noted and the number of days from sowing to this date was calculated.

3. Ear-bearing tillers:- Only those tillers which bore panicles were counted for each plant. These include both primary and secondary tillers.

4. Leaf number :- The number of nodes per plant in the main axis was counted at maturity. Since the number of nodes corresponds to the number of leaves, the former was taken as a measure of the total number of leaves produced on the main culm.

5. Internode length:- The length of the middle internode of the main culm was measured in centimetres.

6. Internode girth :- This was measured in centimetres with the help of a piece of thread at the middle portion of the internode whose length was recorded.

7. Fourth leaf area:- The leaf area measurements were taken in centimetres. The fourth leaf from the top of the plant in the main axis was measured for both lamina length and width. The breadth of the leaf was taken at the middle of the lamina. The product of the two was taken as an approximate measure of leaf area. This observation was recorded at the time of full emergence of the earhead.

8. Flag leaf area:- The area of the flag leaf of the main axis was similarly obtained as that for the fourth leaf after measuring lamina length and breadth at midpoint.

9. Ratio of lamina to leaf sheath of flag leaf (LL/Ls):- The length of flag-leaf sheath was measured from the topmost node of the main culm to the junctura of the flag leaf and the length of the lamina was measured from junctura to the tip of the leaf and the ratio was determined.

10. Short internode frequency :- In Ragi, the internodes at certain places in the stem are some what shortened and the number of such short or condensed internodes as well as total number of internodes were counted at maturity, and the percentage of short-internode was calculated.

The following characters were noted just after harvest and the observations were recorded in the laboratory.

11. Finger Number per earhead :- The number of ears per plant and the number of fingers in each earhead were counted. Then the average number of fingers per earhead per plant was obtained by dividing the number of fingers by the earhead number.

12. Peduncle length :- The length of peduncle was taken to be the distance from the topmost node to the base of the earhead and was measured in centimetres.

13. Peduncle girth :- The girth of peduncle was measured in centimetres at the middle portion of the peduncle .

14. Earhead length :- This was measured on the ear of the main tiller from the base of the earhead to the tip of the longest finger in centimetres.

15. Earhead weight (Dry):- The weight of earhead includes the weight of about 0.5 cm. stalk with which it was cut. The total weight of earheads per plant was taken in grams, a few days after harvesting.

16. Grain yield per plant (Single plant yield):- The earheads of individual plants were threshed separately with hands and the grain weight was recorded in grams.

17. <u>1000-grain weight</u> :- After threshing the earheads of each plant, 1000-grains were counted out at random from the bulk of the individual plant yield and weighed in grams.

18. <u>Fodder yield per plant</u> :- After removing the ears, plants were allowed to dry for several days inside the laboratory and finally the weight of the individual air-dried plants was recorded.

Out of twenty seven varieties studied in the present experiment, most of the plants of one variety, named Red Ragi, did not reach full flowering till the final harvesting was done on the 5th November, 1963. Only four of the selected plants flowered and reached maturity. The seed setting was also very poor and the earhead and other grain observations thus recorded were insufficient to include in the calculations. Therefore, the variety has been totally eliminated from the study and the data of the remaining twentysix varieties have been subjected to necessary statistical analysis.

III. ANALYSIS OF DATA:

General means, standard error of means, F values, critical difference at 5 per cent level and the range of variation for all the eighteen characters under study were worked out by the method of analysis of variance used for the randomised block design (Panse and Sukhatme, 1954). The percentages of short-internode were transformed into corresponding arcsin values (Snedecor, 1961) and were used for statistical analysis.

<u>Heritability and Genetic coefficient of variation</u>:- For computing the heritability and the genetic coefficient of variation, the

error, phenotypic and genotypic variances for different characters were worked out. The mean sum of squares at error level, worked out by the method of analysis of variance, was taken as the environmental variance. To obtain genotypic variance, the error mean square was subtracted from the varietal mean square and this number was further divided by the number of replications. (Burton and Devane, 1953). Denoting the genotypic and environmental variances by V_G and V_e respectively and the number of replications by N, the expectations of the mean squares may be given as follows:

$V_e + NV_G$ = the expectation of the varietal mean sum of squares.

V_e = the expectation of error mean square

V_G = the total genotypic variance

N = the number of replications of each variety.

Heritability in a broad sense was obtained by using the formula $\frac{V_G}{V_G + V_e}$ (Burton and Devane 1953).

The genetic coefficient of variation was calculated by the following formula suggested by Burton (1952):

$$G.C.V. = \frac{\sqrt{\text{Genotypic variance}}}{\bar{X}} \times 100$$ where

G.C.V. is the genetic coefficient of variation and $\bar{X}$ is the mean of the character.

CORRELATION BETWEEN CHARACTERS :-

Standard statistical procedures were adopted for calculating phenotypic, genotypic and environmental correlations between different characters under study.

The association existing between the different characters studied was estimated by calculating the correlations at three levels.

For calculating the correlation coefficients the formula suggested by Fisher (1954) for environmental and Al-Jibouri, Miller and Robinson (1958) for phenotypic and genotypic correlation coefficients were adopted. The general formula may be expressed as follows:

$$r_{1.2} = \frac{\text{Covariance } 1.2}{\sqrt{(\text{Variance } 1)(\text{Variance } 2)}}$$

The error, phenotypic and genotypic variances and covariances were used for calculating the environmental, phenotypic and genotypic correlation coefficients respectively. The sum of squares and the sum of products at error and varietal levels were taken as error and phenotypic variances and covariances, respectively. The genotypic correlation coefficient was calculated by obtaining the variance and covariance by deducting the sum of squares and the sum of products at error level from their respective values at varietal level.

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CHAPTER IV

EXPERIMENTAL RESULTS

A. Variation and heritability:-

Means, F values, standard errors of means, critical differences and the range of variation for each of the eighteen characters under study, worked out by the method of analysis of variance have been presented in Table 1.

As indicated by the F values, the differences observed amongst the varieties were highly significant in respect of all the characters studied, except for tiller number, internode girth, finger number and earhead weight. These differences were of a very high order for panicle emergence, plant height, leaf number, flag leaf area and earhead length. Table 2 embodies the data regarding the phynotypic values of five important metric traits of individual varieties.

Estimates of phenotypic, genotypic and environmental variances have been recorded in Table 3. Estimates of genetic coefficient of variation and heritability of different characters have been furnished in Table 4.

The genetic coefficient of variation of various characters ranged from the minimum value of 3.92 for finger number to the maximum value of 30.10 for peduncle girth. A few characters, such as panicle emergence, plant height, leaf number, lamina/leaf-sheath ratio of the flag leaf, peduncle girth, earhead length, grain

TABLE- 1

Phenotypic variation in various plant characters

Character	Unit	Range	General mean	Calculated F.value	S.E.	C.D. at 5% level
Panicle emergence.	Days	61.4 -109.4	81.105	101.12**	1.000	2.813
Plant height	Cm.	46.38-114.62	82.143	14.84**	3.203	9.013
Tiller number	No.	0.8 - 5.2	2.342	1.31	0.400	1.125
Leaf number.	No.	7.6 - 25.2	16.467	27.89**	0.214	0.602
Internode length	Cm.	6.26- 12.8	9.663	2.79**	0.512	1.441
Internode girth	Cm.	1.02- 1.94	1.552	0.49	0.173	0.487
Fourth leaf area	Sq.Cm.	20.87- 45.58	34.373	1.73*	2.074	5.836
Flag leaf area.	Sq.Cm.	11.85- 35.06	21.737	25.48**	1.640	4.615
LL/LS of flag leaf	Cm.	1.83- 4.33	2.711	5.86**	0.160	0.450
Short internode frequency.	Arcsin value	26.87- 45.72	37.61	9.52**	1.107	3.120
Finger number/earhead.	No.	4.0 - 6.7	5.275	1.56	0.274	0.771
Peduncle length	Cm.	13.58- 25.35	18.523	3.37**	0.823	2.316
Peduncle girth	Cm.	0.5 - 1.24	0.784	2.32**	0.206	0.579
Earhead length	Cm.	4.58- 13.76	7.621	15.61**	0.370	1.041
Earhead weight	Gms.	3.63- 19.47	9.796	1.16	1.440	4.052
Grain yield/plant	Gms.	2.05- 15.94	7.892	2.39**	1.160	3.264
1000-Grain weight	Gms.	1.96- 3.56	2.747	6.74**	0.09	0.253
Fodder yield/plant	Gms.	2.98- 34.96	15.449	4.74**	2.230	6.275

S.E. - Standard error of means
C.D. - Critical difference

* - Significant at 5%
** - Significant at 1%

TABLE - 2

Estimates of means and standard deviations of different varieties for five important characters

Variety	Plant height		Duration		Leaf number		Earhead length		1000-grain weight	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
55-136-2	63.3	10.24	64.3	4.01	9.8	1.87	6.5	1.78	2.3	0.36
Bistuguda-I.	104.8	12.44	94.8	4.72	19.2	2.58	9.3	1.78	2.8	0.47
Bistuguda -2.	103.6	14.59	94.7	5.36	20.0	1.97	8.8	1.96	2.8	0.41
Black Ragi.	92.8	14.38	90.6	6.99	19.2	3.11	8.8	2.61	2.6	0.88
Jalantri Ragi.	65.2	9.82	67.9	5.22	11.3	2.16	6.7	1.30	2.9	0.58
Sikiri-I	62.3	8.29	63.6	4.48	8.9	2.02	7.2	1.67	2.5	0.54
BhodeiRagi	88.3	14.81	106.5	5.54	23.3	3.68	13.3	1.96	2.2	0.65
A.K.P.7	80.6	13.61	86.2	3.27	17.3	2.23	6.6	1.44	2.9	0.74
Kara Ragi	57.4	13.63	63.7	4.81	9.4	1.54	7.4	1.14	2.7	0.20
V.Z.M.I	82.1	13.04	85.7	4.70	18.0	2.70	6.6	1.64	2.9	0.66
55-98-4	61.6	13.42	66.5	4.72	10.1	2.02	7.1	1.62	2.2	0.44
N.R.124	70.8	15.47	79.3	4.32	16.2	3.28	7.3	1.69	2.9	0.42
Co.6	93.4	16.15	84.9	4.03	18.7	2.62	9.5	2.79	2.7	0.70
Paluria	94.2	13.59	85.6	4.35	18.0	2.94	7.7	1.82	3.0	0.65
Gauntia	85.8	13.90	83.6	3.29	17.0	2.47	7.1	1.70	2.5	0.75
Aska	89.1	11.56	81.1	2.56	18.7	3.04	6.4	1.15	2.5	0.57
A.K.P.6	83.4	6.49	81.3	3.74	18.2	2.32	6.3	1.49	3.0	0.28
Co.5	88.3	9.04	77.5	3.29	17.8	1.61	7.8	1.23	2.8	0.28
Padar Ragi	78.9	7.38	76.4	1.81	17.7	1.81	6.4	1.57	2.9	0.73
Deogaon	88.5	10.51	86.9	3.74	17.3	1.97	7.1	1.54	2.7	0.37
Prunagunupur	80.6	8.01	82.1	3.33	17.5	1.95	6.9	1.45	2.7	0.60
P.No.1	83.8	12.63	81.4	3.03	17.2	2.94	7.4	1.46	2.7	1.04
Punnadi Ragi	80.5	12.66	86.9	4.04	16.7	2.14	7.1	2.27	2.8	0.36
A.K.P.3	82.9	12.63	80.3	3.82	16.1	2.32	6.7	1.62	2.8	0.63
Sodangi	82.8	14.51	79.4	4.47	17.4	1.79	7.4	1.93	2.9	0.52
Kakari Ragi	89.5	9.11	77.3	2.04	16.5	2.44	7.4	1.38	2.6	0.36

TABLE - 3

Estimates of phenotypic, genotypic and error variances for different characters

Character	Phenotypic variance	Genotypic variance Vg.	Error variance Ve.
Panicle emergence	414.49	102.62	4.00
Plant height	609.05	142.001	41.045
Tiller number	0.88	0.052	0.67
Leaf number	51.05	12.305	1.83
Internode length	2.937	0.471	1.052
Internode thickness	0.06	0.005	0.055
Fourth leaf area	29.847	3.157	17.217
Flag leaf area	38.99	6.032	14.86
LL/LS of flag leaf	0.62	0.127	0.11
Short internode frequency	52.62	11.77	5.53
Finger number/earhead	0.473	0.043	0.301
Peduncle length	9.161	1.612	2.712
Peduncle girth	0.395	0.562	0.17
Earhead length	8.562	2.003	0.548
Earhead weight	9.635	0.343	8.263
Grain yield/plant	12.96	1.88	5.42
1000-grain weight	0.221	0.047	0.032
Fodder yield/plant	94.789	18.704	19.973

yield and fodder yield; were found to have a high genetic coefficient of variation while other characters like tiller number, length and girth of internode, peduncle girth, finger number, fourth leaf area, earhead weight and 1000-grain weight showed lower values.

Eight of the eighteen characters studied showed high heritability values. Girth of internode had the lowest heritability and panicle emergence had the highest value. High values of heritability were obtained for panicle emergence, plant height, leaf number, ratio of lamina to leaf sheath of the flag leaf, short internode frequency, earhead length and 1000-grain weight. Yield of fodder and peduncle length had moderately high values of heritability. On the other hand, comparatively lower heritability estimates were recorded for characters like grain yield, tiller number, length and girth of internode, fourth leaf area, flag leaf area, finger number, girth of peduncle and earhead weight.

An attempt was also made to study variation and heritability separately in the three duration groups, viz. early, medium and late. The varieties were classified according to the period for panicle emergence as shown below:-

Early group	Medium group	Late group
55-136-2	N.R. 124	Bistuguda - 1
Jalantri Ragi	Co. 6	Bistuguda - 2
Sikiri I	Paluria	Black Ragi
Kara Ragi	Gauntia	Bhodei Ragi
55-98-4	Aska	A.K.P. 7
	A.K.P.6	V.Z.M. I
	Co.5	Deogaon
	Padar Ragi	Punnadi Ragi.
	Prunagunpur	
	P.No.1	
	A.K.P. 3	
	Sodangi	
	Kakeri Ragi	

TABLE - 4

Estimates of Genetic coefficient of variation and Heritability for different characters

Character	Genetic coefficient of variation	Heritability %
Panicle emergence	12.49	96.24
Plant height	14.49	77.57
Tiller number	9.73	7.20
Leaf number	21.29	87.05
Internode length	7.09	30.92
Internode girth	7.86	1.81
Fourth leaf area	5.16	15.49
Flag leaf area	11.29	28.86
LL/LS ratio of flag leaf	13.13	53.58
Short internode frequency	9.11	68.03
Finger number/ earhead	3.92	12.50
Peduncle length	6.85	37.28
Peduncle girth	30.10	7.67
Ear-head length	18.56	78.51
Earhead weight	5.97	3.98
Grain yield/plant	17.37	25.75
1000-grain weight	7.86	59.49
Fodder yield/plant	27.98	48.35

General means, F values, standard errors of means and critical differences calculated for the three groups separately have been presented in Table 5. The phenotypic, genotypic and environmental variances and the genetic coefficients of variation and heritability estimates have been summarized in Table 6 and Table 7 respectively.

In the early group, the varieties showed significant differences in respect of characters like plant height, 1000-grain weight and flag leaf area. In the medium group, the variation differed significantly in respect of all characters except leaf number and flag leaf area. In the late group, the varieties showed highly significant differences for almost all characters except for flag leaf area and LL/LS ratio of flag leaf.

Considering the genetic coefficient of variation among the three duration-groups, only 1000-grain weight showed a high value in the early group. In the medium group, earhead length and flag leaf area showed greater G.C.V. values, whereas in the late group plant height, leaf number, earhead length and 1000-grain weight were observed to have higher G.C.V. values than others.

As regards difference in the heritability values among the three groups, plant height, 1000-grain weight and flag leaf area showed higher values than other characters in the early group. Panicle emergence and short internode frequency gave moderately low values (35.02% and 32.65% resp.) but very low values were obtained for earhead length (1.66%) and LL/LS ratio of flag leaf (17.93%). In the medium group, higher heritability values were

TABLE - 5

Phenotypic variation in various plant characters of Ragi varieties grouped according to duration

A - Early Group.

Character	Unit	Range	General mean	Calculated F.value	S.E.	C.D. at 5% level
Panicle emergence	Days	61.4 - 72.60	65.25	3.16	1.07	3.28
Plant height	Cm.	46.38- 76.92	61.98	4.44*	2.60	7.98
Leaf number	No.	7.6 - 12.0	9.92	2.13	0.60	1.84
Short internode frequency.	Arc. val.	26.87- 37.49	32.12	2.93	1.25	3.84
Earhead length	Cm.	4.58- 7.86	7.03	0.93	0.38	1.17
1000-Grain weight	Gms.	1.96- 3.03	2.55	8.25**	0.10	0.31
Flagleaf area	Sq.Cm.	13.41- 35.06	25.12	4.08*	2.12	6.51
LL/LS of flag leaf	Cm.	2.48- 4.33	3.36	1.91	0.24	0.74

B - Medium Group

Character	Unit	Range	General mean	Calculated F.value	S.E.	C.D. at 5% level
Panicle emergence	Days	75.2 - 87.0	80.80	9.04**	0.90	2.58
Plant height	Cm.	49.92-101.68	84.93	3.41**	3.40	9.75
Leaf number	No.	12.4 - 20.6	17.48	1.39	0.71	2.04
Short internode frequency.	Arc. val.	33.19- 43.91	37.67	2.98**	1.11	3.18
Earhead length	Cm.	5.38- 10.50	7.30	6.21**	0.34	0.97
1000-grain weight.	Gms.	2.06- 3.56	2.81	4.00**	0.09	0.26
Flagleaf area.	Sq. Cm.	13.21- 34.07	20.77	1.87	1.61	4.62
LL/LS of flag leaf.	Cm.	1.96- 3.50	2.64	2.16	0.12	0.34

contd....

TABLE - 5 (Contd.)

C - Late Group

Character	Unit	Range	General mean	Calculated F. Value	S.E.	C.D. at 5% level
Panicle emergence	Days	82.4 -109.4	91.52	79.07**	0.79	2.32
Plant height	Cm.	67.66-114.62	90.20	11.20**	2.80	8.23
Leaf number	No.	15.6 - 25.2	18.90	11.85**	0.62	1.82
Short inter-node frequency	Arc. val.	34.58- 45.72	40.63	3.80**	1.25	3.67
Earhead length	Cm.	5.50- 13.76	8.50	33.94**	0.38	1.12
1000-grain weight.	Gms.	2.03- 3.19	2.74	11.50**	0.07	0.21
Flag leaf area	Sq. Cm.	11.85- 29.37	21.18	2.05	1.65	4.85
LL/LS of flag leaf	Cm.	1.83- 3.02	2.39	1.20	1.09	3.20

S.E. - Standard error of means

C.D. - Critical difference

* - Significant at 5%

** - Significant at 1%

TABLE - 6

Estimates of phenotypic, genotypic and environmental variances of a few characters in Ragi varieties, grouped according to duration

Character	Phenotypic variance	Genotypic variance Vg.	Environmental variance Ve.
A - Early Group			
Panicle emergence	14.60	2.49	4.62
Plant height	120.83	23.41	27.18
Leaf number	3.15	0.42	1.48
Short internode frequency	18.56	3.06	6.31
Earhead length	0.63	0.01	0.59
1000-grain weight	0.33	0.07	0.04
Flag leaf area	73.68	4.39	18.03
LL/LS of flag leaf	0.44	0.05	0.23
B - Medium Group			
Panicle emergence	31.73	7.055	3.51
Plant height	157.85	27.89	46.26
Leaf number	2.85	0.202	2.04
Short internode frequency	14.83	2.46	4.97
Earhead length	2.86	0.60	0.46
1000-grain weight	0.12	0.02	0.03
Flag leaf area	19.46	13.91	1.87
LL/LS of flag leaf	0.13	0.017	0.06
C - Late Group			
Panicle emergence	201.65	49.77	2.55
Plant height	375.46	85.49	33.50
Leaf number	18.36	4.202	1.55
Short internode frequency	24.04	4.43	6.32
Earhead length	20.03	4.86	0.59
1000-grain weight	0.23	0.52	0.02
Flag leaf area	22.59	2.90	10.99
LL/LS of flag leaf	0.06	0.002	0.05

TABLE - 7

Estimates of genetic coefficient of variation and heritability of a few characters in Ragi varieties grouped according to duration.

A - Early Group

Character	Genetic coefficient of variation	Heritability %
Panicle emergence	2.40	35.02
Plant height	7.79	46.27
Leaf number	6.55	22.10
Short internode frequency	5.41	32.65
Earhead length	1.42	1.66
1000-grain weight	10.19	63.63
Flag leaf area	8.32	70.12
LL/LS of flag leaf	6.54	17.93

B - Medium Group

Character	Genetic coefficient of variation	Heritability %
Panicle emergence	3.27	66.77
Plant height	6.21	37.61
Leaf number	2.40	8.92
Short internode frequency	4.14	33.10
Earhead length	10.54	56.60
1000-grain weight	4.98	40.00
Flag leaf area	17.95	43.55
LL/LS of flag leaf	4.92	14.28

C - Late Group

Character	Genetic coefficient of variation	Heritability %
Panicle emergence	7.70	95.12
Plant height	10.35	71.84
Leaf number	10.84	73.04
Short internode frequency	5.16	41.20
Earhead length	26.00	96.29
1000-grain weight	26.27	89.17
Flag leaf area	8.02	20.87
LL/LS of flag leaf	1.84	3.84

obtained for panicle emergence and earhead length; moderately low values were recorded for plant height, 1000-grain weight and flag leaf area; and very low values were estimated for leaf number and LL/LS ratio of flag leaf. In the late group, characters like panicle emergence, plant height, leaf number, earhead length and 1000-grain weight showed high heritability. But, however, comparatively low values were obtained for short internode frequency and flag leaf area and a very low value was found in case of LL/LS ratio of the flag leaf.

B. Correlations :-

It should be pointed out, at the outset, genotypic correlations could not be established in a large number of cases, where imaginary numbers were obtained. Further, a number of correlation coefficients exceeding unity were reported. Although similar values have been also obtained by previous workers in certain other crops (in Pearl millet by Burton, 1951; in Korean Lespedeza by Hanson, Robinson and Comstock, 1956; and in Linseed by Joshi, Ramanujam and Sisodia in 1961) these must be taken as indicating the experimental error involved in the determination of this parameter.

(a) Correlation between yield and other characters:-

The correlations observed between yield and other characters and the covariances obtained at the three levels have been summarized in Table 8 and Table 8a respectively.

Grain yield was found to be positively and significantly correlated with panicle emergence, plant height, leaf number,

TABLE - 8

Estimates of phenotypic, genotypic and environmental correlation coefficients of grain yield per plant with other characters.

Character pair	Phenotypic r	Genotypic r	Environmental r
Panicle emergence	0.435*	.....	0.101
Plant height	0.592**	.....	0.328
Tiller number	0.047	.....	0.551**
Leaf number	0.632**	.....	0.314
Internode length	0.325	.....	0.104
Internode girth	0.442*	.....	0.240
Fourth leaf area	0.066	.....	0.563**
Flag leaf area	-0.431*	.....	0.285
LL/LS of flag leaf	-0.651**	.....	0.056
Short internode frequency	0.436*	.....	0.001
Finger number/earhead	-0.164	.....	0.266
Peduncle length	0.185	.....	0.345
Peduncle girth	-0.442*	.....	0.420*
Earhead length	-0.171	.....	0.223
Earhead weight	0.952**	.....	0.976**
1000-grain weight	0.649**	.....	0.216
Fodder yield/plant	0.547**	.....	0.556**

* - Significant at 5%

** - Significant at 1%

..... - Imaginary number obtained.

TABLE - 8a

Estimates of phenotypic, genotypic and environmental covariences of grain yield per plant with different characters

Character	Phenotypic covariance	Genotypic covariance	Environmental covariance
Panicle emergence	797.349	761.818	35.531
Plant height	1315.958	948.821	367.137
Tiller number	3.987	-74.886	78.873
Leaf number	406.275	331.061	75.214
Internode length	50.134	31.342	18.792
Internode girth	9.706	- 4.871	14.577
Fourth leaf area	32.813	-375.140	407.953
Flag leaf area	-242.224	-434.716	192.492
LL/Ls of flag leaf	- 46.354	- 49.487	3.133
Short internode frequency	284.620	283.922	0.698
Finger number/earhead	- 10.170	- 35.659	25.488
Peduncle length	50.501	- 48.733	99.234
Peduncle girth	- 7.914	- 17.283	9.368
Earhead length	-44.909	- 73.770	28.861
Earhead weight	266.153	-220.910	487.063
1000-grain weight	27.473	20.608	6.864
Fodder yield/plant	479.435	45.455	433.979

internode girth, 1000-grain weight and short internode frequency at the phenotypic level. Grain yield was also positively correlated both phenotypically and environmentally with earhead weight and fodder yield.

A significant negative phenotypic correlation of yield was observed with flag leaf area, LL/LS ratio of the flag leaf and girth of peduncle at the phenotypic level.

The environmental correlation coefficients revealed that grain yield was positively correlated with all the characters. However, the correlation was significant only with tiller number, fourth leaf area and peduncle girth.

At the genotypic level, yield did not show correlation with any trait as imaginary figures were obtained in all cases.

(b) Panicle emergence and other characters :-

The correlations and the covariances of panicle emergence with other characters have been presented in Table 9 and Table 9-a respectively.

The number of days taken for panicle emergence bore high positive correlation with plant height at all the three levels. Positive and genotypic correlations were also obtained with leaf number, short internode frequency, fodder yield and earhead length. However, these correlations were not significant at the error level. Positive and highly significant phenotypic correlations were obtained with length and girth of internode and 1000-grain weight. The positive correlation obtained with grain yield was not significant at the environmental level but significant at the phenotypic level.

TABLE - 9

Estimates of phenotypic, genotypic and environmental correlation coefficients of panicle emergence with other characters.

Character pair	Phenotypic r	Genotypic r	Environmental r
Plant height	0.821**	0.927	0.703**
Tiller number	-0.388*	.....	0.104
Leaf number	0.921**	0.971	0.299
Internode length	0.565**	.....	0.028
Internode girth	0.602**	.....	0.547**
Fourth leaf area	-0.272	.....	0.169
Flag leaf area	-0.013	.....	0.231
LL/LS of flag leaf	-0.806**	-1.163	0.038
Short internode frequency	0.928**	1.128	0.075
Finger number/earhead	-0.163	.....	-0.077
Peduncle length	-0.005	0.048	-0.131
Peduncle girth	-0.658**	.....	0.054
Earhead length	0.646**	0.708	0.254
Earhead weight	0.348	.....	0.151
Grain yield/plant	0.435*	.....	0.101
1000-grain weight	0.939**	0.089	0.251
Fodder yield/plant	0.801**	1.396	0.112

* - Significant at 5%

** - Significant at 1%

..... - Imaginary number obtained.

TABLE - 9a

Estimates of phenotypic, genotypic and environmental covariances of panicle emergence with different characters.

Character	Phenotypic covariance	Genotypic covariance	Environmental covariance
Plant height	10322.852	10255.205	67.647
Tiller number	-185.49	-198.290	12.8
Leaf number	3350.02	3289.140	60.88
Internode length	493.326	488.985	4.341
Internode girth	75.165	-15.344	90.509
Fourth leaf area	-756.554	-862.412	105.858
Flag leaf area	- 40.34	-137.602	133.568
LL/LS of flag leaf	-324.215	-326.080	1.865
Short internode frequency	3427.312	3400.713	26.599
Finger number/earhead	- 57.381	- 51.015	-6.366
Peduncle length	- 8.032	24.424	-32.456
Peduncle girth	- 66.693	- 67.756	1.063
Earhead length	963.137	934.824	28.313
Earhead weight	550.917	485.858	65.059
Grain yield/plant	797.349	761.818	35.531
1000-grain weight	22.483	15.644	6.839
Fodder yield/plant	3968.106	3892.514	75.592

High negative correlation was found between panicle emergence and LL/LS ratio of the flag leaf at the phenotypic and genotypic levels, but the correlation was positive and non-significant at the environmental level. Negative phenotypic correlations were observed with tiller number and peduncle girth. The value was very high in case of peduncle girth.

The environmental correlation coefficients were not significant except in case of internode girth and plant height.

The genotypic correlations of panicle emergence with 1000-grain weight and peduncle length were very low. Correlation of this trait with many characters could not be established at the genotypic level, the values obtained being imaginary.

(c) Tiller number and other characters:-

The data relating to these associations have been indicated in Table 10 and 10-a.

It was observed that the number of tillers per plant was negatively correlated at the phenotypical level with a large number of characters except LL/LS ratio of the flag leaf, peduncle girth, earhead weight and grain yield per plant. The correlations with the four characters were, however, almost negligible. The negative phenotypic correlation obtained with panicle emergence and plant height was found to be significant at 5 per cent level and were of the same magnitude.

Tiller number did not appear to have any genotypic correlation with any character studied, the values recorded being imaginary. At the error level, it was significantly correlated with

TABLE - 10

Estimates of phenotypic, genotypic and environmental correlation coefficients of tiller number with other characters

Character pair	Phenotypic r	Genotypic r	Environmental r
Panicle emergence	-0.388*	.....	0.104
Plant height	-0.388*	.....	-0.312
Leaf number	-0.318	.....	0.189
Internode length	-0.369	.....	-0.077
Internode girth	-0.337	.....	0.149
Fourth leaf area	-0.144	.....	0.385
Flag leaf area	-0.001	.....	0.280
LL/LS of flag leaf	0.367	.....	-0.105
Short internode frequency	-0.058	.....	-0.001
Finger number/earhead	-0.118	.....	-0.196
Peduncle length	-0.265	.....	0.220
Peduncle girth	0.095	.....	0.355
Earhead length	-0.341	.....	0.085
Earhead weight	0.127	.....	0.684**
Grain yield/plant	0.047	.....	0.551**
1000-grain weight	-0.236	.....	0.124
Fodder yield/plant	-0.152	.....	0.469*

* - Significant at 5%

** - Significant at 1%

..... - Imaginary number obtained.

TABLE - 10a

Estimates of phenotypic, genotypic and environmental covariances of tiller number with different characters

Character	Phenotypic covariance	Genotypic covariance	Environmental covariance
Panicle emergence	-185.490	-198.290	12.800
Plant height	-224.876	-101.710	-123.166
Leaf number	- 53.410	- 69.190	15.78
Internode length	- 14.862	- 10.061	- 4.801
Internode girth	- 1.938	- 5.146	3.208
Fourth leaf area	- 18.495	-117.990	98.495
Flag leaf area	- 2.180	- 68.676	66.496
LL/LS of flag leaf	6.823	8.940	- 2.117
Short internode frequency	- 6.517	- 6.362	- 0.155
Finger number/earhead	- 1.920	4.744	- 6.664
Peduncle length	- 18.840	-41.202	22.362
Peduncle girth	0.448	- 2.398	2.846
Earhead length	- 23.470	-27.376	3.906
Earhead weight	9.311	-111.847	121.158
Grain yield/plant	3.987	- 74.886	78.873
1000-grain weight	- 2.606	- 3.992	1.386
Fodder yield/plant	-34.194	-163.538	129.344

only four characters, such as tiller number, earhead weight, grain yield and fodder yield.

The positive correlation with earhead weight and grain yield was of small magnitude at the varietal level but highly significant at the error level.

The correlations between tiller number and fodder yield were positive and highly significant at the environmental level but negative and negligible at varietal level.

(d) 1000-grain weight and other characters:-

The data relating to these associations have been presented in Table 11 and the covariances in Table 11-a.

Genotypic correlation of 1000-grain weight could be obtained with eight of the total number of characters studied . Of these , the genotypic correlations with LL/LS of the flag leaf and earhead length were negative and that with peduncle length was high and positive. The association with other characters was of a very low order.

At the error level, the corelation of this trait with internode length was positive and with flag leaf area negative, both values being highly significant. Other environmental correlations were too low to be noted.

As to the phenotypic association, 1000-grain weight was found highly positively correlated with panicle emergence, leaf-number, earhead weight and grain yield.

Associations between pairs of highly heritable characters at the three levels have been summarized in Table 12 for the sake of easy reference.

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Associations between pairs of highly heritable characters at the three levels have been summarized in Table 12 for the sake of easy reference.

TABLE - 11

Estimates of phenotypic, genotypic and environmental correlation coefficients of 1000-grain weight with other characters

Character pair	Phenotypic r	Genotypic r	Environ-mental r
Panicle emergence	0.939**	0.089	0.251
Plant height	0.233	0.122	-0.076
Leaf number	0.727**	0.334	-0.022
Tiller number	-0.236	.....	0.124
Internode length	0.023	.....	0.048
Internode girth	0.274	.....	0.663**
Fourth leaf area	0.343	.....	-0.169
Flag leaf area	-0.029	.....	-0.947**
LL/LS of flag leaf	-0.362	-0.666	-0.033
Short internode frequency	0.073	0.241	-0.202
Finger number/earhead	-0.084	.....	-0.082
Peduncle length	0.216	0.876	-0.001
Peduncle girth	0.013	.....	-0.085
Earhead length	-0.370	-0.568	0.032
Earhead weight	0.599**	.....	0.171
Grain yield/plant	0.649**	.....	0.216
Fodder yield/plant	0.075	0.209	-0.035

* - Significant at 5%

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* - Significant at 5%

** - Significant at 1%

..... - Imaginary number obtained.

TABLE - 11a

Estimates of phenotype, genotypic and environmental covariances of 1000-grain weight with different characters

Character	Phenotypic covariance	Genotypic covariance	Environmental covariance
Panicle emergence	22.483	15.644	6.839
Plant height	67.897	74.562	-6.665
Leaf number	19.334	19.759	-0.425
Tiller number	- 2.606	- 3.992	1.386
Internode length	0 . 468	- 0.214	0.682
Internode girth	0.792	- 2.348	3.141
Fourth leaf area	22.093	31.662	-9.568
Flag leaf area	- 2.204	47.430	-49.634
LL/LS of flag leaf	- 3.371	- 3.116	- 0.154
Short internode frequency	6.246	12.672	- 6.425
Finger number/earhead	- 0.679	- 0.073	- 0.605
Peduncle length	7.715	7.753	- 0.037
Peduncle girth	0.034	0.183	- 0.149
Earhead length	-12.741	-13.070	0.328
Earhead weight	21.860	15.189	6.671
Grain yield/plant	27.473	20.608	6.864
Fodder yield/plant	8.657	10.820	- 2.162

TABLE - 12

Estimates of phenotypic, genotypic and environmental correlation coefficients of different characters

		Panicle emergence	Plant height	Leaf Number	LL/LS of flag leaf	Short internode frequency	Earhead length	1000-grain weight
Panicle emergence	P		0.821**	0.921**	-0.806**	0.928**	0.646**	0.939**
	G		0.927	0.971	-1.163	1.128	0.708	0.089
	E		0.703**	0.299	0.038	0.075	0.254	0.251
Plant height	P			0.865**	-0.713**	0.843**	0.414*	0.233
	G			0.916	-1.065	1.007	0.488	0.122
	E			0.426*	-0.151	0.185	0.108	-0.076
Leaf number	P				-0.800**	0.886**	0.498**	0.727**
	G				-1.203	1.125	0.541	0.334
	E				-0.022	0.035	0.269	-0.022
LL/LS of flag leaf	P					-0.801**	-0.234	-0.362
	G					-0.124	0.616	-0.666
	E					-0.198	-0.488*	-0.033
Short internode frequency	P						0.543**	0.073
	G						0.696	0.241
	E						0.105	-0.202
Earhead length	P							-0.370
	G							-0.568
	E							0.032
1000-grain weight								

P = Phenotypic correlation

G = Genotypic correlation

E = Environmental correlation

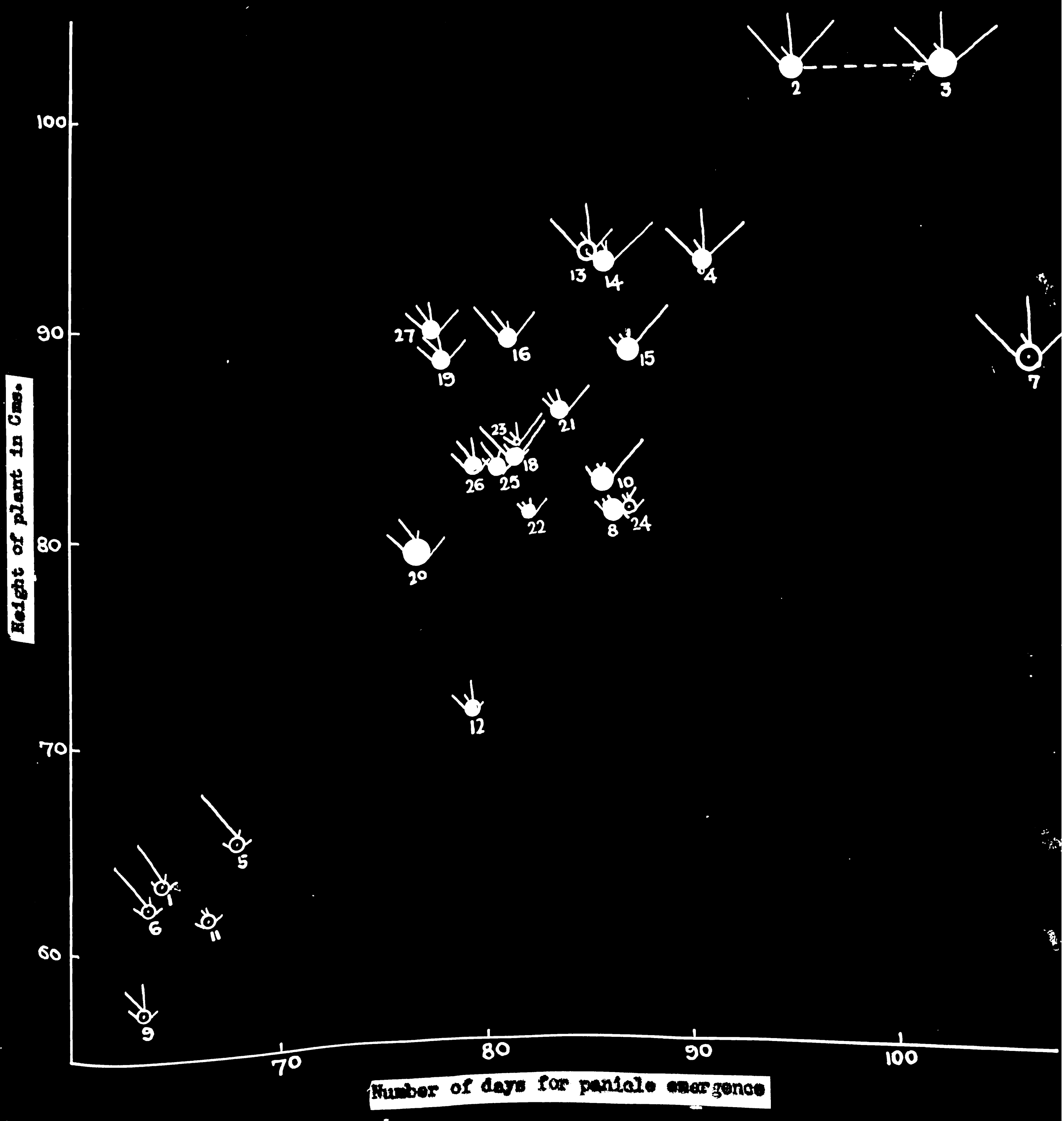
* = Significant at 5%

** = Significant at 1%

In Figure 1, an attempt has been made to represent the association amongst different characters in the form of a pictorialized scatter diagram of the type used by Anderson (1949) for the analysis of introgression. The figure clearly reveals (1) the positive association between days to panicle emergence and certain other characters like plant height, leaf number, earhead length, short internode frequency, fodder yield and grain yield and (2) the negative correlation between panicle emergence and lamina/leaf sheath ratio of the flag leaf. Exceptions to this general trend of character - association are also evident and the characteristic association in case of each variety is clearly shown by the figure. It is further evident from Figure 1 that the early varieties forming a homogenous group are well differentiated from the rest, whereas there is no sharp demarcation between medium and late varieties.

Analysis of a few selected varieities :

A few high-yielding varieties were selected to study the degree of variation in regard to both heritable and non-heritable characters. It was presumed that (1) the variation in highly heritable traits like height, panicle emergence etc. would indicate the degree of purity of varieties and (2) the variation in non-heritable traits would reflect the quantum of environmental influences to which the varieties may be susceptible. Thus it was hoped to obtain at a glance a comparative idea of the variation patterns in the high yielding varieties. The data pertaining to variation in this selected group have been presented


Height of plant in Cms.
100
90
80
70
60
70
80
90
100
Number of days for panicle emergence
2
3
13
14
4
27
16
19
15
7
21
23
26
25
18
10
22
8
24
20
12
5
1
6
11
9

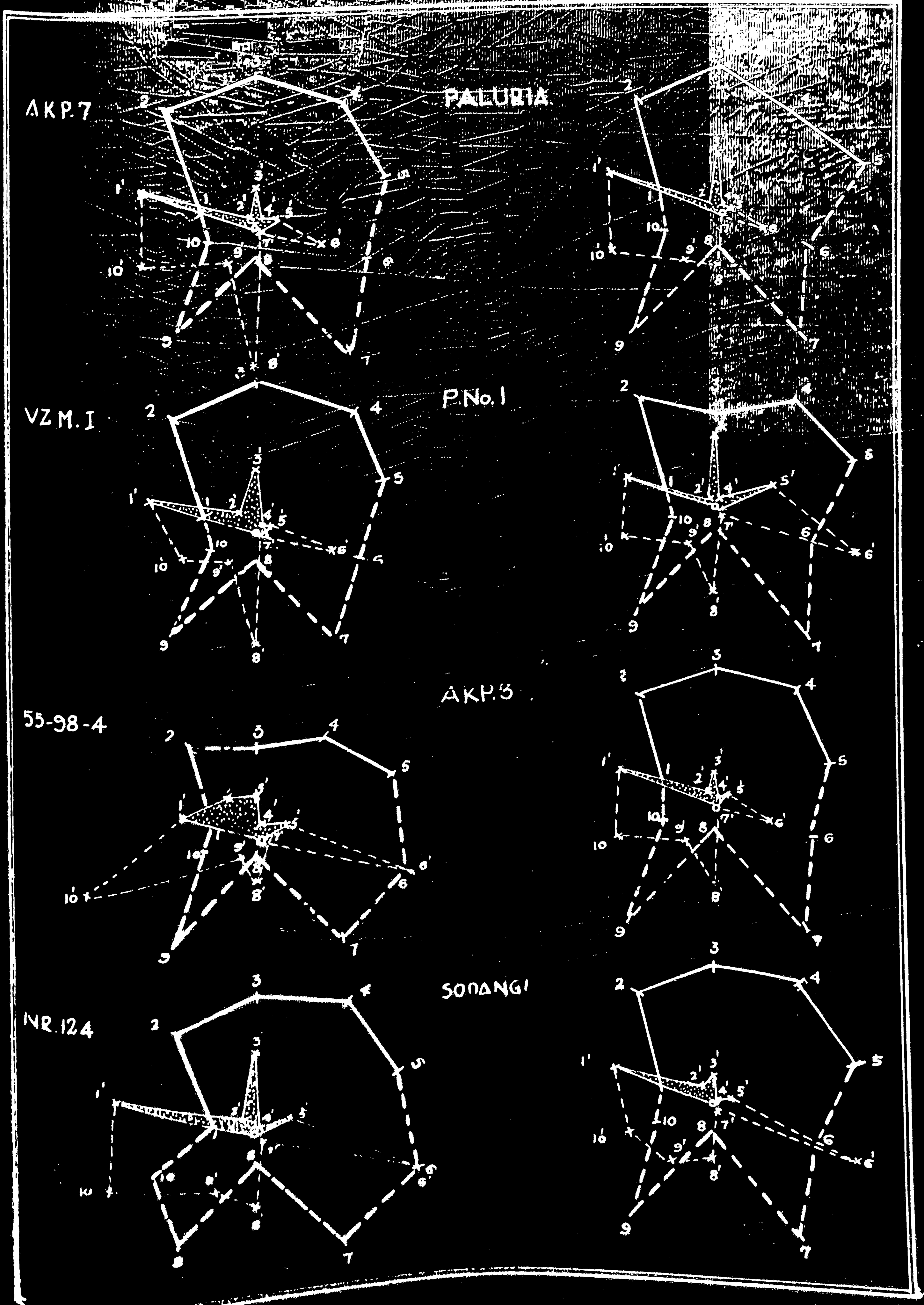
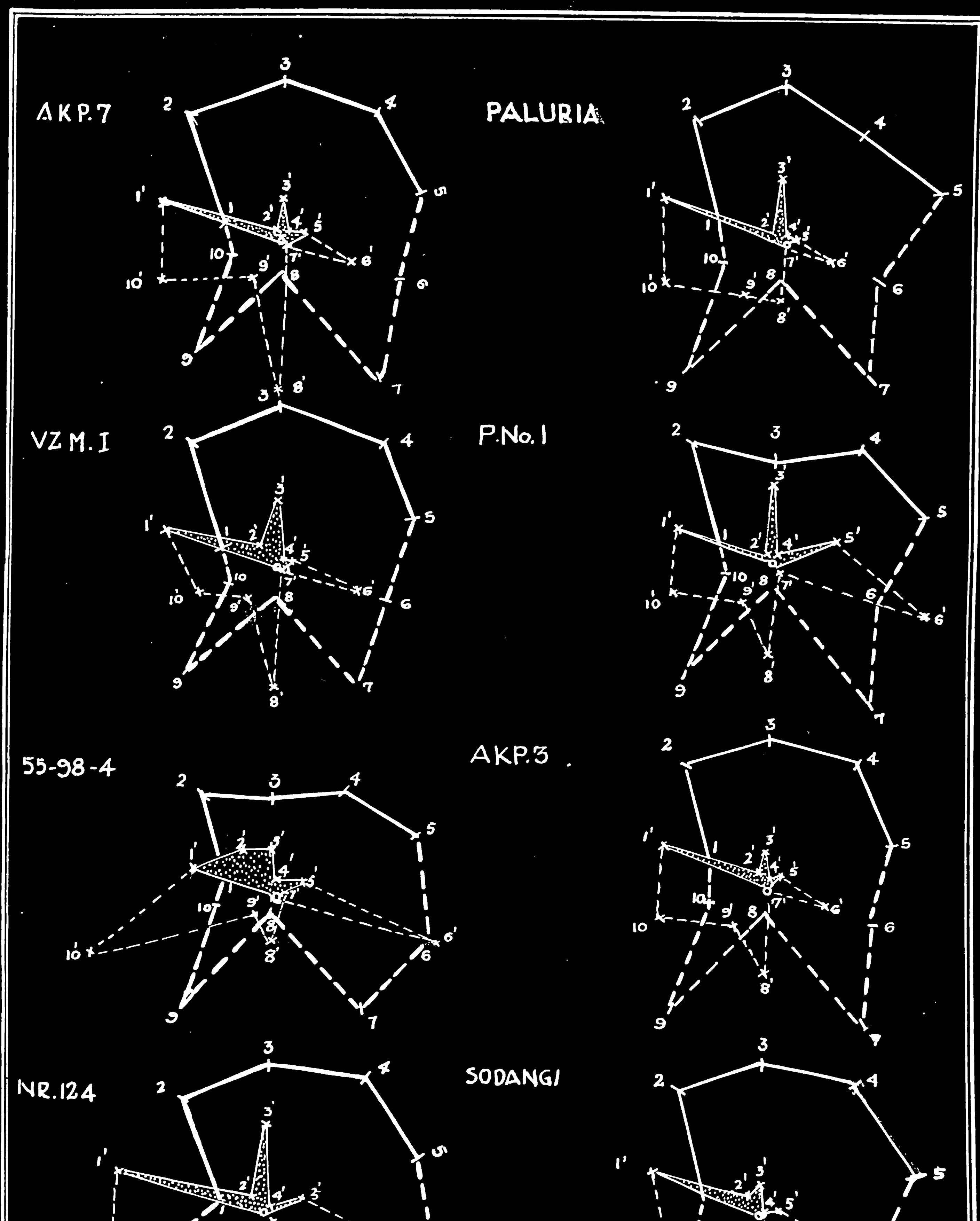

AKP.7
PALURIA
VZM.I
P.No.1
55-98-4
AKP.3
NR.124
SODANGI

FIGURE - 2

Polygons showing means and variances of a few metric characters along axes as given below :

1 - 1'	-	Plant height
2 - 2'	-	Panicle emergence
3 - 3'	-	Leaf number
4 - 4'	-	1000-grain weight
5 - 5'	-	Earhead length
6 - 6'	-	Tiller number
7 - 7'	-	Internode girth
8 - 8'	-	Earhead weight
9 - 9'	-	Finger number
10- 10'	-	Flagleaf area

Details have been given in the text (page 49)


AKP.7
PALURIA
VZM.I
P.No.1
55-98-4
AKP.3
NR.124
SODANGI

graphically in Figure 2. The means of each of the five highly heritable traits have been indicated on axes numbered 1 to 5 by lengths 0-1, 0-2, 0-3, 0-4 and 0-5. The variances of these characters have been indicated along the corresponding axes by lengths 0-1', 0-2' etc. A similar procedure has been adopted with regard to non-heritable traits represented along axes numbered 6-10. Finally, the corresponding parts on different axes have been joined by solid lines in case of heritable traits and broken lines in case of non-heritable traits for obtaining characterstic polygons that afford easy comparison. The polygons so obtained for variances of heritable traits have been further rendered prominent for clearer impression by shading. As can be noted for these variation polygons in Figure 2 the varieties differ appreciably from each other in respect of (1) magnitude of heritable traits, (2) magnitude of non-heritable traits, (3) variation in heritable traits and (4) variation in non-heritable traits. The figure appears to reveal the following salient features: (1) Least genetic variation exists in case of two of the five heritable traits. These are panicle emergence and leaf number represented on axes 2-2' and 4-4' respectively (Fig.2), (2) The variety P.No.1 appears to possess maximum genetic variation as judged by high variances in respect of three highly heritable traits, (3) The least amount of genetic variability is observed in the variety 'Sodangi' , (4) with regard to environmental variation, the maximum is observed in the variety N.R.124. The genetic variability in respect of the heritable traits in the variety 55-98-4 an early duration type are actually much lower than that indicated by total variances. This is because the characters are highly influenced by environment in case of early duration variety (Table 6) .

From these considerations it appears that some varieties of Ragi are genotypically more heterogenous than others. A comparison of the standard deviations of the traits recorded for all the varieties in Table 2 would also substantiate this conclusion. In this context, it may be pertinent to mention that if standard deviation for highly heritable traits are taken as rough guides of gonotypic variation, varieties like "Black Ragi" and Co.6 appear to possess maximum genetic variability (Table 2). On the other hand, the variety 'Kara Ragi' appears to be genotypically uniform. As pointed out earlier some caution is necessary in case of early varieties, while applying total variance of heritable character as a rough index of genetic variability.

CHAPTER V

DISCUSSION

In the present investigation, most of the characters studied showed a wide range of phenotypic variation. The varietal differences in respect of characters, like panicle emergence, plant height, leaf number, flag leaf area, short internode frequency, earhead length, 1000-grain weight, internode length, lamina to leaf sheath ratio of the flag leaf, peduncle length and girth, and yields of grain and fodder were found to be highly significant. The differences were of very high order for the first seven characters mentioned above.

However, the characters being susceptible to environmental influences to varying degrees, it is necessary to know the relative amounts of heritable and non-heritable variation for each character. Only such characters as are least influenced by environment can be of value in (1) ascertaining the nature and extent of genotypic differences among varieties and (2) in basing selection on phenotypic performance. The determination of the range of variation in respect of such characters helps to obtain an idea as to the genetic diversity within a collection of several varieties. However, before any attempt is made to determine genetic diversity within the present collection of Ragi varieties, it is necessary to select such characters by means of a parameter like heritability estimate.

As is evident from the data contained in Table 4, characters such as plant height, duration, leaf number, lamina to leaf-sheath ratio of the flagleaf, short internode frequency, earhead length, peduncle length, fodder yield and 1000-grain weight are highly heritable . Grain yield and flag leaf area showed a moderate degree of heritability. But other characters have yielded much lower heritability estimates. High heritability values for plant height, duration and ear length, were also reported in rice by Nei and Syakudo (1957), Syakudo and Kobari (1957) and Toriyama and Futschura (1958); in barley by Murthy and Sethi (1961); and in sorghum by Swarup and Chaugale (1962). Contrary to the present findings in Ragi, low heritability estimates were obtained for earhead length (Robinson, Comstock and Harvey, 1949) in corn and Sakai and Niles, 1957 in rice) and for leaf number (Burton, 1951 in pearl millet). Low or moderate heritability estimates for grain yield have been reported by several workers in other crops which is in confirmity with the result obtained in the present investigation .(Burton, 1951 in Pearl millet; Robinson, Comstock and Harvey, 1949 in Corn; Sikka and Jain, 1958 and Davis et al; 1961 in wheat; and Weber and Murthy, 1962 in soybean). Swarup and Chaugale (1962), however, report a quite high value of heritability in Sorghum.

Having selected highly heritable characters, the genetic coefficients of variation can now be compared with reference to Table 4 as summarized below:

Genetic variability of characters measured by G.C.V. values

High

1. Pre-flowering duration
2. Plant height
3. Leaf number
4. LL/LS of flag leaf
5. Earhead length
6. Fodder yield

Low

1. Short internode frequency
2. Peduncle length
3. 1000-grain weight.

High genetic coefficient of variation was also obtained by Swarup and Chaugale (1962) in sorghum for plant height, leaf number, length of panicle and yield of fodder. In barley, Murthy and Sethi (1961) also found high genetic coefficient of variation for characters, like plant height, duration and earhead length. The data of Swarup and Chaugale (1962), however, differ in respect of peduncle length and 1000-grain weight which showed higher G.C.V. values in sorghum.

The discrepancy between the present data and those in sorghum may be due to the fact that Ragi varieties, with genotypic difference in respect of characters, like peduncle length and 1000-grain weight have not been included in the present investigation. In that case, an effort should be made for obtaining these varieties.

Burton (1952) points out that both heritable estimate and genetic coefficient of variation should be considered together to obtain information as to the amount of advance to be expected from selection. Rapid progress in selection can be achieved when both the parameters are of a high order (Johnson, Robinson and Comstock, 1955). Applying this criterion to the data in Ragi, it appears that selection would be worth while in case of a few characters only viz. leaf number, earhead length, plan height, panicle emergence and fodder yield. With regard to grain yield, although sufficient genetic variability offers a scope for selection for this trait relatively low heritability would impose some difficulty. The existence of appreciable genetic variation in respect of these characters in certain varieties as indicated in Table 4 and Fig. 2 points to the need of a preliminary selection (rather secondary selection in case of improved strains) before embarking on any hybridization programme.

If the indication as to high degree of genetic variation is confirmed by an independent method of analysis, it would mean that many Ragi varieties are actually mixtures of discrete genotype. This appears plausible since mutations, escaping selection would tend to remain in homozygous state favoured by self-pollination, that is normal for this species. Further, it appears possible that certain varieties may owe their high yield potential to the favourable interaction amongst its component genotypes as reported by Roy (1961) in rice and also suggested by Simmonds (1962). It will be highly interesting to investigate this problem by trying to isolate different genotypes from a variety like P. No.1.

A comparison of the heritable estimates of different characters in early, medium and late flowering varieties (Table 7) appears quite interesting. The heritability values are found to be higher in the late duration group than either early or medium except possibly a few characters like flag leaf area which show a reverse trend. The lower values recorded in the three groups for LL/LS of the flag leaf in constrast to the high value of about 54% estimated for the entire collection (Table 4) appears anomalous. The variation in heritability in different maturity groups could be due to epistatic action of gene(s) for flowering on the penetrance of other genes or the stability of their expression. A second possibility is that the hormonal change associated with flowering may interfere with the expression of vegetative characters in the early flowering plants.

Correlation :-

As has been emphasized earlier, a knowledge of both phenotypic and genotypic correlations is of definite help to the plant breeder. Especially a knowledge of negative genotypic correlations between economically important traits is imperative if the gain accrued by assiduous selection is not to be nullified by correlated responses in unselected traits (Haskell, 1954). Unfortunately, genotypic correlations could not be established between yield and other characters, imaginary numbers being recorded in such cases. Consequently, the phenotypic correlation coefficients only can be used to know the nature of association of grain yield with other characters.

Grain yield was found to be positively and significantly associated with characters like panicle emergence, plant height, leaf number, internode girth, short internode frequency, earhead weight, 1000-grain weight and fodder yield per plant and negatively correlated with flag leaf area, lamina to leafsheath ratio of the flag leaf and peduncle girth. These negative correlations together with the fair degree of heritability of yield suggest that there is not much risk in carrying a straight forward seléction for yield. Correlation studies in sorghum (Swarup and Chaugale, 1962) and rice (Abraham et. al,1956) have also led to the same conclusion. Hence, the application of rather complex selection indices does not appear to be much warranted.

It is necessary to indicate here as to how the associations of yield with other traits observed in the present study compare with those recorded in other crops. A positive correlation between yield and panicle emergence noted in the present study has also been reported in rice (Vibar, 1923), wheat (Goulden and Elders, 1926; Hayes et. al, 1923; and Bridgford and Hayes, 1931) and barley (Fiuzat and Atkins, 1953). On the otherhand, Sikka and Jain (1958) observed a low and non-significant correlation while Rangaswami Ayyangar et. al (1933) found a high negative correlation between these two characters. Since the breeder often aims at combining early naturity with high yield, this particular association is of the utmost significance and hence needs further scrutiny . The imaginary number recorded for genotypic correlation may be taken to mean that no significant association exists at the genotypic level. Further the magnitude of the phenotypic correlation co-efficient (0.435) indicates the probability of combining earliness and high yield in one variety. Conversely, late flowering low yielding types would also be encountered. A reference to figure 2 would clearly point out the occurrence of the latter types, though not the former.

A significant positive correlation of plant height with grain yield is in accord with the observations in rice (Ramiah, 1933), Wheat (Love, 1912; Hayes, et.al, 1927), sorghum (Swarup and Chaugale, 1962; Kulkarni, 1932; and Venkatraman and Subramanyam, 1933), Corn (Robinson et.al, 1951; Murthy and Ray, 1957) and pearl millet (Burton, 1951). But results obtained by Immer and Stevenson (1923)in wheat, and Kiesselback and Webster (1940) in barley did not indicate any such association, while Chaubey (1952) in barley found a negative correlation between the same pair of characters. The magnitude of the phenotypic correlation coefficient estimated in the present study indicates the possibility of evolving dwarf and high yielding varieties. Such plants would resist lodging which has been found to be a problem in some of the varieities of Ragi. Plant height was found to be significantly correlated with number of leaves and seed weight. The present study correborate similar findings of Swarup and Chaugale (1962) in sorghum.

Although tiller number is considered to be an important yield component (in rice by Ganguli and Sen, 1947;

Ramiah, 1953; Brown, 1953; in wheat by Csukly, 1954; Sikka and Maini, 1962; in corn by Robinson et.al,1951 and in ragi by Samathuvam, 1961), only a feeble correlation was obtained between this trait and yield in the present investigation. This observation finds support in the studies of Sikka and Maini(1962), who also failed to find any correlation of grain yield and tiller number. These workers point out a sort of compensatory machanism in the wheat plant in that heavy-tillering types bear smaller and lighter ears and vice versa. This appears to be true of Ragi varieties as well. Further, a negative correlation between yield and number of tillers per plant in oats reported by Fore and Woodworth (1933) also runs counter to the usual belief that heavy tillering leads to high yield.

Grain yield and 1000-grain weight were found to be correlated positively. Similar association has been reported in wheat (Waldron, 1929; Bridgford and Hayes, 1931; Sikka and Jain, 1958; and Sikka and Maini, 1962), sorghum (Rangaswami Ayyangar, et.al, 1935) and maize (Murthy and Roy, 1957). In certain crops like wheat (Sikka and Maini, 1962) and maize (Jugenheimer, 1960), the boldness of grain as measured by Kernel weight is found to be negatively correlated with protein content. Should this relationship exist in Ragi as well, the high yielding bold-grain types may be poorer in protein. This point is of interest for breeding for quality.

Investigations in rice (Ramiah, 1953; Alim, 1957 and Katwe, 1958), barley (Leasure et.al, 1948 and Choubey, 1952), sorghum (Venkatraman and Subramanyam, 1933 and Rangaswami Ayyangar et.al, 1935) and Corn (Robinson et.al, 1951 and Murthy and Roy, 1957) have indicated a significant positive correlation between grain yield and earhead length - an observation, which agrees well with the finding of the present investigation.

The significant and positive correlation of yield with earhead weight and leaf number is corroborated by several investigators in sorghum (Kottur and Chavan, 1928; Patel and Patel, 1928; Weatherspoon and Wentz, 1933; Rangaswami Ayyangar, 1935 and Kolhe, 1951); rice (Pao,1945), wheat (Sikka and Jain, 1958) and Corn (Murthy and Roy, 1957). The high value of the correlation coefficient (0.952) of yield with earhead weight indicates that the latter is a fairly reliable index of yield.

A positive correlation between grain yield and fodder yield was obtained in the present case. The result is in conformity with those obtained by Martin (1928), Kolhe (1951), Ahmed and Bhatti (1964) in sorghum and Shafer and Wiggans (1941) in maize. Swarup and Chaugale (1962), however, found a negative correlation between the same pair of characters in sorghum.

Contrary to the reports on positive correlation between leaf area and grain yield (Davies, 1940 in field bean; Swanson, 1941 in Sorghum; and Mishra, 1958 in groundnut) no appreciable association of yield with area of the fourth leaf was noted in Ragi varieties. Further, a significant negative correlation was obtained between yield and flag leaf area.

The findings of the present investigation support observations in other crops regarding (1) a positive correlation between yield and length of internode in Italian millet(Ayyangar and Hariharan , 1937); and (2) a positive correlation of yield with peduncle length in sorghum (Kottur and Chavan, 1958).

Some of the important genotypic correlations obtained in the present study may be mentioned now. Positive genotypic correlation was recorded for (a) panicle emergence with plant height, leaf number, short internode frequency and fodder yield, (b) short internode frequency with plant height and leaf number and (c) peduncle length and 1000-grain weight. Negative genotypic correlation was observed between panicle emergence and LL/LS of flag leaf. Association at the genotypic level could arise due to (1) linkage or (2) pleiotropic action of one gene or gene-complex of two different characters or (3) a common physiological mechanism underlying the action of two gene or gene-systems controlling two characters. It is beyond the purview of the present investigation to ascribe any particular cause for the genotypic correlations mentioned above . However, the significance of the genotypic association between short-internode frequency and plant height can hardly be ignored. The presence of short internodes appears to be an adaptive mechanism that provides a Ragi plant with higher number of leaves and hence, perhaps, greater photosynthetic ability and at the same time helps to prevent lodging. The association between peduncle length and 1000-grain weight may be helpful in breeding for quality for the reason mentioned earlier.

It may be mentioned here that since grain colour was found to be segregating in one variety namely "Bistuguda", two sublines were established by separating grains into two classes: light brown and deep brown. A comparison between the two sublines viz. Bistuguda-1 and Bistuguda-2, serially numbered as 2 and 3 (Fig.1) thus affords a study of any possible correlated response, i.e. simultaneous and unintentional selection of character (s) along with deliberate selection of a particular trait. A reference to Fig. 1 would clearly show that definite difference appeared between the two sublines in respect of fodder yield. The apparent correlated response of fodder yield to selection for grain colour may be ascribed to one of the following possibilities: (1) a pleiotropic effect of the gene or gene-complex for grain colour on vegetative growth, (2) linkage of genes controlling these two characters and (3)"chance association of genes in the selected parents" (Clayton et.al, 1957).

Again, referring to Fig. 1, no difference could be noted between the two sublines with regard to other metric traits. It is evident that the pictorialized scatter diagram, by indicating different patterns of character-associations in individual varieties, helps to reveal quite well to similarities or differences among the varieties. Considering the trend of character-association as revealed by Fig.1, the variety 'Bhodei Ragi' (No.7 in the figure) - a local unselected material, appears to be quite exceptional in that it combines late maturity with relatively short height and low yield. This variety appears to have originated along a line different from that followed by the remaining varieties. In fact, the long and slender spikes of this variety well resemble those of Eleusine indica and it is possible that introgression with the latter species might have given rise to varieties like "Bhodei Ragi". An analysis of certain key characters of definite taxonomic value is necessary to test the validity of such a hypothesis. Alternatively, indica - like character(s) might have arisen independent of introgression, through mutation.

CHAPTER VI

SUMMARY

1. Phenotypic variation, heritability, genetic coefficient of variation (G.C.V.) and correlation coefficients at three levels i.e. phenotypic, genotypic and environmental, were worked out for different pairs of metric traits supposed to have some direct or indirect bearing on yield in a collection of twentyseven varieties of Ragi.

2. A wide range of phenotypic variability was observed in most of the characters.

3. High heritability estimates were recorded for characters such as panicle emergence, plant height, leaf number, lamina to leaf sheath ratio of the flag leaf, short internode frequency, earhead length, peduncle length, fodder yield and 1000-grain weight. Moderate degree of heritability was noted for grain yield and flag leaf area.

4. High genetic coefficients of variation were obtained for panicle emergence, plant height, leaf number, lamina to leaf sheath ratio of flag leaf, peduncle girth, earhead length, grain yield and fodder yield.

5. When these parameters were estimated separately in three duration-groups, viz. early, medium and late types, greater values were obtained in the late group in respect of all characters except for flag leaf area, for which the highest values of heritability and G.C.V. were recorded in the early and medium duration -

groups respectively and the lowest in the late group.

6. The degree of variation in highly heritable characters of a few high yielding varieties revealed least genetic variation in case of panicle emergence and leaf number. Maximum genetic variation was manifested in the variety P. No.1 and the least amount in the variety 'Sodangi'.

7. From a pictorialized scatter diagram shewing the association of different characters it was observed that the early varieties formed a homogenous group, well differentiated from the rest, whereas no sharp demarcation could be observed between medium and late flowering varieties. A variety called 'Bhodei Ragi' possessing a few wild Ragi traits appeared to have a type of character-association, quite distinct from the rest.

8. Phenotypic correlation coefficients revealed that grain yield was positively and significantly associated with characters like panicle emergence, plant height, leaf number, internode girth, short internode frequency, earhead weight, 1000-grain weight and fodder yield .

9. Negative phenotypic correlation of grain yield was obtained with area and lamina/leaf sheath of the flag leaf and peduncle girth. Plant height was found to be significantly correlated with panicle emergence, leaf number and 1000-grain weight .

10. A feeble correlation obtained between grain yield and tiller number shows that heavy tillering types bear smaller and lighter ears. The magnitude of positive correlations between grain yield and panicle emergence as well as plant height indicated

the probability of combining earliness and high yield in a variety and of evolving high yielding varieties with dwarf, non-lodging character.

11. Genotypic correlations could not be established between grain yield and other characters, imaginary numbers being recorded in such cases. At the genotypic level, panicle emergence was found to be positively correlated with plant height, leaf number, short internode frequency and fodder yield and negatively associated with lamina/leaf sheath of flag leaf. Significant positive correlations were also obtained between short internode frequency and plant height as well as leaf number and between 1000-grain weight and peduncle girth.

12. At the environmental level grain yield was found to be positively correlated with all characters, the values being significant with tiller number, fourth leaf area and peduncle length. Panicle emergence was also positively but not significantly correlated with all characters except plant height and internode girth.

13. Considering the high values of G.C.V. and heritability, selection appears to be fruitful for a few characters like panicle emergence, plant height, leaf number, earhead length and fodder yield.

14. The significant and positive correlation of grain yield with certain characters together with high heritability estimates of the latter indicate that panicle emergence, plant height, leaf number, short internode frequency, earhead weight, 1000-grain weight and fodder yield ~~as~~ are fairly good indices of high yield, of which much reliance can be put on earhead weight.

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B I B L I O G R A P H Y

1.* Ahmed, G.V. and Bhatti, A.G. 1954 Correlation of different morphological characters with fodder yield in sorghums . Proc. 6th Pak.Sci.Congr. III: 2-3.

2. Alim, A. and Sen, J.L. 1957 Intrarelationship of some plant characters with the yield of spring paddy (boro). Pak. J.Sci. Res. 9: 54-57. Pl. Br.Abs. 28(2) 1958. Abst.1713.

3. Al-Jibouri, H.A., Miller, P.A. and Robinson, H.F. 1958 Genotypic and environmental variances and covariances in an Upland cotton of Interspecific origin. Agron.Jour.50: 633 - 636.

4.* Beaven, E.S. 1947 Fifty years of observation and experiment. Duckworth Co. London.

5.* Bollich, C.N. 1957 Inheritance of several economic characters in rice. Diss. Abs. 17: 21983.

6. Bridgford, R.O. and Hayes, H.K. 1931 Correlation of factors affecting yield in Hard Red Spring Wheat. J. Amer. Soc. Agron. 31: 106-117.

7. Burton, G.W. 1951 Quantitative inheritance in Pearl Millet. Agro. Jour.43: 409-417.

8.* Burton, G.W. 1952 Quantitative inheritance in grasses. Proc. 6th International Grassland Congr. 1: 277-283.

9. Burton, G.W. and DeVane, E.M. 1953 Estimating heritability in tall Fescue (Festuea Arundinaceae) from replicated clonal material. Agro. Jour. 45: 478 - 481.

10.*Charles, D.R. and Smith, H.H. 1939 Distinguishing between two types of gene action in quantitative inheritance. Genetics:24: 34-38.

11.* Chinoy, J.J. 1947a Correlation between yield of wheat and temperature during ripening of grain. Nature(Lond).159: 442-444.

12.* Choubey, S.D. 1952 Effect of nitrogen and phosphate on yield and quality of barley varieties with special reference to correlation and regression studies. Thesis, Associateship, I.A.R.I.

13. Csukley, J. 1954 Quantitative analysis of winter yield. Novenytermeles. 3: 77-102. Pl.Br.Abs. 26(3)1956. Abst.2158.

14. Davis, H.F. 1940 The relationship between leaf area and yield of the Field Bean with a statistical study of methods for determining leaf area. J. Amer. Soc.Agron.32: 323-329.

15. Davis, W.H., Middleton, G.K. and Hebert, T.T. 1961 Inheritance of protein, texture and yield in wheat. Crop Science.1:235-238. Pl.Br. Abs. 32(1) 1962.Abst.320.

16.* East, E.M. 1916 Studies on size of inheritance in Nicotiana. Genetics 1: 164-176.

17.* Fisher, R.A. 1918 The correlations among relatives on the supposition of Mendelian inheritance. Trans.Royal Soc. of Edinburgh L.N. 399-433.

18.* Fisher, R.A., Immer, F.R. and Tedin, O. 1932 The genetical interpretation of statistics of the third degree in the study of quantitative inheritance. Genetics. 17: 107-124.

19. Fisher, R.A. 1954 Statistical methods for research workers. 12th edn. Oliver and Boyd. Ltd; London.

20. Fiuzat, Yahya, and Atkins, R.E. 1953 Genetic and environmental variability in segregating barley populations. Agro. Jour. 45: 414-419.

21. Fore, R.E. and Woodworth, C.M. 1933 Analysis of yield in certain oat varieties. Jour. Amer. Soc. Agron. 25: 190-202.

22. Frey, K.J. and Horner, T. 1957 Heritability in Standard Units. Agro. Jour. 49: 59 - 62.

23. Frey, K.J. 1959 The relation between Environmental and Genetic variances for heading dates and plant heights in Oats. Agro.Jour. 51: 545-546.

24. Ganguli, P.N. and Sen, J.L. 1941 Intrarelationship of some plant characters with yield of boro paddy. Ind.Sci.Cong.1941.III: P.256.

25.* Goulden, C.H. and Elders, A.T. 1926 A statistical study of the characters of wheat varieties influencing yield. Sci.Agr.6: 337 - 345.

26. Hanson, C.H., Robinson, H.F. and Comstock, R.E. 1956 Biometrical studies of yield in segregating populations of Korean Lespedeza. Agro.Jour.48: 268-272.

27. Hayes, H.K., Aamodt, O.S. and Stevenson, F.J. 1927 Correlation between yielding ability and reaction to certain diseases and other characters of wheat in rod-row trials. J. Amer. Soc. Agro. 19: 896-910.

28. Hutchinson, J.B., Panse, V.G. and Govande, G.K. 1938 Studies in plant breeding technique IV. The inheritance of Agricultural characters in three inter strain crosses in cotton. Ind. Jour. Ag. Sci.8: 757-775.

29.* Hutchinson, J.B. 1940 The application of genetics to plant breeding. I. The genetic interpretation of plant breeding problems . Jour. Genetics, 40: 271 - 282.

30. Immer, F.R. and Stevenson, F.J. 1928 A biometrical study of factors affecting yield in Oats. J. Amer. Soc. Agro. 20: 1108-1119.

31. Immer, F.R. and Ausemus, E.R. 1931 A statistical study of wheat and oat strains grown in rod-row trials. J. Amer. Soc. Agron.23: 118-131.

32.* Jacobson 1916 Correlation characters of rice plants . Phillliphine Agric. - Rev. 9: 74-119.

33.* Johannson, W. 1909 Elemente der exakten Erblichkeitslehre. Jena: Gustav. Fischer.

34. Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955a Estimates of Genetic and Environmental Variability in soybeans. Agro. Jour. 47: 314-318.

35. Johnson, H.W., Robinson, H.F. and Comstock, R.E. 1955b Genotypic and Phenotypic correlations in soybeans and their implications in selection. Agro. Jour. 47: 477 - 483.

36. Joshi, A.B., Ramanujam, S. and Sisodia, N.S. 1961 Breeding for quantitative characters in Linseed II. Genetic correlations and correlated genetic response with special reference to tillering and earliness. Ind. J. Gen. Pl. Breed. 21: 122-128.

37. Kalton, R.R. et. al. 1952 Parent inbred progeny relationships of selected orchard grass clones. Agro. Jour. 44: 481-486.

38. Kalton, R.R. 1958 Breeding of rice strains for different levels of fertility. I.A.R.I. Thesis.

39. Khem Singh Gill and Gursham Singh 1958 Correlation studies in a cross between K_2, an improved variety and a local Punjab variety of linseed. I.J. Gen. Pl. Breed. 18: 210-219.

40.* Kiesselbach, T.A. and Webster, O.S., and Quisenberry, K.S. 1940 Varieties of oats, barley and spring wheat in Nebraska. Neb. Ag. Expt. Sta. Bull. 328.

41.* Kolhe, A.K. 1951 Study of correlations of East Khandesh jowars (Andropogan sorghum). Poona agric. Colleg. Mag. 42: 10-14.

42.* Kottur, G.L. and Chavan, V.M. 1927 Correlation between yield and some prominent characters in Andropogan sorghum. Poona agr. Colleg. Mag. 19: 25-29.

43.* Kottur, G.L. and Chavan, V.M. 1928 Selections in jowars of Bombay. Bombay Dept. Agric. Bull. 151: 9-15.

44.* Kulkarni, R.K. 1932 Type and variability in Maldandi jowar. Poona agric. Colleg. Mag. 24: 51-54.

45. Leasure, J.K., Down, E.E. and Brown, H.M. 1948 The correlation of certain characters with yield in barley strains. J. Amer. Soc. Agron. 40: 370-373.

46.* Leighty, C.E. 1914 Variation and correlation of oats. Cornell Univ. Agr. Exp. Sta. Memoir No. 4.

47.* Love, H.H. 1912 Studies of variation in plants. Cornell.agric.Expt.Stn.Bull.297: 593 - 597.

48. Love, H.H. 1914 Relation of yield of straw and grain in oats . Jour. Amer. Soc. Agron.6: 97-108.

49.* Lush, J.L. 1940 Intra sire correlations or regressions of offspring on dams as a method of estimating heritability of characteristics. Proc.Amer.Soc.An.Prod.33: 293-301.

50.* Lush, J.L. 1945 Animal breeding plans.Ames: Iowa State College Press.Ed,3:443 pp.

51.* Lush, J.L. 1949 Heritability of quantitative characters in farm animals. Proc. 8th Int.Con.Genetics.1948 Heriditas Suppl. Vol. 356-375.

52. Mahmud, Imam, and Kramer,H.H. 1951 Segregation for yield,height and maturity following a soybean cross. Agro. Jour.43: 605-609.

53. Martin, J.H. 1928 Plant characters and yield in sorghum. J.Amer. Soc. Agro. 20: 1177-1182.

54. Mather, K. 1949 Biometrical genetics.London: Mathuen & Co.

55. McDonald, E.D.et.al.1952 Intrarelationship and relative variability among S_1 and open pollinated progenies of selected brome grass clones. Agro. Jour. 44: 20 - 25.

56. Mishra, S.P. 1958 Correlation studies in ground nut. Ind. J. Genet. Pl. Breed.18: 49-53.

57. Moussouros,B.G.and Papadopoulos, D.C. 1935 Correlating yield with phenological averages to increase efficiency in wheat breeding. J. Amer. Soc. Agro. 27: 715-723.

58. Murthy, G.S. and Roy, N.N. 1957 Study of the Indian collection of maize varieties with special reference to the relationship between yield and other characters. Ind.J.Gen.Pl.Br.17: 73 - 89.

59. Murthy, G.S. and Sethi, K.L. 1961 Variability in quantitative characters in Barley . Ind. J. Agron. VI: 37-51.

60. Musgrave, G.W. 1925 Correlation of yield of straw and grain in oats in new Jersey. J. Amer. Soc. Agr.17: 769-775.

61. Nei, M. and Syakudo, K. 1957 Heritability and genetic correlation in F_2 of some agronomic characters in rice plant. Jap. Journ. Genet: 32. 235-241. Pl.Br.Abs.29(2):1959.Abst.1569.

62* Nilsson-Ehle, H. 1909 Kreuzung untersuchungen an Hafer und weizem lunds Univ.Arsskr. N.F.Afd.2,Bd.5,Nr.2 pp.1 - 22.

63. Panse,V.G., and Sukhatme, P.V. 1954 Statistical methods for agricultural workers. I.C.A.R. Publication.

64. Pao, T.P. 1945 Study on the application of analysis of covariance and correlation formulae to quantitative characters in rice. New Agric. J.Fukien.4: Nos.1-4: P.9 - 24. Pl.Br.Abs.20(3)1950: Abst. 1660.

65.* Patel, G.B. 1923 Characters of an ideal jowar plant. Poona agric. Coll. Mag.15: 116-117.

66.* Patel, M.L., and Patel, G.B. 1928 Studies in jowars of Gujarat.I. The jowars of the Surat district. Mem.Dept.Agric.India,Bot.,16: 1-57.

67. Philipp, L. 1960 Studies of variability of yield composition in spring wheat. Z.Acku-u.Pfl.Bau: 111:334-363. Pl. Br. Abs. 31(3)1961.Abst.3229.

68.* Powers, Le Roy 1942 The nature of the series of environmental variances and the estimation of the genetic variances and the geometric means of crosses involving species of Lycopersicon. Genetics. 27: 561-575.

69. Quisenberry,K.S. 1928 Some plant characters determining yields in fields of winter and spring wheat in 1926. J.Amer. Soc.Agro.20: 492 - 499.

70. Ramanujam, S. and Sushil Kumar 1963 Correlation studies in two populations of Vetiveria. Ind. J. Genet. Pl. Br. 23: 82-89.

71. Ramiah, K. 1933 Inheritance of flowering duration in rice. Ind. J. Agr. Sci. 3: 377-410.

72. Ramiah, K. 1933 Inheritance of plant height in rice. Ind. J. Agr. Sci. 3: 411 - 432.

73. Ramiah, K. 1933 Genetic association between duration and plant height and their relationship to other characters. Ind. J. Agri. Sci. 3: 433 - 445.

74. Ramiah, K. 1953 Rice breeding and genetics; I.C.A.R. Publication, 1953.

75. Rangaswami Ayyangar, G.N. et. al. 1935 The relation of some plant characters to yield in sorghum. Ind. J. Agri. Sci. 5: 75-100.

76. Rangaswami Ayyangar, G.N. and Hariharan, P.V. 1937 Inheritance of height of plants in the Italian millet. Mds. Agric. J. 25: 141-143.

77.* Robertson, D.W. and Koonce, D. 1936 Barley production in colorado. Colo. Agr. Expt. Sta. Bull. 431.

78. Robinson, H.F., Comstock, R.E. and Harvey, P.H. 1949 Estimates of heritability and the degree of dominance in Corn. Agr. Jour. 41: 353-359.

79. Robinson, H.F., Comstock, R.E. and Harvey, P.H. 1951 Genotypic and phenotypic correlations in corn and their implications in selection. Agr. Jour. 43: 282-287.

80. Sakai, K.I. and Niles, J.J. 1957 Heritability of grain shedding and other characters in rice. Agriculturist 113: 211-218.

81. Samathuvam, K. 1961 Preliminary studies on population and yield in Ragi. Mds. Ag. J. XLVIII(48): 185-186.

82. Sandfaer, J. 1953 Arsskb, K. Vet. og. Landb Hojak 1953 (Studies on the basis of selection for yield in cereal crops) 1-14. Pl. Br. Abs. 24(1) 1954. Abst. 182.

83.	Scherffius, Woosley.	1908	Wheat Ky. Agr.Exp.Sta.Bull.135.
84.	Shafer, J. and Wiggans, R.G.	1941	Correlation of total dry matter with grain yield in maize. J.Amer.Soc.Agr.33: 927-932.
85.	Sikka, S.M. and Jain, K.B.L.	1958	Correlation studies and the application of discriminant function in aestivum wheats for varietal selection under rainfed condition. Ind.J.Gen.Pl.Br. 18: 178-186.
86.	Sikka, S.M. and Maini, N.S.	1962	Correlation studies in some Punjab wheats. Ind. J.Gen. Pl.Br. 22: 181-186.
87.	Simlote, K.M.	1947	An application of discriminant function for selection in durum wheats. Ind. J.Agr.Sci. 17: 269-280.
88.	Smith, R.W.	1925	The tillering of grass as related to yield and rainfall. J. Amer. Soc. Agron.17: 717-725.
89.*	Smith, H.F.	1936	A discriminant function for plant selection. Ann. Eng.7: 240-250.
90.	Swanson, A.F.	1941	Relation of leaf area to grain yield in sorghum. J. Amer.Soc.Agro.33: 908-914.
91.	Syakudo, K. and Kobori, O.	1957	Studies on the inheritance and quantitative function of genes determining heading period. Pl.Br.Abs.1957.Vol.27(3).Abst.3020.
92.	Tan, M.T.	1945	The correlation on some important agronomic characters in wheat. J.Agric.Ass.China.182: 3-4. Pl.Br.Abs.14(4).1949.Abst.2469.
93.	Ting, V.	1936	Investigation on rice plant characters with reference to breeding. J.Agri.Ass.China. 144: 1-14. Pl.Br.Abs.8(2) 1938: Abst.516.
94.*	Toriyama, K. and Futsuhara, Y.	1958	Estimates of heritabilities in individuals and lines of rice. Jap. Jour. Breed. 7: 208-212.

95. Venkatraman, S.N., and Subramanyam, P. 1933 Biometric studies in grain sorghum. The relation of yield to other characters in Andropogan sorghum. Ind. J. Ag. Sci. 3: 609 - 625.

96. Vishnu Swarup and Chaugale, D.S. 1962 Studies on genetic variability in sorghum I. Phenotypic variation and its heritable component in some important quantitative characters contributing towards yield. Ind. J. Gen. Pl. Breed. 22: 31-36.

97. Vishnu Swarup and Chaugale, D.S. 1962 Studies on genetic variability in sorghum II. Correlation of some important quantitative characters contributing towards yield and application of some selection indices for varietal selection. Ind. J. Gen. Pl. Br. 22: 37-44.

98. Waldron, L.R. 1929 A partial analysis of yield of certain common and durum wheats. J. Am. Soc. Agron. 21: 295-309.

99. Wallace, A.T., et. al. 1955 Variability in Letoria and Fulwin Oats. Agr. Jour. 47: 178-181.

100. Warner, J.H. 1952 A method for estimating heritability. Agr. J. 44: 427-430.

101. Weatherspoon, J.H. and Wentz, J.B. 1933 A statistical analysis of yield factors in soybeans. J. Am. Soc. Agron. 25: 524-528.

102. Weber, C.R. and Moorthy, B.R. 1952 Heritable and nonheritable relationships and variability of oil content and agronomic characters in the F_2 generation of soybean crosses. Agr. Jour. 44: 202-209.

103. Whitecomb, W. 1913 A study of statistical method with barley. J. Amer. Soc. Agron. 5: 83-101.

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* - Original not seen.

104.	Anderson, E.	1949	Introgressive hybridization. New York, Willy and Sons.
105.	Falconer, D.S.	1960	Introduction to quantitative genetics. The Ronald Press Co., New York.
106.	Huskell, G.	1954	Correlated responses to polygenic selection in animals and plants. Amer. Nat. 89: 5-20
107.	Jugenheimer, R.W.	1958	Hybrid Maize Breeding and seed production. F.A.O., Rome.
108.	Roy, S.K.	1960	"Interaction between rice varieties". J. Genetics. 57: 137-52.
109.	Simmonds, N.W.	1962	Variability in crop plants, its use and conservation. Biol. Rev. 37: 422-465.
110.	Snedecor, G.W.	1956	Statistical methods. Iowa state college press, Ames, Iowa, U.S.A.

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