ESTIMATION OF GGENETIC VARIABILITY IN A SORGHUM POPULATION (*Sorghum bicolor* L. Moench)

BY

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CHAPTER I

INTRODUCTION

The plant breeder aims at selecting superior genotypes for constituting an improved or agronomically useful population which can be further used in the breeding programme. For selection to be effective, broad-based random-mating populations with wider range of genotypes have to be used. Development of random mating populations has been made possible in self-fertilized crops such as sorghum (Sorghum bicolor L. Moench) by the discovery of male-sterile genes (MS). The MS_7 discovered in Nigeria by Andrew and Webster (1971) has made sorghum improvement successful as in maize (Zea mays L.) because the population improvement techniques involving recurrent selection, used extensively for maize improvement, are now being applied to sorghum.

Several breeding schemes are available for population improvement through recurrent selection. The choice of which one to use depends on the objective of the breeder and the resources available to him S1 family selection has been recognised as the most promising breeding method in sorghum (Eberhart et al., 1967; Dogget and Eberhart, 1968; Eberhart, 1971; Dogget, 1972; Gardner, 1972; Jan-Orn, 1973, and Eckebil , 1974) This method is commonly practised by sorghum breeders because of the ease of manipulation of the plants and interpretation of the genetic variances among S_{-1} lines (Jan-Orn, 1973).

Stratified mass selection and S_{-1} progeny testing are currently being used at the Institute for Agricultural Research (Samaru) for the random-mating populations developed for the population improvement scheme initiated in 1974.

Genetically broad-based sorghum has been noted for its wealth of variability in almost all plant characters. Knowledge of the nature of the genetic variability expressed from generation to generation enables the breeder to discriminate effectively among individuals or families. Unlike qualitative characters which can be recognised and classified easily, the measurement of quantitative characters is in continuous units. Many genes are generally involved, both directly and indirectly, in governing a quantitative character. And character expression is very sensitive and greatly influenced by environment. Therefore, to get information about a quantitative character one has to deal with statistics estimated from replicated experiments over various environments. Information can be obtained from first order statistics (means) and second order statistics (variances). These can be used further to estimate genetic variances and for predicting possible future performances of heterogeneous populations.

The objective of this study was to obtain genetic information on several quantitative traits in a genetically broad-based sorghum population, YZC using S-1 lines. Estimates of genetic variance, correlation coefficients, heritability and expected gain from selection were obtained for the lines also.

CHAPTER II

LITERATURE REVIEW

The use of exotic germplasm to increase genetic variability and to introduce new sources of possible heterosis has made sorghum wealthy of variability in almost all plant characters. The variability present in various plant traits has been reported by several workers in the world. Only some of these have studied the range of genotypic variation in various plant characters and their relationships in random mating populations.

Genetic variability

In a study of genetic variability in a collection of seventy divergent varieties including indigenous as well as exotic types, Swarup and Chaugale (1962) observed a wide range of phenotypic variability in panicle emergence, plant height and length and weight of panicle. This study revealed that a large portion of the phenotypic variability was genetic.

Basu (1971) studying days to flowering, plant height, panicle length and width, and grain yield in a winter season sorghum cross found that variability of all characters in F_2 was more than that of parents. He also found that increase in variability was quite marked in plant height, days to flowering and panicle width.

In an investigation for plant height, number of days to 50% flowering, number of leaves per plant, grain yield per plant, 1000-grain weight, grain number per panicle and protein content in Sorghum vulgare, Vasudeva (1973) found that variances due to general combining ability and specific combining ability were significant for all characters while variances due to reciprocal effects were significant for days to 50% flowering only. He found that additive gene action was more important for plant height, leaf number, days to 50% flowering and grain yield, while dominant gene action was more important for panicle length, grain number, and 1000-grain weight. Overdominance was recorded for height, leaf number, flowering and grain yield.

In a study of 30 indigenous grain sorghum varieties Abu-el Gasim and Kambal (1975) reported a wide range in variability, particularly grain yield, number of grains per head, 1000-grain weight, head exertion (head emergence) and leaf area. Estimates of genotypic variance ranged from 0.82 for head diameter to 1011.12 for plant height. The genetic coefficient of variation values ranged from 17.7% for leaf width to 45.6% for grain yield.

Among 30 lines of sorghum studied by Naphade and Ailwalar (1978), the coefficient of variation of seven characters ranged from 10.2% for leaf number to 30.4% for plant height, 22.9% for grain yield and 27.8% being recorded for panicle length.

Also in the same year, Eckebil et al., (1977) tested 200 S_{-1} families from each of three random populations of sorghum and found that populations NP5R has more genetic variability for yield and most other characters than population NP3R. NP7BR, a genetically narrow-based population, yielded the same as NP5R but had the lowest variability for height and number of days to flowering.

Genetic variability in a random-mating population (PP9) was investigated for yield, days to flowering and lodging by Bittinger and Cantrell (1979). They reported estimates of additive genetic variance and dominance deviation for each trait. Additive variance was found to be greater than dominance variance for all traits except yield.

Correlations

Relationship among traits of economic importance is valuable in making decisions in breeding programmes, especially for selection purposes. Sieglinger (1936) recognised in sorghum the association between number of leaves, size, diameter and height of stalk, and vigour of plant. He also showed that varieties have different numbers of leaves. Quinby and Karper (1945) reported linkage between a height gene in milo and the maturity gene, Ma. Later in 1972 Quinby reported that maturity genes control time of floral initiation and in addition influence rate of growth as measured by leaf size and panicle weight.

Goud and Vasudeva (1976), working with 50 true breeding lines selected from mutants for height induced by gamma irradiation in GM 2-3-1, reported that plant height was positively correlated, genotypically and phenotypically, with node number and internode length; and node number and internode length were positively correlated. These authors further stated that gene dw_4 affected panicle length, dw_1 and dw_2 controlled internode length with cumulative effect and operate pleiotropically on leaf characters, and dw_3 affected number of nodes, internode length and panicle length. In an earlier study of a single height gene (Dw_3) of Sorghum bicolor at a 1-dwarf and 2-dwarf height levels, Campbell and Cassady (1969) reported that the state of Dw_3 gene influenced main head yield, tiller yield, total yield, kernels per head, heads per plant; 1000-kernel weight, head length as well as culm height; length, width and area of fourth leaf blade. They found that node number was not affected which indicated that maturity was not influenced by this gene.

Martin (1928) reported that grain yield in sorghum was correlated more closely with the number of heads per hectare than with the size of head or weight of grain per head. Anderson and Webster (1959) reported that when plant populations were equal, variations in yield were dependent upon differences in the number of heads per plant and weight of grains per plant.

Stickler and Pauli (1961) found that variations for all three yield components had an impact on the expression of total grain yield, but that number of seeds per head and seed weight generally underwent greater changes than did the component number of heads per unit area and therefore had a greater effect on total yield.

Positive genotypic correlations were reported between 100 seed weight and grain yield (Beil and Atkins, 1965); yield per unit area and grain yield per head, height and threshing percentage (Eckebil et al., 1977); plant height and node number, node number and panicle length (Goud and Vasudeva, 1976); head length and spike length and 100 seed weight (Mandouh et al., 1971). Negative genotypic correlation was reported between days to flowering and yield by Eckebil et al., (1977).

Positive phenotypic correlations were reported between seed weight and grain yield; yield per unit area and grain yield per head by Swarup and Chaugale (1962) and Eckebil et al., (1978); respectively. Ali-Khan and Weibel (1969) obtained a negetive phenotypic correlation between 100 seed weight and grain yield in 'Redlan' x 'Plainsman'. Many more studies have shown positive correlations between yield and plant height, number of seeds per head, days to flowering, seed weight, panicle size and leaf size (Liang et al., 1969; Abu-el-Gasim and Kambal, 1975; Jan-Orn et al., 1976; Naphade and Ailwalar, 1978; Vasudeva and Goud, 1978; Choudhari and Mahojan, 1979;

Goud and Asawa, 1979). Negative phenotypic correlations among traits were reported by Panchal et al., (1979) who concluded that tall varieties may not produce longer and wider heads having heavier grains, and that linkages among the gene governing positively and closely related characters could be expected.

Heritability

The study of hereditary and environmental components of variation had its beginning in the work of Johannsen (1909), East (1916) and Nilsson-Ehle (1909). Johannsen demonstrated that both heritable and non-heritable agencies contributed to somatic variation in segregating populations and that variation in pure-lines was entirely environmental. East and Nilsson-Ehle further confirmed the work of Johannsen and demonstrated how such results conformed with the concept of Mendelian genetics.

Fisher (1918) first partitioned genetic variance into three components; that due to additive effects of genes, that due to dominance deviations from the additive scheme, and that due to deviations from the additive scheme atributable to inter-allelic interactions. This breakdown was useful for purposes of estimating the magnitude of various types of gene action and in describing types of gene action. Charles and Smith (1939) and Powers (1942) seperated genetic from total variance by use of estimates of environmental variance

based on non-segregating populations and possible relations between means and variance. The epistatic variance was further partitioned into factorial components by Cockerham (1954) and Kempthorne (1955). The usefulness of this partitioning method appears to be primarily one of estimation. It makes it possible to calculate how much of each kind of epistatic variance (additive x additive, additive x dominance, dominance x dominance, additive x additive x dominance, additive x dominance x dominance, dominance x dominance x dominance) appears in the covariance between relatives. Consequently, it is possible to estimate portions of the epistatic variance relative to the dominance and additive genetic variances.

Smith (1936), Panse (1940) and others have studied heritable variation and have further subdivided it into that portion attributable to additive genetic effects and that due to deviations from additive scheme. Panse (1940) and Lush (1945) proposed the use of the ratio of the additive genetic components of variance to total variance as a measure of the degree of heritability. Robinson, Comstock and Harvey (1949) used a method involving estimates of components of variance through study of bi-parental progenies to measure heritability in maze. They compared this method with heritability as calculated from parent-offspring regressions. Techniques for estimating the degree of heritability in crop plants previously reported in the literature fall into three main categories:

(a) parent - offspring regression

(b) variance components from an analysis of variance, and

(c) approximation of non-heritable variance from genetically uniform populations to estimate total genetic variance.

Heritability estimates of quantitative traits of Sorghum bicolor have been reported in literature, though some of the estimates reported are not useful for predicting progress from selection because of biases due to linkages. The best estimate is the narrow-sense estimate on an individual plant basis as calculated by Jan-Orn et al.,(1976) and Panchal et al., (1979). The former obtained estimates as low as 0.09 for yield and up to 0.88 for days to 50% flowering; while the latter obtained estimates as low as 0.09 for 1000-seed weight and up to 0.76 for head length.

Heritability of head length in Sorghum bicolor was estimated on a plot mean basis by Chiang and Smith (1967) as 62% in a seven variety diallel cross. They found that additivity in inheritance of stalk diameter, leaf width, head length, days to flowering, leaf length, number of tillers, head width and threshing percentage appeared to be rather important in grain sorghum. However,there were indications that some dominance and overdominance were also involved.

Estimates obtained for the number of effective factors controlling each character ranged from one to three. They found that average frequency of positive and negative genes were symmetrically distributed in the parents with an excess of negative genes. Heritability values were found to be relatively low except for head length and tiller number. They concluded that the possibility of epistasis induced biases in the estimates of overdominance and heritability exist.

Liang and Walker (1968), working on a population of Sorghum vulgare, reported that heritability of grain yield and seed number were of lower magnitude than those of head weight, stalk diameter and days to 50% flowering. Heritability of plant height and germination percentage were of a still higher order. They found that additive gene effects seemed to have a minor contribution to the inheritance for grain yield, head weight, kernel weight and kernel number, but appeared to be more important for other traits. Dominant gene effects seemed to be more important in the inheritance of most of the traits. They also found that among the three types of epistatic gene effects, additive x additive and dominance x dominance gene effects, were of minor importance in general, except for germination percentage.

They concluded that effect of epistasis cannot be considered negligible and that genetic models assuming negligible epistasis may be somewhat biased. The importance of epistasis in grain sorghum was later emphasised by Reddy and Liang (1970) and Liang, Dayton and Walker (1974).

Ali-Khan and Weibel (1969) estimated heritability of head length to be 23% in 8 'Redlan' x 'Plainsman' and 41% in 'Combine Kafir-60' x 'Combine 7078'. High heritability estimates of plant height, days to flowering, panicle length and width, leaf number and spike length were reported by Basu (1971), Mandouh et al., (1971) and Vasudeva (1973). Low heritability estimates of node number per head and 100-seed weight were reported by Mandouh et al., (1971).

Eckebil et al., (1977) found that broad-sense heritability for flowering date, height of plants, yield and grain weight were high in all three random crossed populations they studied. Heads per plant showed the lowest heritability, especially in NP7BR.

Panchal et al., (1979) worked out heribability estimates by variance components, parent-offspring regression (conventional) and parent-offspring correlation (standard) unit) methods. They found, using broad-sense heritability, low values for peduncle length, number of spikes per head, length and width of head, weight of head, grain weight and days of flowering but very high heritability estimates by the standard unit method. According to them this indicated that the additive effects were more or less operative for these characters and that the low heritability estimates found for leaf number and 100 grain weight indicated that dominance and epistatic gene actions might be involved in these characters.

Expected Progress from Selection

Estimates of genetic and environmental variances are used to predict progress from recurrent selection. Estimated values for heritability on a family mean basis can also be used as an indicator of expected progress from selection.

Chiang and Smith (1967) obtained high heritability values for head length and concluded that rapid and effective selection could be made per trait in the population studied.

Similar conclusions were made by Basu (1971) for plant height, days to flowering and panicle width; and by Mandouh et al., (1971) who obtained high heritability values and high positive genotypic correlations for head length and spike length.

Abu-el-Gasim and Kambal (1975) reported expected genetic advance for a 5% selection intensity in a sorghum population to be 28.2% for leaf length, 42.4% for head length, 55.8% for plant height, 65.5% for 1000-grain weight and 92.8% for grain yield per plant, all expressed as a percentage of the mean. They realised a close association between the genetic coefficient of variation and the corresponding values for genetic advance.

Jan-Orn et al., (1976) predicted expected gain from mass selection of individual fertile plants, mass selection of individual sterile plants, S_{-1} family selection, half-sib family selection, and full-sib family selection of NP3R sorghum random mating population. They concluded that S_{-1} family selection would be most effective for improving grain yield, but mass selection could effectively improve highly heritable traits such as days to flowering and plant height.

Eckebil (1974) reported full-sib and S_{-1} family selections in 3 random mating sorghum crops. S_{-1} selection was expected to be more efficient for grain yield than half-sib family selection; and in 1977 Eckebil et al.,reported predicted gains in yield from selecting the highest 20% of the families

in each population to be 16.3, 10.2 and 8.7 g/ha per cycle for NP5R, NP3R and NP7BR populations, respectively. They found smallest gains for tiller number per plot and grain protein percentage.

Obilana and El-Rouby (1980b) predicted gains from recurrent mass selection for yield in two random mating populations. After three cycles of selection they reported a gain of 38.4% and 40.4% for yield in B and Y composites, respectively, with selection intensities of 5% which were comparable with their expectations of 29.4% and 41.8% in the two composites.

CHAPTER III

MATERIALS AND METHODS

III. 1. Genetic background of plant materials investigated

Si_X randon mating populations (composites) were developed for the Nigerian sorghum improvement programme. Two of the heterogenous populations and their pedigrees, which relate to this study, together with the population used in the study are shown in Table 1. In the formation of these breeding populations, germplasm from locally adapted and acceptable varieties with elite exotic cultivars have been utilized. The composites thus developed have high levels of variability and genetic diversity. Their synthesis has been described by Obilana and El-Rouby (1980a).

The Y composite was found to be more adapted than the B composite, although the B composite had better quality heads. Both populations had generally low yield. Therefore, the two composites were combined into one (Z composite) and then backcrossed to Y composite in order to have a genetically broad-based population. This genetically broad-based and diverse population, YZ composite (YZC) was used as the base population in the study.

S_{-1} lines were developed from YZC) by selfing 500 fertile plants in a 5000 plant population. Two hundred and fifty lines were evaluated for obtaining genetic estimates and statistical parameters. Six elite pure-line varieties (Appendix Table 1) were used as checks in the study.

These were S.K. 5912, L.187, L.181, L.1499, L.1500 and L.123, which are elite, high yielding pure lines resistant to striga (Striga hermonthica Benth) and headsmut (Sphacelotheca reiliana).

Table 1: Description of three sorghum composites developed in IAR, Samaru, and from which the material used in this study was derived

Population	Male Sterile gene	Entries	Brief description
Y Composite	ms_7	Short kaura (SK); (CKA-AxFF x FF; SK x dwarf Hegari x FF; SK x Feterita; 2123 (CK x FF); 1898 (CK x Makajo da wayo); Shallu/ kafir x MDW; 2743 (CK x SK) x SK;	A well mixed collection of locally adapted germplasm and cultivars from Sudan, Chad, and Ethiopia. Selected for acceptability. Adapted to Northern Guinea Savanna
B Composite	ms_7	Local germplasm and adapted 'B' lines	A mixture of exotic and locally adapted germplasm crossed with non-restorer 'B' lines
YZ Composite	ms_7	Y composite and B composite	(Y composite x B composite) x Y composite.

III. 2. Experimental layout

The 250 S_1 lines with six check varieties (elite purelines) were planted in Samaru on 24th May 1979 and 19th June 1980. Split application of a compound fertilizer (Nitro-chalk) was done after thinning and just before heading at the rates of 125 and 251 kg per hactare, respectively. The fertilizer was top dressed on each ocassion. The experimental design was a 16 x 16 simple lattice with two replications. Each plot of two rows and 6m long was over planted and thinned after three weeks to a minimum of 21 plants per row, thus giving 42 plants per plot. Seeds were treated with Aldrex-T before planting. Missing hills were compensated for in most plots by transplants during thinning. The rows were spaced 90 cm apart and the hills within the row were spaced 30cm apart.

III. 3. Observations

Data were collected on 10 plants whenever possible, for 16 quantitatively inherited characters; plant height, node number per plant, flag-leaf lenght and width, peduncle length, head length and width, middle-spike length, number of spikes per head, 1000-grain weight, days to 50% flowering, head weight, grain weight per plot and per plant, number of heads per plot, stand count after thining, stand count at harvest and number of grains per head.

(a) Plant height: The height of each plant was measured (to the nearest cm) from ground level to the base of the flag leaf.

(b) Node number: The number of nodes per plant was recorded by counting the number of leaves per plant.

(c) Flag-leaf length: The length of the flag leaf was recorded to the nearest 0.1 mm.

(d) Flag-leaf width: The width of the flag-leaf was measured at the estimated widest point and recorded to the nearest 0.1 mm.

(e) Peduncle length: The total peduncle length of all harvested heads was obtained to the nearest centimeter. This length was then divided by the number of heads to obtain the average peduncle length per plant.

(f) Head Numbers The number of heads was obtained and recorded for each plot.

(g) Head length: The total head length of all harvested heads was obtained to the nearest centimeter. The head length was then divided by the number of heads to obtain the average length per plant.

(h) Head width: The total head width was obtained to the nearest centimeter. This width was then divided by the number of heads to obtain the average width of the head per plant.

(i) Middle-spike length: One main branch was picked from each head for measurement. Total middle-spike lengths were measured to the nearest centimeter. The total lengths were then divided by the number of heads to obtain the average middle-spike length per head.

(j) Number of spikes: Total number of spikes were counted on each head and this was divided by the number of heads to obtain the average number of spikes per head.

(k) 1000-grain weight: 1000-grains were counted from each plot after threshing and weighed to the nearest 0.1 gram.

(l) Head weight: The total head weight per plot was recorded to the nearest 0.01 kg.

(m) Grain weight: Total grain weight was measured on per plot and plant basis and was recorded to the nearest 0.01 kg and 0.1 gram, respectively.

(n) Days to 50% flowering: The number of days of 50% flowering was recorded when 50% of the plants in a plot showed anthesis.

(c) Number of seeds per head: These were obtained by calculation using grain weight per plant and 1000 grain weight as described by Jan-Orn (1973), thus:

1000-grain weight = x_g

$\therefore$ 1 grain weight $= \frac{x}{1000} g$

If $\frac{x}{1000}$ is weight of 1 grain

$\therefore$ y g is weight of y x $\frac{1000}{x}$ grains

where

x is 1000-grain weight and

y is grain weight per plant.

III. 4. Statistical analyses

The two experiments were laid out in a 16 x 16 simple lattice design at two locations (X-fields 1979 and T-fields 1980). The lattice design was however, not found to be more efficient for the combined analyses of variance over the two environments than the randomized complete block design. The experiments were consequently analysed as randomized complete block design. The check entries were omitted from the combined analysis.

The statistical model used for the combined analysis of variance (ANOVA) was:

$$Y_{ijk} = u + E_i + R_{ij} + G_k + (GE)_{ik} + e_{ijk}$$

where

u = overall mean

E_i = the effect of the i^{th} environment; i = 1, 2

R_{ij} = the effect of the j^{th} replication in the i^{th} environment; j = 1, 2.

G_k = effect of the k^{th} genotype (S-1 lines); k = 1,2,....250

$(GE)_{ik}$ = the interaction effect between k^{th} genotype in the i^{th} environment, and

$\varepsilon_i \sim NID\ (0, \sigma^2 E)$

$G_k \sim NID\ (0, \sigma^2 G)$

$e_{ijk} \sim NID\ (0, \sigma^2)$

Analyses of variance were performed for all characters from each experiment. The analysis for each character was computed on plot means. Both entries and environments were treated as random effects. The form of analysis of variance with the expected mean squares which were used for the estimation of genetic parameters is shown in Table 2.

Table 2: Form of ANOVA with expected mean squares (EMS) in one environment for each character

Sources of Vatiation	d.f.	MS	EMS
Replications	(r - 1)		
Entries	(g - 1)	M_g	$\sigma^2 + r\sigma^2_g$
Error	(r - 1)(g-1)	M_e	σ^2

r = number of replication

g = number of entries

σ^2 = error variance

σ^2_g = total genetic variance among entries

M subscript = the observed mean square of the subscripted effect.

For each one year experiment, components of variance were estimated from the expected mean square for each trait by using observed mean squares, thus

$\sigma^2 = M_e$ and

$$\sigma^2_g = \frac{M_g - M_e}{r}$$

A combined analysis of variance for the two experiments in the two years for each character provided more valid estimates of the variance components including the genotype x environment interaction (Table 3).

Table 3: Form of ANOVA with expected mean squares (EMS) in two environments for each character.

Source of Variation	d.f.	MS	EMS
Environments	(l -1)		
Reps/environments	l(r -1)		
Entries	(g -1)	M_g	$\sigma^2+r\sigma^2_{gl}+rl\sigma^2_g$
Entries x Environments	(g-1)(l-1)	M_{gl}	$\sigma^2+r\sigma^2_{gl}$
Pooled Error	l(g-1)(r-1)*	M_e	σ^2

l = number of environments

r = number of replications

g = number of entries

M subscript = Observed mean square of the subscripted effect

σ^2_{gl} = Genotype x environment interaction variance

σ^2 = error variance

* Due to the difficulty in getting the computer programme available to obtain both the analysis of variance and co-variance efficiently and correctly because of the large number of entries and observations studied (16000 units), the 250 entries were subdivided into 10 different sets of 25 treatments each.

The ANOVA for each set, combined for the two years, were then pooled. This resulted in the total degrees of freedom to be (n - t) instead of (n - 1) where t is the number of sets into which the data was subdivided and n is the total number of experimental units observed. The outcome for pooling the results was that instead of using d.f = (499) to estimate σ^2, d.f = (489) was used; thus the estimate of σ^2 was biased slightly upwards, though with no significant loss in sensitivity of the error mean square for test purposes considering the very large data used in the study.

The components of variance and their standard errors were estimated from expected mean squares using observed mean square values of each character, thus:

$$\sigma^2 = M_e \quad \text{with S.E.} = \sqrt{\frac{2(M_e)^2}{\text{d.f.} + 2}}$$

$$\sigma^2_{gl} = \frac{M_{gl} - M_e}{r = 2} \quad \text{with S.E.} = \sqrt{(\tfrac{1}{2})^2 \left[\frac{2(M_{gl})^2}{\text{d.f.}+2} + \frac{2(M_e)^2}{\text{d.f.}+2}\right]}$$

$$\sigma^2_{g} = \frac{M_g - M_{gl}}{rl=4} \quad \text{with S.E.} = \sqrt{(\tfrac{1}{4})^2 \left[\frac{2(M_g)^2}{\text{d.f.}+2} + \frac{2(M_{gl})^2}{\text{d.f.}+2}\right]}$$

The phenotypic variance among S-1 lines was estimated as

$\sigma^2_{ph} = \sigma^2_g + \frac{\sigma^2}{r=2}$ for one environment

$\sigma^2_{ph} = \frac{\sigma^2}{r1=4} + \frac{\sigma^2_{gl}}{r=2} + \sigma^2_g$ for two environments.

The standard error of the phenotypic variance was estimated as

$$S.E.\ (\sigma^2_{ph}) = \sqrt{(\tfrac{1}{2})^2 \left[\frac{2(M_g)^2}{d.f. + 2}\right]}$$ for one environment

$$S.E.\ (\sigma^2_{ph}) = \sqrt{(\tfrac{1}{4})^2 \left[\frac{2(M_g)^2}{d.f. + 2}\right]}$$ for two environments

To determine if the variation among entries and their interaction with the environment were significantly different from zero, F tests were used for both single and combined ANOVA as follows:

$F = \frac{M_g}{M_e}$ with $(g - 1), (r-1)(g-1)$ degrees of freedom for one environment:

$F = \frac{M_g}{M_e}$ with $(g-1), l(r-1)(g-1)$ degrees of freedom and

$F \frac{M_{gl}}{M_e}$ with $(g-1)(l-1), l(r-1)(g-1)$ degrees of freedom for two environments.

According to Mode and Robinson (1959) the expectations of mean products, in analysis of covariance, have the same form as the expected mean squares of analysis of variance and therefore the procedure for the analysis of covariance are analogous to those used for analysis of variance. Table 4 shows the form of analysis of variance and covariance of a pair of characters (x and y) with the expected mean cross-products at two environments.

Table 4: Form of analysis of variance and covariance with observed expected mean products for two characters (x and y) at two evnironments.

Source of variation	d.f.	Trait x	Trait y	Mean Product xy	Expected Mean Product
Entries	(g-1)	M_{gx}	M_{gy}	M_{gxgy}	$\sigma_{xy} + r\sigma_{glxgly} + rl\sigma_{gxgy}$
Entries x Envir.	(g-1(l-1)	M_{glx}	M_{gly}	M_{glxgly}	$\sigma_{xy} + r\sigma_{glxgly}$
Pooled Error	l(r-1)(g-1)*	M_{ex}	M_{ey}	M_{exey}	σ_{xy}

* = Error degrees of freedom from the pooled data of the 10 sets of 25 treatments.

Genotypic and phenotypic correlations were estimated for pairs of traits measured.

The genotypic correlation coefficients were calculated from components of variance and covariance. The formula used was that of Mode and Robinson(1959):

$$r_{gxy} = \frac{\sigma_{gxgy}}{\sqrt{\sigma^2_{gx} \cdot \sigma^2_{gy}}}$$

where

σ_{gxgy} = genotypic covariance of characters x and y

σ^2_{gx} = genotypic variance of character x

σ^2_{gy} = genotypic variance of character y

r_{gxy} = correlation coefficient of characters x and y.

The phenotypic correlations were computed using mean squares and mean cross products in the formula:

$$r_{ph} = \frac{M_{gxgy}}{\sqrt{M_{gx} \cdot M_{gy}}}$$

where

M_{gx} = entry mean square of character x

M_{gy} = entry mean square of character y

M_{gxgy} = entry mean product of characters x and y

The error correlation was also computed for a pair of characters using the error mean square. This is the measure of the effect of environment on the association of characters in each pair:

$$r_{exy} = \frac{\sigma_{xy}}{\sqrt{\sigma^2_x \cdot \sigma^2_y}}$$

where

r_{exy} = error correlation coefficient for characters x and y

σ^2_x = error variance for character x

σ^2_y = error variance for character y

σ_{xy} = error covariance for characters x and y.

Heritability (h^2) estimates were based on entry means over two environments. They were computed from variance component estimates by using the formula:

$$h^2 = \frac{\sigma^2_g}{\frac{\sigma^2}{4} + \frac{\sigma^2_{gl}}{2} + \sigma^2_g} \quad \text{with S.E.} = \frac{\text{S.E.}\ (\sigma^2_g)}{\sigma^2_{ph}}$$

where

σ^2_g = genotypic variance

σ^2 = random error variance and

σ^2_{gl} = component of variance due to interaction of genotypes with environments.

Heritability on plot basis was also estimated as:

$$h^2 = \frac{\sigma^2_g}{\sigma^2 + \sigma^2_{gl} + \sigma^2_g}$$

Estimates of genetic and phenotypic variances were used to calculate the predicted genetic gain from S-1 selection per cycle, thus:

$$\text{Expected genetic gain } (\triangle G) = \frac{c.k.\ \sigma^2_g}{\sqrt{\frac{\sigma^2}{rl} + \frac{\sigma^2_{gl}}{l} + \sigma^2_g}}$$

where

c = parental control = 1 for S-1 selection

k = selection intensity (in this study 10% selection pressure were used i.e. k = 1.75)

σ^2 = error variance

r = number of replications

l = number of environments

σ^2_{gl} = genotype x environment interaction variance

σ^2_g = genetic variance among S-1 lines.

CHAPTER IV

RESULTS

The 1980 growing season was characterised by abnormal weather and pest infestations. There was a long period of drought after plant emergence, In addition, plants were attacked at the seedling stage by armyworm (Spodoptera exempta) and stem-borer (Buseola fusca).
Despite the efforts made to control these pests the 1980 crop yielded lower than that of 1979. In 1979, means of most of the characters paralleled fairly well those of the combined years. Sincethe primary objective of this study was the estimation of genetic variability of the YZC population using S-1 progenies, the data from the two years were pooled to obtain greater precision on the estimates. Only pooled results are presented in the main body of this chapter. Individual year data are in the appendix.

IV. 1. Population Means

A summary of the 16 characters measured within the 250 S-1 lines, including the grand means, standard deviations of the means (S.E.$\bar{x}$), ranges, and the coefficients of variation (C.V.%) is shown in Table 5. A similar table for each of the years is shown in Table A2 of the appendix.

Table 5: Mean ($\bar{X}$), Standars error of the mean (S.E.$\bar{X}$), Range and Coefficient of variation (C.V.) for YZC population grown in Samaru in 1979 and 1980.

Character	Mean ± SE $\bar{X}$		Range	C.V.(%)
Days to 50% flowering	139.46	10.06	132.25-147.75	3.76
Plant height (cm)	161.70	41.03	105.00-219.63	17.46
Flag leaf length(cm	31.90	5.06	22.68-38.83	13.49
Flag leaf width (cm)	4.96	0.99	3.57- 9.16	19.87
Node number	18.65	1.20	15.50-21-00	7.86
Peduncle length (cm)	5.90	2.57	2.43-10-58	37.71
No. of heads/plot	33.77	10.46	16.75-50.00	26.28
Head length (cm)	25.58	3.95	18.88-31.16	12.61
Head width (cm)	8.28	1.58	6.28-11.22	17.87
Head weight (kg)	2.35	0.91	1.31- 3.43	31.41
Grain Wt/plot (kg)	1.34	0.58	0.68-2.12	35.81
Grain Wt/plant (g)	39.91	13.35	22.05-59.85	30.66
1000 grain Wt (g)	26.77	4.69	20.68-31.93	11.25
No. of grains/head	1506.62	503.48	828.45-2326.90	31.04
No.of spikes/head	82.79	13.43	66.25-107.00	13.63
Mid-spike length (cm)	9.33	1.48	6.33- 11.78	13.05

Considerable and significant variation among the lines were observed for each character. The C.V.'s ranged from 3.8% for days to 50% flowering to 37.7% for peduncle length. Wide ranges were also observed on number of grains per head (828.5 - 2326.9), grain weight per plant (22.1 - 59.9 g) and number of heads per plot (16.8 - 50.0). The population displayed variation in leaf size, plant height, head size as well as in 1000-grain weight.

In order to compare means of the S-1 lines with those of the elite lines used as checks, means of the check varieties were calculated and these are presented in Table A1 of the appendix. Table A5 of the appendix shows means for the 16 characters of the 250 lines evaluated. There was little difference between the means of the S-1 lines and those of the adapted elite lines for all the 16 characters. From the total number of 250 S-1 lines, 44.4% were equal to or better than the mean grain yield of the elite lines used as checks; 2.4% were significantly higher than the mean yield of the elite lines Table A5.

The highest yielding elite line was L. 1500 with 1.81 kg per 5.67 m^2 plot while the highest grain yield of the S-1 lines was 2.12 kg per plot, given by Entry E.123. Six of the S-1 lines (E.85, E.220, E.174, E.246, E.203 and E.123 with yields 1.85, 1.85, 2.00, 2.01, 2.10 and 2.12 kg per plot, respectively) yielded higher than the highest yielding elite line.

IV. 2. Population Variability

The analyses of variance of data collected on the 16 characters of the S-1 lines for the two seperate years is shown in Table A3 of the appendix. The results are generally similar for the two years except that the 1980 population has higher entry mean squares with variation among entry means statistically significant for all characters. Plant height, flag-leaf length, peduncle length and head width showed no significant variation among entry means in 1979.

The combined analysis of variation and the results of the F test for the deviation of mean squares from zero are presented in Table 6.

Table 6: Mean squares for 16 characters of S-1 lines of the YZC population grown in Samaru in 1979/1980.

Source of Variation	d.f.	MEAN SQUARES							
		Days to 50% flowering	Plant height	Flag-leaf length	Flag-leaf width	Number of nodes	Peduncle length	Number of heads	Head length
Replicates/Environ.	2	811.28**	11299.16**	390.56**	13.53**	76.02**	182.29**	6108.09**	311.72
Environments (E)	1	67566.64**	606176.31**	376.10**	29.05**	1410.78**	547.96**	20233.65**	385.12
S-1 lines (G)	249	39.65**	1394.91**	32.81**	1.20**	4.03**	6.60**	99.35**	16.65
G X E	249	38.99**	1252.21**	28.23**	1.12**	3.85**	6.92**	67.24	18.35
Pooled Error	489	26.53	759.94	18.48	0.69	2.71	4.86	75.44	12.60

Source of Variation	d.f.	Head Width	Head Weight	Grain weight per plot	Grain wt. per plant	1000 grain weight	Number of grain per head	Number of per head	Mid-Sp length
Replicates/Environ.	2	51.56**	16.92**	9.47**	4725.81**	135.53**	4723276.20**	3525.36**	37.47
Environments (E)	1	88.25**	239.94**	93.38**	13200.21**	8827.73**	6128057.30**	10700.20**	62.99
S-1 lines	249	2.35**	0.62**	0.27**	163.23**	17.43**	269432.61**	211.13**	2.59
G X E	249	2.87**	0.56**	0.23**	173.89**	8.20	254261.85**	197.67**	3.10
Pooled Error	89	2.06	0.55	0.22	148.16	8.88	214979.79	119.15	1.45

** = Significant difference at 1% level of probability

Differences between years were statistically significant for all characters which indicates that the environment or growing conditions in the two years were different as mentioned earlier. As in the case of the individual year analyses, highly significant differences (P=0.01) were observed among entries for all characters indicating that genetic variability exists among the S-1 lines for every character. Significant genotype-environment interactions (G x E) were also observed among the characters except for heads per plot and 1000 grain weight. The non-significant G X E mean squares for head number and 1000-grain weight suggest the stability of these characters in the YZC population.

IV. 3. Estimates of Genetic Variance Components

Estimates of genetic variance components were obtained from the combined analysis of variance. Table 7 shows the estimates of genetic variance (σ^2G), genotype x environment interaction variance (σ^2GL), phenotypic (σ^2_{ph}) and error (σ^2) variances with their standard errors. Out of the 16 characters studied, eleven showed positive σ^2G. These include days to 50% flowering, plant height, flag-leaf length and width, number of nodes per plant, number of heads per plot, head weight, grain weight per plot, 1000-grain weight, number of grains per head and number of spi[illegible]

Table 7: Estimates of genetic variance (σ^2_G), genotype x environment interaction (σ^2_{GL}) variance, phenotypic variance (σ^2_{ph}) and error variance (σ^2) for the 16 characters of S-1 lines derived from YZC population in Samaru 1979/1980.

Character	Components of Variance			
	σ^2_G	σ^2_{GL}	σ^2_{ph}	σ^2
Days to 50% flowering	0.162±1.241	6.233±1.94	9.913±0.88	26.531±1.69
Plant height	35.675±41.831	246.139±60.91	348.729±31.23	759.936±48.45
Flag-leaf length	1.144±0.97	4.876± 1.39	8.203± 0.73	18.482± 1.18
Flag-leaf width	0.020±0.04	0.210±0.055	0.299± 0.03	0.697± 0.045
Node number	0.046±0.12	0.572±0. 19	1.009± 0.09	2.706± 0. 17
Peduncle length	-0.079±0.21	1.033±0. 35	1.651± 0.15	4.855± 0. 31
No. of heads/plot	8.028±2.688	-4.099±3. 85	24.838± 2.22	75.439± 4. 81
Head length	-0.425±0. 55	2.873±0. 91	4.162± 0.37	12.602± 0. 80
Head width	-0.130±0. 08	0.405±0. 14	0.587± 0.05	2.056± 0. 13
Head weight	0.015±0. 02	0.003±0. 03	0.154± 0.01	0.550± 0. 04
Grain Wt/plot	0.008±0. 01	0.005±0. 01	0.066± 0.01	0.221± 0. 01
Grain Wt/plant	-2.665±5. 32	12.865±9. 09	40.808± 3.64	148.163± 9. 45
1000 grain wt.	2.308±0. 43	-0.342±0. 46	4.358± 0.39	8.883± 0. 57
No. of grain per head	3792.69±8267.29	19641.03±13257.11	67358.15±6012.68	214979.79±13706.61
No. of spikes/head	3.365±6.45	39.26±9.61	52.784±4.71	119.154±7.60
Mid-spike length	-0.130±0.09	0.828±0.15	0.646±0.06	1.448±0.09

Although these characters showed positive σ^2G estimates, most of them have their standard errors larger than the estimates. Negative genetic variances were observed for peduncle length, head length and width, grain weight per plant and middle-spike length. With the exception of head width and middle-spike length, all the other characters with negative σ^2G estimates had large standard errors indicating that either the estimates were not different form zero, or they are small values.

Estimates of genotype x environment interaction variance (σ^2GL) were relatively small compared to those of phenotypic and error variances though higher than those of genetic variances. The estimates of σ^2GL were positive for all characters except for head number - 4.099 $\pm$ 3.85 and 1000-grain weight - 0.342 $\pm$ 0.46. For most of the characters, the estimates of σ^2GL were at least four times larger than ther respective standard errors.

Phenotypic and error variance estimates were positive for all characters and they had very low standard errors. Plant height, head number, grain weight per plant, number of grains per head and number of spikes per head had large estimates of σ^2_{ph} , σ^2 and σ^2GL.

IV. 4. CORRELATIONS

Correlation coefficients (r) were computed from the combined analysis of variance and covariance for genotypic correlations and error correlations. All possible phenotypic correlations were computed among sixteen characters from means of the S-1 lines studied. Genotypic and error correlations were computed only for grain yield per plot and 1000 grain weight with all characters with which they were significantly correlated phenotypically. Table 8 shows the phenotypic correlations (r_{ph}) while Table 9 shows the genotypic (r_g), phenotypic (r_{ph}) and error (r_e) correlation coefficients.

Days to 50% flowering was negatively correlated with all traits and the correlation was significant except with flag-leaf length, head length, number of grains per head and middle-spike length (Table 8).

Plant traits (plant height, flag-leaf length and width, number of nodes and head number) were all positively and significantly correlated with most of the other traits. Peduncle length showed negative correlation with all other characters except plant height, head length and width, and 1000-grain weight. In general, grain yield and related components such as 1000-grain weight, head size (comprising head length and width), and head weight were correlated with the plant characters.

Table 8: Phenotypic correlation coefficients for the 16 characters of S-1 lines of the YZC population in Samaru.

	Plant height	Flag-leaf length	Flag-leaf width	Node number	Peduncle length	Head number	Head length	Head width	Head weight	Grain wt per plot	Grain wt per plant	1000 grain wt.	No. of grain per head	No. of spikes per head	Mi... le...
	2	9	10	8	11	4	3	2	5	6	7	15	16	13	
Days to 50% flowering	-0.54**	-0.01	-0.10*	-0.47**	-0.17**	-0.45**	-0.01	-0.23**	-0.57**	-0.54**	-0.29**	-0.52*	-0.03	-0.24**	-0.
Plant height		0.08	0.12**	0.37**	0.16**	0.39**	0.19**	0.21**	0.46**	0.44**	0.20**	0.44**	-0.03	0.24**	0.
Flag-leaf length			0.55**	0.08**	-0.13**	0.06	0.20**	0.14**	0.20**	0.19**	0.18**	0.11*	0.13**	0.21**	0.
Flag-leaf width				0.10*	-0.09**	0.03	0.08	0.12**	0.20**	0.20**	0.26**	0.16**	0.20**	0.19**	0.
Node number					-0.32**	0.44**	0.10*	0.13**	0.53**	0.52**	0.27**	0.46**	0.03	0.16**	0.
Peduncle length						-0.06	0.13**	0.06	-0.07	-0.05	-0.02	0.15	-0.09	-0.21**	0.
Head number							-0.08	0.01	0.72**	0.66**	-0.07	0.23**	-0.20**	0.13**	0.
Head length								0.42**	0.06	0.08	0.19**	0.17**	0.10*	0.09*	0.
Head width									0.27**	0.26**	0.36**	0.13**	0.30*	0.11**	0.
Head weight										0.93**	0.52**	0.42**	0.31**	0.30**	0.
Grain Wt/plot											0.66**	0.44**	0.44**	0.26**	0.
Grain Wt. per plant												0.35**	0.84**	0.22**	0.
1000 grain wt.													-0.18**	0.22**	0.
No. of grain per head														0.09**	0.
No. of spike per head															-0.

* = Significant difference at 5% level of probability

** = " " " 1% " " "

As expected, tillering (number of heads per plot) was negatively correlated with grain weight per plant and number of grains per head as well as head length. This was also true for the correlations between 1000-grain weight and number of grains per head.

A positive and significant correlation was observed among the head and yield traits. As expected, yield per plot and yield per plant were highly and positively correlated.

Although most of the phenotypic correlations were low, moderately high ones were observed between the following characters:

Days to 50% flowering with plant height (r_{ph} = -0.54), head weigth (r_{ph} = -0.57), grain weight per plot (r_{ph}= -0.54) and 1000-grain weight (r_{ph}= -0.52). Plant height with head weight (r_{ph}= 0.46), grain yield (r_{ph}= 0.44) and 1000-grain weight (r_{ph}= 0.44). Number of nodes with head weight (r_{ph}=0.53), grain weight per plot (r_{ph}= 0.52) and 1000-grain weight (r_{ph} = 0.46). Head number with head weight (r_{ph}= 0.72) and with grain weight per plot (r_{ph} = 0.66). Head weight with grain weight per plot (r_{ph}= 0.93), grain weight per plant (r_{ph}= 0.52) and 1000-grain weight (r_{ph}= 0.42).

Grain weight per plot with grain weight per plant (r_{ph}= 0.66), 1000-grain weight and number of grains per head (r_{ph}= 0.44). Grain weight per plant with number of grains per head ($r_{ph=0.84}$).

The genotypic and error correlations (Table 9) were generally lower than the phenotypic correlations. Grain yield per plot was negatively and highly correlated with days to 50% flowering (r_g = -0.69). Positive and significant genotypic correlations were observed between grain weight per plot and plant height (r_g = 0.24), flag leaf length (r_g = 0.13), number of heads (r_g = 0.10), number of spikes per head (r_g = 0.25) and number of grains per head (r_g= 0.15). 1000-grain weight showed very low genotypic correlations with all traits studies except number of grains per head (r_g = 0.21).

Significant error correlation coefficient values were obtained between grain yield and days to 50% flowering, plant height, number of heads, and number of spikes per head. This was also true for correlations between 1000-grain weight and plant height as well as number of grains per head. The environmental correlations between these two traits, grain yield per plot and 1000-grain weight and other traits measured were however very low except for grain yield per plot and plant height (r_e = 0.57), number of head per plot (r_e = 0.43) and number of spikes per head (r_e = 0.23).

Table 9: Genotypic (r_g), Phenotypic (r_{ph}) and error (r_e) correlation coefficients of the characters significantly phenotypically correlated with grain yield per plot and 1000 grain weight.

Character	Grain weight per plot			1000 Grain weight		
	r_g	r_{ph}	r_e	r_g	r_{ph}	re
Days to 50% flowering	-0.69**	-0.54*	0.09*	0.001	-0.52**	0.02
Plant height	0.24**	0.44**	0.57**	0.04	0.44**	0.10*
Flag-leaf length	0.13**	0.19**	0.08	0.01	0.11*	0.01
Flag-leaf width	0.001	0.20**	0.02	0.001	0.16**	0.03
Node number	0.03	0.52**	0.03	0.003	0.46**	0.01
Peduncle length	- a	-	-	-	-	-
Head length	-	-	-	-	-	-
Head width	-	-	-	-	-	-
Head weight	-0.004	0.93**	0.003	0.001	0.42**	0.002
Grain Wt/plot	-	-	-	0.001	0.44**	0.002
Grain Wt/plant	-	-	-	-	-	-
1000 grain Wt.	0.03	0.44**	0.07	-	-	-
No. of grains/head	***	0.44**	***	0.21**	-0.18**	0.72**
No. of spikes/head	-0.25**	0.26**	0.23**	0.02	0.22	0.04
Mid-spike length	-	-	-	-	-	-
No. of heads/plot	0.10*	0.66**	0.43**	0.02	0.23**	0.03

a = Characters with no values (-) have negative of σ^2_g

* = Significant difference at 5% level of probability

** = Significant difference at 1% level of probability

***= Correlation greater than 1.

1000-grain weight and number of grains per head showed a high, positive environmental correlation (r_e = 0.72).

IV. 5. Heritability Estimates

As a result of the negative estimates of σ^2G obtained for some traits, heritability (h^2) estimates for these traits were not computable. For the characters with positive σ^2G, heritability was computed by using the components of variance estimated from the combined analysis of variance. The estimate

$$h^2 = \frac{\sigma^2_g}{\sigma^2_g + \sigma^2_{gl} + \sigma^2}$$

which is h^2 on plot basis has been indicated as the only estimate resembling heritability whenever data on individual plants within plots are not available (C.O. Gardner. Biometrical Genetics and Plant Breeding (cited by Jan-Orn 1973). Jan-Orn (1973) found that this estimate over-estimates heritability and is of no real use unless selection of S-1 families is practiced in a non-replicated experiment. Using this formula for YZC population, over-estimation of heritability was not observed but instead the estimates were much lower than those obtained by using the formula $h^2 = \frac{\sigma^2_g}{\frac{\sigma^2}{4} + \frac{\sigma^2_{gl}}{2} + \sigma^2_g}$ on family mean basis.

1000-grain weight and number of grains per head showed a high, positive environmental correlation (r_e = 0.72).

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Table 10: Heritability (h^2, estimates for the characters of the 250 S-1 lines of the YZC population grown in Samaru 1979, 1980 and 1979/1980.

Characters	1979		1980		1979/1980	
	h^2/family	h^2/plot	h^2/family	h^2/plot	h^2/family	1979/1980 h^2/plot
Days oto 50% flowering	0.110 ± 0.115	0.058 ± 0.060	0.736 ± 0.091	0.582 ± 0.072	0.016 ± 0.125	0.005 ± 0.037
Plant height	-a	-	0.858 ± 0.089	0.752 ± 0.078	0.102 ± 0.120	0.034 ± 0.040
Flag leaf length	-	-	0.740 ± 0.091	0.587 ± 0.072	0.139 ± 0.118	0.047 ± 0.039
Flag leaf width	0.117 ± 0.118	0.062 ± 0.063	0.631 ± 0.102	0.462 ± 0.074	0.067 ± 0.134	0.022 ± 0.043
Node number	0.001	0.000	0.700 ± 0.092	0.539 ± 0.071	0.046 ± 0.119	0.014 ± 0.036
Peduncle length	-	-	0.097 ± 0.097	0.051 ± 0.063	-	-
Head number	0.198 ± 0.113	0.110 ± 0.063	0.422 ± 0.102	0.581 ± 0.065	0.323 ± 0.108	0.101 ± 0.034
Head length	0.225 ± 0.111	0.127 ± 0.063	0.471 ± 0.100	0.308 ± 0.065	-	-
Head width	-	-	0.572 ± 0.073	0.400 ± 0.051	-	-
Head weight	0.296 ± 0.100	0.174 ± 0.058	0.303 ± 0.125	0.179 ± 0.073	0.097 ± 0.130	0.026 ± 0.035
Grain wt/plot	0.348 ± 0.111	0.211 ± 0.067	0.470 ± 0.083	0.309 ± 0.056	0.122 ± 0.151	0.034 ± 0.042
Grain wt/plant	0.199 ± 0.118	0.063 ± 0.064	0.085 ± 0.120	0.044 ± 0.062	-	-
1000 grain wt.	0.015 ± 0.125	0.007 ± 0.063	0.709 ± 0.092	0.549 ± 0.071	0.530 ± 0.099	0.213 ± 0.040
No. of grains/ head	0.071 ± 0.120	0.037 ± 0.062	0.357 ± 0.105	0.217 ± 0.064	0.056 ± 0.123	0.016 ± 0.035
No. of spikes/head	0.126 ± 0.123	0.067 ± 0.063	0.485 ± 0.099	0.320 ± 0.065	0.064 ± 0.122	0.021 ± 0.04
Mid-spike lwngth	0.011 ± 0.129	0.005 ± 0.064	0.665 ± 0.094	0.499 ± 0.071	-	-

a = Characters with no value (-) have negative σ^2_g

Heritability estimates by the two methods are presented in Table 10 together with single-year estimates obtained for the population in 1979 and 1980, for comparison.

Estimates from the 1979 and the combined years data were very low, ranging from 0.005 to 0.021, which was expected since their estimated σ^2_G were very low while the σ^2GE and σ^2 estimates were relatively high. The 1980 heritability estimates, however, were comparatively high, ranging from 0.05 to 0.75 for grain weight per plant and plant height respectively, because of the high σ^2G and low σ^2 estimates. The 1980 results could be grouped into three classes: relatively high, moderate and low estimates. Relatively high estimates were obtained for days to 50% flowering (73%), plant height (86%) flag-leaf length (74%), flag-leaf width (63%), number of nodes (70%), 1000 grain weight (71%) and middle-spike length (66%). Estimates of number of head (42%), head length (47%) and head width (57%), grain weight per plot (50%), number of grains per head (36%), number of spikes per head (49%) and head weight (29%) were moderate. Very low estimates were obtained for yield per plant (9%) and peduncle length (10%).

Table 11: Expected gain (ΔG) for 16 characters of the 250 S-1 lines of the YZC population planted in Samaru 1979, 1980 and 1979/1980.

Characters	1979	1980	1979/1980
Days to 50% flowering	0.435	7.810	0.090
Plant height (cm)	- a	42.257	3.343
Flag-leaf length (cm)	-	5.920	0.699
Flag-leaf width)(cm)	0.337	0.851	0.064
Node number	0.002	2.059	0.080
Peduncle length (cm)	-	0.283	-
Head number	2.53	4.783	2.819
Head length (cm)	1.19	2.863	-
Head width (cm)	-	1.612	-
Head weight (kg)	0.33	0.262	0.067
Grain wt/plot (kg)	0.26	0.283	0.054
Grain wt/plant (g)	1.66	1.528	-
1000 grain wt. (g)	0.06	4.375	1.935
No. of grains/head	35.56	290.105	25.574
No of spikes/head	2.18	10.968	0.811
Mid-spike length (cm)	0.02	1.605	-

a = characters with no values (-) have negative σ^2_g

IV. 6. Expected Genetic Gain

The estimated response from the YZC population, for all traits, when the highest 10% of the families are selected for grain weight, is shown in Table 11 based on the 1979, 1980 and combined data. These were computed from estimates of genetic components of variance. The standardized selection differential, k, for selecting the upper 10% is 1.75. The predicted gains for the years 1979 and 1980 were quite different due to the differences in performance of the lines caused by environmental differences. Estimates of the combined data were lower than those of the two years. Plant height, head number (tillering), 1000-grain weight and number of grains per head are expected to increase by 3.33 cm, 2.82 heads, 1.92 g and 25.57 grains, respectively. Grain yield per plot and head weight are expected to increase by 0.06 kg per plot and 0.07 kg, respectively. The reliability of the prediction will not be known until the results of selection practised are observed in the experiments planned for comparing original and improved population cycles.

CHAPTER IV

DISCUSSION

A lattice field design was used in this study with the purpose of comparing the genotypes tested precisely and validly estimating genetic and environmental variance components from the different S-1 lines in the Samaru environment which is highly heterogeneous for site and years. Relative efficiency values of the lattice design obtained from the analysis of data were quite low in most cases particularly in yield and related yield components. The randomised complete block design was then used for data analyses for the two years combined. The two designs have been used together and discussed fully by Jan-Orn (1973).

YZC has been described as a genetically broad-based and diverse population (Obilana 1981a, 1981b) and therefore, availability of variability cannot be doubted and was expected. The ranges and means of traits (Table 5) and significant mean squares of variation among S-1 lines (Table 6) have confirmed the presence of variability in this population. These results compare fairly well with those reported by Jan-Orn (1973), Eckebil (1974), and Eckebil *et al.* (1977) who worked on S-1 progenies from different populations.

Genetic variability has been reported to exist in other sorghum populations (Swarup and Chaugale, 1962; Basu, 1971; Vasudeva, 1973; Naphade and Ailwalar, 1978; Bittinger and Cantrell, 1979).

The high percentage of S-1 lines yielding better than the elite lines used as checks indicate that good materials can be selected from this population. These will constitute an improved population which can be further used in the breeding programme to develop superior genotypes (Lines and hybrids). Development of such genotypes, however, involves the study of the genetic variance components.

Results obtained from genetic variance studies have not always been satistafcory, and further study is generally needed for verification of the results.

Jan-Orn (1973) interpreted genetic variance among S-1 lines and the expectation of genetic variance (σ^2_g) was equated to $\sigma^2_A + \frac{1}{4}\sigma^2_D$ where σ^2_A and σ^2_D stand, respectively, for the additive genetic variance and dominance variance among S-1 families. These two components cannot, however, be seperated by the analysis of variance of S-1 families per se. He pointed out that what is estimated is the total genetic variance.

The amount of dominance variance present in many of the experiments is questionable because of bias in the estimtes obtained from all mating designs. Often, however, many of the significant estimstes of σ^2D and σ^2A are negative. The predominant type of variance in these extensive studies seems to be σ^2A. The data obtained so far do not support the hypothesis that dominance variance is a major component of genetic variance in sorghum. Consequently, using the genetic variance among S-1 families as an estimate of additive genetic variance is not likely to cause much bias in the upward direction. Even if it does, it probably is of no consequence.

Four different estimates of variance components, σ^2_g, σ^2_{gl}, σ^2_{ph} and σ^2, were computed in this study (Table 7). For all the characters, and considering the four different estimates, experimental variance (σ^2) was of the greatest magnitude. In the estimation of σ^2_g, plant height, flag-leaf length, node number, peduncle length, head width and 1000-grain weight in the combined estimates compare favourably with the individual year estimates. Estimates of phenotypic and error variances were also comparable with individual year estimates for most of the traits. This may indicate that a combination of thetwo experiments for the calculation of genetic variance components would be a better procedure than from the years individually.

This,however, is not without limitations:
The principal problem evolving from the use of the combined data was the very low and sometimes negative values of σ^2_g (Table 7).

Low estimates of σ^2_g among S-1 lines were also obtained by Jan-Orn (1973) who interpreted them as a result of σ^2_g being equated to $\sigma^2 A + \frac{1}{4} \sigma^2 D - X$ where

$$X = 2 \sum_{i=1}^{n} p_i \, qi \left[(qi - pi) \, ai \, hi + \tfrac{3}{4} (qi - pi)^2 \, hi^2 \right] .$$

According to Jan-Orn (1973) the smaller value of estimated genetic variance among S-1 families is an indication of the positive value of X. X is positive when qi>pi in which case dominance is important. This indicates an opportunity for increasing the frequency of favourable alleles (pi) in a population.

It is very difficult to seperate the genetic variance into additive and dominance variance using the evaluation of S-1 progenies, and because of the relatively small dominance variance. A negative genetic variance therefore could mean one or more of the following:

(1) negative estimate for $\sigma^2 D$ higher than $\sigma^2 A$;
(2) negative estimate for $\sigma^2 A$ higher than $\sigma^2 D$; and
(3) negative estimate of both variances.

Negative estimate for σ^2A higher than σ^2D is possible here since the σ^2A in this study is additive genetic variance in the S-1 population and not in a random mating population, although the estimate can be approximated to that of the random base population, YZC, since the sample size is large (250) and chosen randomly.

The occurrence of negative genetic variances cannot be interpreted as absence of genetic variability in the affected characters: Table 6 showed that all mean squares in this study had significant differences and considering that estimates of variance are linear functions of mean squares, therefore, the variance of such estimates can be written as a function of the variance of the mean squares contributing to the estimates. Rather it could be considered as a low value. Negative estimates of genetic variance components have been reported in the literature on cereals by Robinson et al. (1949), Jan-Orn, (1973), Mukuru (1973), Eckebil (1974), Campos (1977) and Obilana et al. (1979). Most of these authors found negative estimates of the dominance variance, and attributed this to the following factors: deficiency in the genetic model; sampling and sample size; assortative mating; linkage and estimates of actual zero values. The fact that they could be true zero or very small values is deduced from the relatively large standard errors associated with some of the estimates.

Large standard errors coupled with negative estimates also could be a result of sampling variation due to insufficient sampling in the basic populations, as postulated by Marquez-Sanchez and Hallauer (1970). Problem of sampling variation is not present in this case of the S-1 lines with a large random, representative sample size of 250 lines.

Matzinger (1963) associated large standard errors of estimates of genetic variance in self-pollinating plants with the inefficiency of the field design used. The importance of the design used in estimating genetic variance was also emphasized by Schutz (1962) and later by Jan-Orn (1973). Schutz reported that although the modified randomized complete block design (RCBD) with replication within blocks is more suitable for genetic variance studies conducted at a single location, it is not useful in selection experiments due to lack of precision in comparing means of families in the different blocks especially when considerable block-to-block variation occurs.

Jan-Orn (1973) compared RCBD with lattice design (LD) in estimating genetic variance and reported that LD was more effective in reducing experimental error in some cases and ineffective in cases of yield or yield components. He also found that LD was more suitable for S-1 families which are rather homogeneous than for more heterozygous and heterogeneous types of families (half-sibs).

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In my study of the YZC population, lattice design was not more efficient than RCBD in the combined analysis of the data. The large standard errors in my results could not have therefore arisen from design inefficiency but from the large variation in years.

The negative estimates obtained in this study could also have arisen from the mathematical implications of obtaining the estimates as shown in the analysis of variance. Estimates of genetic variance (σ^2_g) values were obtained as:

$$\frac{MS_g - MS_{gl}}{rl}$$

where

MS_g is the mean square of genotype; MS_{gl} is the mean square of genotype x environment interaction, r is the number of replications, and l is the number of environments. For this estimate MS_{gl} was greater than MS_g; thus; resulting in a negative σ^2_g estimate. This situation is not uncommon in quantitative genetic studies especially where only years or locations are considered for the genotype x environment interaction (Comstock and Moll, 1963; Cockerham, 1963). Cockerham (1963) indicated that a large interaction component of variance could be the result of the genetic variance being larger at one environment than the other, and this was found to be true in this population as shown in Table A3 and A4 of the appendix.

The importance of genotype x environment interaction in creating bias in estimates of genetic variance components has been discussed in detail by Robinson and Moll (1960). Evidence indicate that the most important is the genotype x year x location interaction if genotype x year and genotype x location interactions are considered. However, Comstock and Moll (1963) indicated that bias comes into play when estimates are obtained from a single year and one location. Since the experimental materials in this study were evaluated in one location (Samaru) but with two years data, negative estimates of σ^2_g could be due to the upward bias in the estimation of σ^2_{gl} for the S-1 lines.

The negative estimates of genotype x environment interaction, in this study, for number of heads and 1000-grain weight was found to be interesting. It could definitely not mean that these characters are in sensitive to environmental change. Infact both characters have been proved, physiologically, to be highly influenced by environmental conditions. Number of heads per plot (tillering) has an effect on grain size: tillers produce smaller grains than the mother plant and thus 1000-grain weight is affected. The estimated σ^2_{gl} for [illegible] two characters were smaller than the error variance [illegible]ate.

This explains the negative values obtained since genotype x environment interaction was estimated as $\frac{M_{gl} - M_e}{r}$ where M_e was larger than M_{gl}.

Correlation coefficients estimates compare very well with those obtained in previous studies elsewhere. The most significant correlations from the plant breeding stand point are those between yield and other traits. Yield is positively correlated with plant height, flag-leaf length, number of heads, number of nodes, 1000-grain weight and number of spikes per head. The negative correlation between days to 50% flowering and yield is in agreement with the results of Eckebil (1974) but not with those of Liang et al. (1969) and Jan-Orn (1973). This relationship indicates that earlier mating progenies within the YZC population will tend to be higher yielding. The positive genotypic correlations between 1000 grain weight and yield, number of heads and plant height, are in agreement with the findings of Beil and Atkins (1965), Liang et al. (1969), Eckebil (1974), and Eckebil et al.(1977). The positive phenotypic correlation obtained between 1000-grain weight and yield is also in agreement with results obtained by Swarup and Chaugale (1962) but in disagreement with those of Ali-Khan and Weibel (1969),

It should be pointed out that correlations are a measure of the intensity of association between variables, In selection for the high grain yield alone, the correlated responses that occur in other traits in the improved population may be unfavourable as pointed out by Dogget (1972). In the YZC population yield is highly and positively correlated with some traits which are in turn highly and negatively correlated with each other. For example, yield is highly correlated with 1000-grain weight and number of grains per head, while these two are negatively correlated with each other. It is also highly correlated with head weight and tillering (number of heads per plot) which is negatively correlated with number of grains and grain weight per plant. As a whole, the results show that there is an opportunity for improving yield through its components (1000-grain weight, number of grains per head, number of spikes per head), head weight and height. Continuous selection for these traits will therefore indirectly increase yield, The most correlated trait with yield was found to be head weight in this population. Both 1000-grain weight and number of grains per head were equally phenotypically correlated with yield.

The estimates of heritability for all traits from this study are relatively low compared to those previously reported by Chiang and Smith (1974), Liang and Walker (1968), Ali-Khan and Weibel (1969),Basu (1971)Mandouh et al. (1971), Vasudeva (1973), Jan-Orn et al. (1976), Eckebil et al. (1977) and Panchal et al.(1979).

Obilana and Fakorede (1978), in a critical review of heritability stated that if a trait is strongly influenced by some environmental variations, its heritability would be low in a population in which those environments vary widely. On the other hand, in another population in which the environment is rigidly controlled so that those variations do not occur, the same trait would tend to have high heritability. This statement explains the different results obtained in this population. The 1980 heritability results showing high h^2 for height, days to 50% flowering and low h^2 for yield and some of its components like number of grains per head, agree with the findings of Liang and Walker (1968), Jan-Orn et al.(1976), Basu (1971) and Eckebil et al. (1977). Low h^2 found for peduncle length, number of spikes, length and width of head, weight of head, grain weight per plot agree with those of Panchal et al. (1979). The combined data results which are similar to those of 1979 with low h^2 estimates show a high h^2 estimate for 1000-grain weight which is contrary to the findings of Panchal et al. (1979).

The indications of slight increases in some of the characters of this population should be considered with care, noting the heritability and correlation results of these characters. Aslo to be noted is the difference in the results of the two years and therefore the validity of the combined data.

SUMMARY

Two hundred and fifty S-1 lines derived from the YZC random mating population were grown in 1979 and 1980 at Samaru for population evaluation. YZC was developed from two composites (B composite and Y composite) consisting of both exotic and elite lines. Six varieties (elite lines) were used as checks. These cheks include L. 187, L. 181, L. 1499, L. 1500, L. 123, S.K. 5912.

A 16 x 16 simple lattice design was used for this study. Each plot of 2 rows spaced 90 cm apart had a maximum of 42 plants spaced 30 cm apart.

Data were collected on 10 competitive plants, whenever possible, for 16 quantitatively inherited traits: Days tc 50% flowering, plant height, Flag-leaf length and width, number of nodes per plant, Peduncle length, number of heads per plot, head length and width, head weight, grain weight per plot, grain weight per plant, 1000 grain weight, number of grains per head, number of spikes per head and middle-spike length. Analysis of varianceand co-variance were performed on the 2 year data for all traits. Analysis for each trait was computed on plot mean basis,

Considerable and significant variation within each trait was observed. Coefficients of variations (CV.%)ranged from 3.76% for days to 50% flowering to 37.71% for peduncle length.

Grain yield also showed a relatively high C.V. of 35.81%. There was little difference between means of the S-1 lines and those of the adapted elite lines for all 16 characters. 2.4% of the S-1 lines yielded better than the elite lines: highest yielding elite line, L. 1500, yielded 1.81 kg per plot while the highest grain yield of S-1 lines was 2.12 kg per plot given by Entry 123.

Population means were significantly different for each trait. Significant differences were also observed for years, and the population interacted with years for every trait except number of heads per plot and 1000-grain weight.

Genetic variance estimates among S-1 lines were positive for every trait except peduncle length, head length and width, grain weight per plant and middle spike length. Most genetic variance estimates had large standard errors indicating that either the estimates were not different from zero, or they were small.

Grain yield and related grain-yield components (1000-grain weight, head size, and head weight) were positively correlated with plant characters (Plant height, flag-leaf length and width, number of nodes and number of heads). Yield was negatively correlated with 50% flowering and peduncle length. Besides yield, 50% flowering was negatively correlated with all traits while peduncle length was negatively correlated with all other traits except plant height, head length and width, and 1000-grain weight.

Heritability estimates were quite low due to the low genetic variance estimates and relatively high genotype x environment interaction and error variance estimates.

Predicted gains from selecting the top 10% for the years 1979 and 1980 were quite low and different for two years due to the differences in performance of the lines in the two years. Plant height, head number (tillering), 1000-grain weight and number of grains are expected to increase by 3.34 cm, 2.82, 1.84 kg, 25.57, respectively. Grain yield per plot and head weight are expected to increase by 0.06 kg and 0.07 kg, respectively.

The reliability of the prediction will not be known until the results of selection programme are observed in the experiments planned for comparing original and improved population cycles.

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Table A1: Mean performance of the Six check varieties included in the 2 years evaluation os S-1 lined Y-C population.

Check Varieties	Days to 50% flower-ing	Plant height (cm)	Flag-leaf length (cm)	Flag-leaf width (cm)	No.of Node	Peduncle length (cm)	No.of heads	Head length (cm)	Head width (cm)	Head wt, (kg)	Grain wt/plot (kg)	Grain wt/ plant (g)	1000 grain wt. per plant (g)	No.of grains per head	No.of spikes per head	Mid-spikes length (cm)
L. 187	138.25	182.70	29.55	4.79	18.25	4.12	25.50	26.62	7.89	2.03	1.17	42.02	26.03	1606.47	72.00	9.35
L. 181	139.75	204.80	36.20	4.83	18.75	4.83	28.50	27.20	9.31	2.18	1.13	38.30	26.43	1453.32	93.50	10.40
L.1499	138.00	145.23	33.68	5.06	17.75	6.71	31.00	26.54	7.83	2.39	1.19	38.65	24.50	1600.79	88.25	9.80
L.1500	134.75	166.25	30.05	4.69	19.50	5.72	33.75	27.44	8.61	3.03	1.81	52.31	30.03	1726.58	93.25	8.78
L. 123	137.75	152.63	34.78	5.58	18.50	4.34	29.50	23.69	8.46	2.62	1.49	50.11	28.38	1793.02	82.75	9.35
S.K	138.75	184.50	32.93	5.16	19.75	4.82	40.25	24.20	7.36	2.53	1.38	37.15	25.25	1554.44	84.00	9.45
Mean	137.88	172.69	32.87	5.02	18.75	5.09	31.42	25.95	8.24	2.46	1.36	43.09	26.77	1621.44	85.63	9.52
* Mean of S-1 lines	139.46	161.70	31.90	4.96	18.65	5.90	33.77	25.58	8.28	2.35	1.34	39.91	26.77	1506.62	82.79	9.33

* The S-1 lines were included for direct comparison.

A Table A2 Comparative Mean ($\bar{X}$), standard deviation of the mean (S.E. $\bar{X}$) range and coefficient of avariability (C.V.%) for 16 characters of 250 S-1 lines from the YZC for 1979, 1980

Characters	1979 Mean	1979 S.E. $\bar{X}$	1979 Range	1979 C.V.%	1980 Mean	1980 S.E.$\bar{X}$	1980 Range	1980 C.V.%
Days to 50% flowering	131.23	± 2.12	125.142-139.34	2.28	147.60	± 3.12	134.54-162.55	2.98
Plant length (cm)	186.19	± 25.16	126. 7-260.41	19.11	137.38	±10.59	67.75-223.10	10.89
Flag-leaf length (cm)	31.87	± 3.50	23. 32- 42.36	15.53	31.97	± 2.33	18.81- 43.03	10.31
Flag-leaf width(cm)	5.08	± 1.55	2.72 - 6.47	13.03	4.99	± 0.47	2.65- 7.14	13.46
No. of nodes	19.83	± 1.14	16.32 - 22.77	8.15	17.47	± 1.41	12.27- 22.18	7.45
Peduncle length(cm)	6.38	± 1.76	1.82 - 11.49	38.96	5.33	± 1.58	1.27- 11.66	42.64
Head length (cm)	25.76	± 2.67	11.80 - 35.71	14.63	25.26	± 2.52	11.88- 34.35	14.14
Head width (cm)	8.49	± 0.99	5.50 - 11.59	16.43	8.03	± 1.06	4.42- 13.13	18.60
Head weight (kg)	2.81	± 0.53	1.38 - 4.72	26.85	1.90	± 0.41	0.80- 3.27	17.87
Grain wt. per plot (kg)	1.63	± 0.34	0.56 - 2.96	29.75	1.06	± 0.25	0.26- 2.59	33.25
Grain wt. per plant (g)	43.04	± 7.47	23.06 - 66.16	24.53	36.67	± 9.80	8.63- 64.98	37.81
1000 grain wt per plot (g)	29.66	± 2.30	23.45 - 37.75	10.98	23.87	± 1.90	15.80- 34.47	11.28
No. of grain per head	1431.89	±274.82	610.31 -2511.69	27.14	1561.27	±372.12	445.46-2929.17	33.71
No. of spikes per head	86.01	± 9.27	65.50 - 121.00	15.25	78.40	± 9.26	33.92- 123.49	16.71
Mid-spike length (cm)	9.47	± 0.97	6.30 - 12.20	21.72	9.20	± 0.80	5.65- 14.10	12.26

Table A3: Analysis of variance [illegible] cluster obtained in 250 S-1 lines of the YZC 1979 and 1980.

1979 Mean Squares

Source of Variation	d.f.	Days to 50% flowering	Plant height	Flag-leaf length	Flag-leaf width	Node number	Peduncle length	Head number	Head length	Head width	Head wt.	Grain wt. per plot	Grain wt. per plant	1000 grain wt.	No.of grain per head	No.of spikes per head	M sp le
Replicates	1	815.07	4884.43	108.46	16.31	124.03	16.82	9163.20	334.47	40.90	45.75	13.47	89.00	63.01	38364.01	133.05	2
Entries	255	9.57**	1219.40	22.89	5.41**	2.61**	8.88	105.77	18.34**	1.55	0.69**	0.36**	126.56**	10.68	162639.22**	196.65**	
Error	255	9.01	1266.36	24.48	4.78	2.61	6.18	84.78	14.21	1.95	0.57	0.24	111.48	10.60	151049.46	171.93	

1980

Replicates	1	2132.86	69.33	53.63	2.51	0.28	140.92	122.07	37.58	0.28	7.64	0.69	2039.45	22.19	3558795.12	3543.77	
Entries	255	75.55**	1583.40**	41.75**	1.18**	5.65**	5.55**	83.71**	24.10**	3.71**	0.49**	0.23**	210.15**	24.87**	430823.50**	3333.48**	
Errors	255	19.42	224.58	10.85	0.44	1.69	5.01	48.35	12.75	2.23	0.34	0.12	192.25	7.24	276942.83	171.62	1

** Significant at 0.01 level of probability.

Table A4: Genetic, phenotypic and error variances for 16 characters of the 250 lines of the YZC for 1979 and 1980.

Characters	1979 σ^2_g	1979 σ^2_{ph}	1979 σ^2_e	1980 σ^2_g	1980 σ^2_{ph}	1980 σ^2_e
Days to 50%	0.56±0.58	5.06±0.45	9.09±0.80	27.07±3.36	36.76±3.24	19.42±1.71
Plant height	-23.48±77.53	609.70±53.78	1266.36±111.68	679.41±70.52	791.69±69.84	224.58±19.18
Flag-leaf length	-1.59±1.48	10.65±0.94	24.48±2.16	15.45±1.90	20.81±1.84	10.85±0.96
Flag-leaf width	0.32±0.32	2.71±0.24	4.78±0.42	0.37±0.06	0.59±0.05	0.44±0.04
Node number	0.001±0.23	1.31±0.12	2.61±0.23	1.98±0.26	2.82±0.25	1.69±0.15
Peduncle length	-0.15±0.38	2.94±0.26	6.18±0.55	0.27±0.33	2.77±0.24	5.01±0.44
Head number	1049±5.98	52.88±4.66	84.78±7.48	17.68±4.26	41.85±3.69	48.35±4.27
Head length	2.08±1.02	9.17±0.81	14.21±1.20	5.68±1.24	12.05±1.06	12.75±1.12
Head width	-0.40±0.11	0.58±0.05	1.95±0.17	1.48±0.19	2.60±0.23	2.23±0.20
Head weight	0.12±0.04	0.40±0.04	0.57±0.05	0.07±0.03	0.24±0.02	0.34±0.03
Grain Wt/plot	0.06±0.02	0.18±0.02	0.24±0.02	0.06±0.01	0.12±0.01	0.12±0.01
Grain Wt/plant	5.54±7.44	63.28±5.58	111.48±9.83	8.95±12.56	105.07±9.27	192.25±16.96
1000 grain wt.	0.08±0.67	5.38±0.47	10.60±0.94	8.81±1.14	12.43±1.10	7.24±0.64
No. of grain /head	5794.88±9790.36	81319.46±7173.71	151049.46±13325.01	76940.00±22590.34	215411.00±19002.74	276942.83±24430.85
No. of spikes /head	12.36±11.52	98.33±8.67	171.93±15.17	80.93±16.54	166.74±114.71	171.62±15.14
Mid-spike length	0.01±0.12	0.93±0.08	1.87±0.16	1.26±0.18	1.90±0.17	1.27±0.11

MEANS

Entries	V_1 Days to 50% flowering	V_2 Plant height (cm)	V_9 Flag-leaf height (cm)	V_{10} Flag-leaf width (cm)	V_8 No. of node	V_{11} Peduncle length (cm)	V_4 No. of heads	V_3 Head length (cm)	V_{12} Head width (cm)	V_5 Head weight (kg)	V_6 Grain wt per plot (kg)	V_7 Grain wt per plant (g)	V_{15} 1000 grain wt (g)	V_{16} No. of grain per head	V_{13} No. of spikes/ head
1	136.75	152.88	32.65	4.78	17.75	6.78	30.25	26.71	9.00	2.14	1.34	45.20	23.43	1943.67	87.25
2	140.50	168.75	33.20	5.24	18.25	5.54	22.75	25.50	7.84	1.59	0.84	37.91	30.40	1275.69	84.00
3	138.25	151.20	32.83	5.98	19.00	5.11	34.50	26.00	8.28	2.53	1.60	44.34	22.90	1892.76	90.00
4	137.00	170.00	31.10	5.46	21.25	6.12	38.75	27.28	7.76	2.48	1.55	42.00	28.33	1475.09	84.50
5	139.00	160.88	30.20	4.63	19.50	6.25	33.50	28.43	7.99	2.44	1.40	42.09	31.68	1493.05	80.00
6	142.25	169.50	32.38	4.88	20.25	5.14	33.00	27.25	8.68	2.23	1.16	35.52	27.00	1294.89	86.00
7	139.00	152.25	33.25	4.90	70.50	8.06	29.25	28.17	8.68	2.06	1.29	43.79	29.08	1480.00	79.75
8	144.25	127.85	30.90	3.57	15.50	7.06	28.25	23.66	8.21	1.67	0.93	30.91	25.40	1006.05	67.25
9	142.25	169.88	34.38	5.02	19.50	7.10	39.00	29.21	8.66	2.55	1.35	34.81	26.60	1308.59	89.00
10	136.00	158.50	34.30	6.09	19.75	5.89	34.75	26.98	8.88	3.05	1.91	57.04	31.45	1785.96	78.00
11	143.25	151.88	37.13	5.50	19.75	4.02	36.00	28.93	8.80	2.56	1.52	41.73	25.88	1629.30	78.00
12	139.00	127.75	30.20	4.49	18.75	5.08	36.50	23.30	7.31	2.26	1.10	30.69	20.68	1472.33	71.25
13	136.00	135.40	32.80	5.14	18.25	7.44	28.50	24.40	8.63	2.07	1.11	40.74	25.08	1783.91	77.50
14	138.25	160.75	30.10	5.15	20.25	5.73	40.25	26.71	8.85	2.82	1.57	44.19	30.18	1437.03	84.25
15	136.75	171.38	34.64	5.58	17.75	6.47	30.50	26.95	8.57	2.18	1.33	42.77	25.80	1682.36	90.25
16	137.50	155.75	31.85	5.63	18.00	7.51	26.00	24.39	6.95	2.30	1.37	54.29	29.55	1822.57	90.75
17	138.50	189.73	28.53	4.44	16.50	7.53	32.00	23.41	7.60	2.69	1.65	44.93	26.40	1817.93	73.25
18	142.00	161.88	32.90	5.03	19.00	4.91	35.00	26.99	8.55	2.42	1.35	44.67	27.48	1674.45	85.00
19	136.25	153.25	37.40	5.42	18.25	4.65	35.50	22.26	7.78	2.87	1.63	45.08	28.05	1596.98	75.00
20	140.75	161.98	32.43	4.39	17.25	5.66	33.75	23.22	9.30	1.48	0.75	24.10	22.60	1051.59	84.00

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
21	137.75	143.00	31.23	5.04	17.50	6.00	31.25	22.39	8.93	1.82	1.02	33.44	24.58	1399.00	73.50	8.7
22	141.75	143.85	28.48	4.09	18.25	5.81	36.00	25.77	8.15	2.15	1.16	34.24	26.63	1289.65	77.75	8.95
23	141.75	180.98	28.88	4.62	17.75	5.20	23.75	26.81	8.88	2.10	1.12	49.68	30.75	1627.79	87.00	9.83
24	138.00	162.00	38.08	5.10	19.50	8.21	29.75	26.85	6.84	2.05	1.11	38.07	28.63	1354.00	81.50	9.18
25	144.5	165.35	33.48	4.61	18.75	7.36	32.50	25.88	8.08	2.18	1.15	34.20	25.50	1321.60	81.00	9.23
26	138.50	177.88	33.58	4.92	19.00	8.59	33.50	31.16	8.67	2.06	1.06	32.59	29.13	1142.74	86.50	10.25
27	137.75	161.63	27.53	4.28	18.25	7.19	32.75	27.72	6.93	1.90	1.16	35.14	30.83	1141.28	84.25	9.15
28	137.75	184.75	30.08	4.88	18.00	5.72	30.00	28.54	8.19	2.26	1.22	41.46	29.73	1427.50	87.75	8.85
29	143.75	153.63	33.15	5.45	17.50	7.45	34.00	24.80	7.92	2.23	1.18	34.12	26.23	1285.96	74.50	9.78
30	144.50	162.25	31.25	4.38	18.00	7.64	29.25	22.79	7.20	1.57	0.88	27.35	24.65	1086.06	81.25	9.48
31	143.75	173.13	34.83	5.29	17.75	6.71	29.75	27.10	7.77	2.11	1.31	38.26	24.60	1538.61	86.75	9.53
32	140.00	157,50	31.18	4.48	18.50	7.09	31.75	22.69	7.31	2.13	1.21	37.63	24.25	1556.95	91.00	7.85
33	140.50	162.63	28.63	4.96	20.00	6.67	38.50	27.48	8.42	2.39	1.45	37.42	25.90	1450.14	76.50	8.58
34	137.25	169.13	32.70	5.74	19.25	5.59	35.25	28.25	8.65	2.31	1.22	33.87	27.83	1198.02	82.25	9.08
35	140.50	167.58	27.75	4.33	18.75	4.27	35.50	27.31	7.76	2.34	1.35	38.41	26.33	1504.74	81.50	11.05
36	135.25	161.00	31.23	5.19	20.50	5.65	37.75	23.95	7.56	2.59	1.32	34.63	29.88	1173.69	76.00	9.53
37	135.75	149.25	35.38	5.56	19.00	6.68	37.25	25.57	8.24	3.10	1.78	50.19	24.45	2099.83	81.00	9.90
38	135.00	136.40	35.15	5.88	18.00	4.93	36.50	22.82	8.79	2.67	1.41	40.81	24.88	1672.50	82.25	10.00
39	143.50	149.63	25.12	4.37	18.25	8.16	28.25	25.99	7.31	1.43	0.88	38.09	29.45	1360.13	75.25	6.33
40	134.50	140.20	31.18	5.33	17.75	6.31	33.50	22.38	8.59	2.19	1.19	37.51	25.40	1478.09	87.75	8,80
41	140.25	160.38	28.60	5.23	18.00	6.84	29.25	25.34	8.54	2.25	1.31	44.46	30.68	1450.79	84.75	8.75

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
42	139.75	176.00	32.08	4.13	17.75	7.85	26.25	27.48	8.71	1.73	0.81	31.15	24.70	1283.51	78.50	10.48
43	132,25	177.38	34.45	5.19	16.25	5.71	32.25	28.92	8.87	2.42	1.48	45.00	27.95	1681.02	83.75	9.15
44	137.50	168.50	32.28	6.04	19.75	6.45	37.75	27.26	8.58	2.73	1.43	39.48	30.58	1284.52	80.00	9.50
45	144.75	158.53	34.23	4.61	17.75	6.69	20.50	26.10	7.12	1.31	0.68	31.04	27.70	1072.32	79.00	9.48
46	141.25	152.25	26.43	4.41	19.50	5.58	36.50	24.79	7.23	2.37	1.40	39.03	27.28	1411.70	79.25	9.68
47	136.56	131.38	35.23	5.43	17.50	4.34	28.25	23.10	7.19	1.97	1.13	36.38	24.13	1501.40	89.25	8.00
48	142.75	163.25	22.60	3.59	18.75	3.88	27.50	26.52	8.31	1.98	1.18	42.46	25.73	1651.56	83.00	8.70
49	139.25	162.15	31.68	4.48	18.50	6.44	35.00	28.66	6.77	1.73	0.92	22.05	25.86	828.45	73.50	9.55
50	137.00	129.63	27.96	4.70	18.00	5.87	29.25	22.38	7.39	1.71	0.96	32.77	25.51	1261.74	67.00	9.13
51	134.00	168.25	33.43	5.15	19.50	7.16	30.50	27.60	8.48	2.22	1.23	39.12	25.19	1569.70	81.50	9.48
52	142.25	137.35	28.08	4.82	20.00	5.64	40.25	23.15	7.78	2.47	1.48	38.68	28.48	1345.31	75.00	10.00
53	141.75	139.00	29.88	4.31	20.75	6.29	28.75	24.65	7.12	1.73	1.01	35.85	23.97	1486.07	69.25	7.80
54	143.25	122.25	33.93	5.78	19.50	5.51	33.00	22.84	8.31	2.42	1.33	37.22	32.05	1153.22	87.00	8.63
55	136.00	171.50	27.65	4.74	18.50	4.02	29.25	27.72	8.35	2.21	1.38	45.25	28.71	1658.03	73.75	9.70
56	140.50	186.38	28.15	4.68	18.75	4.34	33.75	23.62	7.90	2.13	1.26	37.05	25.66	1425.94	84.25	7.20
57	140.00	192.33	34.43	5.83	19.25	6.15	28.25	24.49	8.32	2.21	1.29	45.74	27.24	1742.28	85.25	9.17
58	141.75	159.00	29.58	4.39	18.50	3.96	34.50	24.55	7.88	2.29	1.36	43.59	23.25	1879.83	84.25	9.28
59	137.75	152.25	30.30	4.88	19.00	6.69	32.25	24.48	7.76	1.81	1.03	31.35	25.93	1192.79	75.00	8.98
60	142.50	154.48	32.38	5.08	20.75	4.20	33.50	20.93	8.40	2.11	1.26	35.95	30.66	1177.16	79.75	8.73
61	138.75	186.50	28.93	4.84	19.75	6.32	34.50	27.34	9.51	2.35	1.52	43.81	28.28	1549.18	82.00	8.73

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
62	141.50	147.88	33.23	4.93	19.00	4.50	30.00	24.66	7.82	1.88	0.99	33.23	26.81	1228.22	74.50	8.88
63	138.25	173.88	35.40	6.13	19.75	6.42	37.75	26.53	8.50	2.88	1.73	45.97	27.23	1702.67	75.75	10.03
64	141.50	124.63	28.55	4.76	20.25	5.09	33.25	22.83	7.40	2.21	1.14	33.32	26.32	1237.67	75.25	8.33
65	143.25	177.88	30.33	5.13	18.50	7.68	35.25	25.44	8.56	2.26	1.16	32.42	27.28	1187.69	86.50	10.20
66	138.00	177.48	33.13	5.24	19.00	3.89	37.00	18.88	8.07	2.86	1.76	47.64	30.13	1593.74	100.25	8.18
67	138.00	188.75	33.88	5.38	17.50	6.75	33.50	26.74	8.48	2.74	1.43	41.83	28.55	1454.40	82.25	9.60
68	137.75	154.38	32.75	5.10	20.75	4.12	38.75	25.78	8.77	2.89	1.70	45.13	27.38	1727.32	90.75	9.70
69	143.00	169.50	28.88	4.77	18.00	6.15	32.50	23.56	7.62	2.24	1.27	39.83	26.15	1517.82	87.75	8.85
70	141.75	155.63	30.13	4.56	17.25	7.27	29.75	26.57	8.47	2.04	1.24	41.75	24.25	1746.92	84.75	8.65
71	139.00	167.00	25.93	4.77	18.50	4.32	36.00	24.71	8.77	2.76	1.76	51.68	25.79	2036.14	94.00	9.58
72	138.75	144.60	30.48	4.73	18.00	5.32	29.75	26.36	9.17	2.10	1.10	36.51	22.80	1648.68	88.00	9.00
73	139.25	202.45	33.33	5.82	17.75	5.43	38.50	23.59	7.43	1.96	1.16	30.90	27.18	1142.15	72.25	9.33
74	141.00	169.50	35.43	5.30	18.50	8.96	35.00	26.96	8.81	2.40	1.25	37.09	24.58	1519.41	79.75	11.08
75	140.00	146.25	32.75	4.96	17.75	5.87	40.50	23.89	8.38	2.46	1.38	33.23	26.90	1269.85	74.75	9.28
76	141.50	168.50	26.25	4.15	15.50	8.90	29.25	23.94	8.20	1.78	0.93	33.09	22.30	1469.20	71.00	8.10
77	140.75	152.18	30.98	4.95	18.25	6.92	23.25	28.33	7.63	1.75	1.00	40.24	28.78	1396.57	75.25	9.38
78	144.75	161.68	30.53	4.73	17.25	5.74	24.00	26.14	8.24	1.73	0.99	44.08	29.05	1603.76	84.75	8.55
79	147.00	141.18	38.03	5.78	19.25	4.50	31.00	27.69	7.53	1.83	1.06	28.84	26.83	1001.06	84.25	9.95
80	138.00	157.00	30.60	5.30	19.25	7.13	38.00	25.38	8.47	3.03	1.69	44.29	22.95	1584.39	81.00	10.58
81	143.25	138.08	34.30	4.87	20.25	5.85	34.50	26.81	7.65	1.67	0.91	28.19	30.25	930.95	76.75	9.73
82	139.00	160.88	36.98	5.79	19.75	6.11	31.75	24.91	6.91	2.00	1.10	32.72	30.03	1098.03	72.00	8.25

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
83	136.75	148.63	34.71	5.56	20.25	5.83	34.75	26.12	9.67	2.75	1.58	45.54	27.25	1683.60	74.25	10.28
84	137.00	136.63	35.33	5.50	18.50	3.64	33.25	22.48	8.83	2.65	1.40	42.05	24.98	1705.92	86.50	9.28
85	137.25	156.50	33.03	5.11	19.00	4.41	47.25	24.14	9.03	3.14	1.85	38.06	25.42	1528.79	84.75	8.53
86	137.25	169.38	35.03	4.96	18.25	5.09	32.50	26.43	8.20	2.86	1.69	49.85	28.10	1759.15	97.50	9.50
87	140.25	132.00	35.98	4.95	20.00	5.06	35.75	21.08	7.44	2.65	1.35	36.41	25.35	1434.38	76.00	9.75
88	143.75	144.23	32.73	5.07	19.50	4.62	33.75	28.55	8.60	1.88	1.06	31.52	25.67	1177.35	73.25	8.60
89	139.25	178.50	28.88	5.04	18.50	4.52	37.25	26.07	6.89	2.24	1.53	39.58	24.92	1568.51	72.25	9.28
90	144.25	149.38	31.25	5.39	17.50	7.43	27.25	27.03	6.29	1.63	0.99	29.58	25.85	1104.10	67.50	8.25
91	144.50	153.88	32.08	5.51	20.00	4.90	38.50	25.86	7.76	2.19	1.27	32.97	25.59	1258.04	85.75	8.00
92	144.25	148.50	38.40	5.44	17.75	4.32	42.50	26.62	7.85	2.98	1.78	39.43	27.28	1411.07	105.50	8.85
93	137.75	153.63	30.57	5.05	19.00	4.23	42.25	25.90	8.65	2.80	1.35	31.92	28.28	1114.27	83.00	9.85
94	134.00	207.63	33.48	5.38	20.00	94	48.50	27.32	9.11	2.40	1.45	29.47	29.15	1014.34	70.75	9.43
95	145.50	195.25	36.05	5.04	19.50	6.93	44.75	29.78	8.74	3.18	1.84	38.69	27.61	1369.49	81.50	10.13
96	140.75	187.00	33.80	5.28	18.00	5.72	31.75	25.83	8.24	1.96	1.12	33.79	27.24	1220.92	77.75	8.68
97	138.50	175.63	35.33	5.73	17.75	5.73	31.75	27.61	8.95	2.34	1.43	44.42	26.30	1687.65	76.75	10.60
98	144.75	172.23	28.20	4.70	20.00	6.76	44.50	27.25	6.83	3.06	1.73	39.53	27.43	1414.07	78.75	8.58
99	140.25	171.13	33.45	4.79	18.25	6.08	29.75	29.74	8.77	2.67	1.34	47.93	28.98	1746.02	79.75	9.43
100	137.25	157.00	30.28	4.28	22.00	6.22	41.50	25.20	7.69	2.65	1.69	39.36	29.90	1314.58	74.25	9.73
101	139.50	165.13	34.42	4.99	20.75	5.38	34.75	26.67	8.29	2.70	1.51	47.98	25.73	1880.93	95.25	10.68
102	138.50	219.63	34.30	4.58	19.50	6.62	34.50	28.52	9.10	2.39	1.48	41.28	25.40	1603.48	84.75	10.13
103	137.75	174.00	31.30	4.57	18.75	5.31	41.00	29.20	8.57	2.70	1.54	38.95	28.53	1397.68	80.00	9.75

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V
104	138.25	145.63	30.40	4.70	20.50	5.65	41.25	25.69	7.42	2.68	1.57	37.53	27.83	1355.36	81.50	9.4
105	134.50	168.63	30.50	4.92	19.00	7.36	32.75	26.61	7.84	2.43	1.47	41.69	28.20	1491.82	77.25	9.1
106	136.50	174.13	29.38	4.72	17.00	6.97	29.50	24.20	8.57	2.25	1.30	43.58	25.20	1736.81	72.00	8.8
107	138.75	111.83	27.20	4.72	17.50	6.59	31.00	23.66	7.04	1.68	0.90	32.90	22.88	1431.40	72.50	8.0
108	137.00	183.13	25.58	4.40	18.25	5.01	41.00	24.90	8.08	2.38	1.39	33.53	25.03	1328.50	90.50	8.4
109	138.00	178.63	29.28	4.90	18.25	5.87	34.00	25.94	8.24	2.77	1.59	46.90	22.63	1734.16	90.00	9.6
110	135.50	163.65	26.40	4.31	17.75	6.96	33.75	24.66	7.85	1.77	0.99	30.42	25.98	1175.09	67.25	8.8
111	140.75	152.30	28.90	4.92	19.00	4.64	33.25	24.42	8.22	2.83	1.78	53.09	23.63	2369.23	78.50	8.5
112	141.00	181.50	34.40	5.11	19.50	6.05	38.50	26.32	8.13	2.38	1.49	37.17	24.80	1521.59	84.75	9.8
113	140.25	155.35	33.98	5.03	18.75	7.48	40.00	27.75	9.05	2.37	1.41	36.59	29.80	1279.09	81.25	11
114	137.75	168.88	30.40	5.03	18.75	6.04	34.25	23.69	8.78	2.39	1.36	39.43	25.40	1571.19	87.50	9.1
115	138.75	130,38	29.65	4.25	18.25	2.43	30.50	25.27	8.66	2.01	1.03	34.87	22.63	1508.28	88.75	9.1
116	141.75	138.50	28.60	4.17	18.75	5.07	34.25	25.36	7.36	2.32	1.20	36.75	25.75	1426.60	88.50	9.1
117	138.00	139.88	33.38	5.01	19.00	4.87	35.25	25.76	7.94	2.78	1.58	41.64	30.38	1393.93	89.25	8.8
118	143.00	170.88	29.83	4.36	19.00	5.36	34.50	26.55	8.52	2.81	1.36	38.31	28.43	1353.21	85.25	9.1
119	141.00	168.15	31.58	5.28	19.25	6.04	31.00	23.33	9.33	2.82	1.78	57.58	31.43	1822.74	91.50	9.0
120	136.25	143.50	35.53	5.08	18.75	4.38	39.50	24.71	8.03	2.63	1.32	33.33	27.73	1200.31	107.00	9.
121	141.00	167.63	34.23	5.00	19.50	4.41	35.75	27.81	9.50	2.94	1.64	46.89	22.93	2159.79	88.75	10
122	133.50	261.88	32.15	4.54	18.25	5.16	50.00	25.46	8.50	2.69	1.69	33.95	37.20	1260.82	107.75	9.
123	139.25	150.10	30.05	4.45	19,50	3.26	42.00	23.62	7.99	3.27	2.12	50.37	25.70	1981.74	78.00	8.

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
124	134.25	160.13	33.45	4.66	19.50	5.49	36.75	27.63	9.56	2.90	1.64	44.71	26.98	1661.15	92.75	10.18
125	138.00	151.88	32.05	4.97	18.25	6.29	33.75	24.51	7.91	2.72	1.73	51.83	27.90	1856.98	93.25	9.20
126	137.75	143.88	30.35	4.62	18.00	4.95	36.50	25.31	7.73	2.75	1.61	45.29	27.33	1650.52	81.50	9.15
127	142.25	136.00	29.60	4.51	17.75	4.94	28.75	23.57	8.82	1.92	0.97	24.49	24.55	973 .81	87.25	8.90
128	135.00	151.38	30.40	5.01	17.75	7.26	32.75	26.03	8.37	2.74	1.77	49.17	29.95	1644.73	81.25	8.68
129	134.00	188.88	34.05	5.39	18.50	3.64	37.25	25.36	8.63	2.86	1.69	44.34	25.78	1690.28	80.75	9.60
130	138.00	167.50	36.43	5.32	21.00	3.52	38.25	28.03	8.55	2.81	1.73	45.04	26.68	1693.37	78.50	9.95
131	135.50	159.63	32.55	5.16	18.00	3.88	37.25	24.18	8.59	2.77	1.50	39.04	27.08	1401.82	78.75	8.83
132	139.25	177.50	30.53	4.91	17.25	6.05	38.25	20.61	7.24	2.52	1.52	37.73	26.98	1388.78	82.75	7.60
133	135.25	164.00	31.30	5.08	19.00	6.09	32.75	21.04	7.67	2.64	1.47	37.15	24.25	1560.69	82.25	8.13
134	146.75	132.50	25.38	4.17	17.75	5.09	24.75	23.88	7.37	1.63	0.97	41.17	24.33	1707.82	67.75	8.70
135	135.75	163.00	32.25	4.86	17.25	4.93	39.75	27.15	7.75	2.88	1.62	39.80	25.35	1584.92	86.00	9.18
136	137.25	162.38	34.30	4.86	17.75	6.36	30.00	25.68	8.06	2.14	1.20	39.95	25.78	1575.64	88.75	9.95
137	142.00	150.28	29.83	4.81	19.00	5.85	36.00	25.07	7.09	2.07	1.24	33.36	27.63	1183.17	74.75	9.15
138	145.75	164.13	29.88	4.13	18.75	6.00	38.75	25.65	7.02	2.03	1.08	27.47	25.55	1078.88	71.25	9.65
139	138.25	152.88	30.30	5.23	18.00	5.99	29.75	24.87	7.60	2.08	1.15	39.69	26.98	1437.26	76.25	9.38
140	139.25	181.75	35.73	5.36	20.00	3.70	39.75	23.51	7.42	2.69	1.37	34.05	25.28	1396.65	96.25	8.03
141	135.00	174.38	37.15	5,20	18.25	6.03	43.25	22.93	8.33	2.91	1.64	38.46	26.08	1513.18	78.50	8.98
142	135.75	102.63	33.51	5.41	20.75	4.93	38.50	26.50	8.69	2.39	1.45	37.26	28.80	1288.10	86.10	8.78
143	143.75	182.78	34.95	5.40	19.75	4.09	37.25	26.02	8.00	2.68	1.18	32.18	30.03	1065.94	96.75	9.10
144	138.25	169.93	33.33	5.22	18.75	5.23	26.25	25.45	9.34	2.32	1.31	47.54	31.93	1523.78	77.75	10.78

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
145	133.75	151.75	34.06	5.24	18.50	5.31	28.25	26.45	8.29	2.04	1.12	39.77	25.78	1507.97	83.00	8.25
146	140.00	174.38	31.38	4.47	19.25	7.37	41.25	28.20	9.93	2.79	1.44	35.39	26.60	1309.44	72.50	11.78
147	134.50	187.13	32.35	5.18	19.00	4.14	38.25	27.74	9.68	2.51	1.55	41.51	28.75	1490.54	89.50	8.80
148	138.25	156.38	33.08	4.28	16.75	7.53	30.50	23.75	7.75	2.25	1.41	40.99	28.08	1479.64	79.50	7.95
149	137.75	161.98	30.35	4.34	16.00	7.76	29.75	23.21	7.11	1.55	0.94	31.00	24.73	1258.87	75.75	9.00
150	141.75	151.88	29.58	5.09	18.25	6.71	29.00	23.69	9.55	2.13	1.09	37.87	26.68	1418.99	72.50	9.43
151	141.75	135.38	29.03	4.13	18.75	2.97	25.50	24.27	8.00	1.95	1.10	43.28	22.08	1921.17	92.75	8.90
152	144.25	152.50	30.18	4.36	19.25	6.56	41.75	24.62	7.19	2.35	1.34	29.93	26.23	1101.71	73.25	9.03
153	140.00	159.00	32.98	4.64	19.00	6.56	31.75	26.63	7.65	2.01	1.16	37.04	28.70	1304.41	97.75	7.63
154	139.25	188.93	38.25	5.113	19.25	7.43	38.00	28.28	11.22	2.79	1.64	42.49	27.70	1533.96	85.25	9.68
155	135.25	155.18	33.10	4.75	17.50	5.93	34.50	25.42	9.08	2.33	1.19	35.44	28.23	1258.68	94.25	9.63
156	138.25	182.50	34.98	5.23	20.00	5.95	31.00	22.51	9.21	2.47	1.40	40.40	26.96	1522.64	77.50	9.60
157	134.25	153.88	31.73	4.38	19.00	7.15	39.00	26.48	10.35	2.70	1.35	33.18	25.25	1261.75	78.50	10.00
158	134.00	183.33	35.78	5.00	18.50	3.85	41.25	24.31	8.82	2.80	1.64	37.64	26.45	1404.61	91.25	9.45
159	137.25	161.00	36.50	5.27	18.00	6.02	40.75	24.79	8.19	2.94	1.68	42.36	29.45	1429.98	94.25	10.50
160	143.00	180.05	28.60	4.68	17.50	5.68	30.25	21.68	8.19	2.31	1.31	45.81	23.73	1954.18	94.25	8 .40
161	145.50	177.25	34.15	5.05	18.25	6.28	28.75	27.90	7.19	1.60	0.77	30.34	26.03	1251.15	82.25	9.70
162	140.75	171.25	33.83	5.03	18.25	4.17	31.75	25.99	7.66	2.06	1.10	33.77	23.68	1482.26	96.25	9.63
163	141.75	177.20	30.88	4.85	18.50	8.18	38.75	25.55	8.86	3.09	1.75	44.83	25.68	1792.44	85.50	9.98
164	147.25	183.13	35.53	5.06	17.75	5.41	40.00	27.99	7.75	2.25	1.17	28.58	25.83	1082.84	88.00	9.88

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
165	134.25	161.63	32.30	5.50	18.25	4.89	24.00	28.29	10.43	2.14	1.31	55.79	25.55	2326.90	79.00	10.55
166	136.50	133.63	38.33	5.18	18.25	5.36	35.00	28.44	9.43	2.72	1.64	49.66	26.10	2011.83	73.25	10.00
167	142.50	105.00	26.30	4.88	18.75	3.12	33.25	22.59	7.56	1.84	1.22	36.28	24.80	1368.20	82.25	8.53
168	136.25	217.88	29.75	5.36	19.50	4.82	37.75	25.91	8.29	2.46	1.31	34.47	22.43	1511.95	83.00	9.45
169	138.00	154.13	34.23	5.34	18.25	5.51	34.75	27.36	9.10	2.33	1.19	33.44	26.53	1301.09	85.25	9.28
170	136.25	158.38	29.60	4.91	20.25	2.53	32.25	21.22	8.36	2.62	1.51	49.74	25.28	1975.80	92.75	7.45
171	136.00	179.39	32.38	5.66	18.00	4.31	36.00	27.18	9.73	2.55	1.57	44.95	24.90	1874.59	83.50	10.70
172	141.75	165.68	27.38	4.16	18.25	7.29	36.25	26.30	8.31	2.78	1.68	45.91	25.83	1806.72	89.75	9.18
173	142.25	205.25	32.25	4.77	19.00	3.49	38.25	29.72	7.05	2.46	1.53	43.02	26.35	1616.63	85.50	8.88
174	135.50	188.93	36.65	5.29	19.25	4.49	45.25	26.58	9.43	3.16	2.00	45.66	26.65	1926.80	74.50	9.90
175	142.25	169.25	34.83	5.09	18.50	5.68	26.00	27.84	8.40	1.88	0.94	37.50	30.73	1232.69	78.10	9.48
176	138.50	159.68	30.88	4.63	18.50	4.64	34.25	24.28	8.27	2.53	1.51	42.52	27.33	1555.97	72.00	9.70
177	140.50	137.58	34.93	5.14	18.75	6.07	32.00	24.99	7.79	2.10	1.11	34.63	29.13	1190.05	85.00	9.70
178	137.25	144.38	30.60	4.50	18.75	6.97	31.50	24.99	7.27	2.22	1.38	46.21	30.25	1634.99	88.25	9.28
179	134.50	164.88	32.20	5.50	18.30	6.08	37.75	24.25	8.04	2.53	1.36	37.41	25.10	1527.60	94.25	8.85
180	133.00	148.25	26.70	4.52	17.50	5.71	31.00	28.88	8.17	2.07	1.16	38.73	24.85	1523.69	77.25	9.28
181	139.00	146.88	32.85	4.70	18.00	6.17	34.25	24.09	7.04	2.12	1.38	40.88	29.58	1402.73	89.25	10.08
182	137.50	186.50	31.08	4.80	19.25	6.39	27.50	28.91	8.45	2.14	1.38	47.50	27.78	1709.52	88.25	9.85
183	140.75	199.90	30.50	5.11	18.25	7.10	31.00	26.21	9.15	2.57	1.33	42.78	26.90	1693.65	95.75	9.28
184	135.50	145.13	27.25	4.60	16.75	7.54	31.75	23.95	7.76	1.85	1.13	34.67	26.15	1352.10	81.50	8.60

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V
185	137.00	167.88	30.30	6.34	18.00	7.35	30.75	25.91	9.21	2.54	1.37	47.74	26.58	1859.95	84.25	8.5
186	140.75	157.35	34.90	5.00	18.00	7.42	35.50	27.60	8.67	2.70	1.55	42.46	29.83	1493.90	82.00	10.
187	132.50	181.88	32.25	5.94	19.00	5.68	32.00	22.49	7.92	2.03	1.09	35.03	23.58	1600.02	84.00	8.8
188	138.75	177.00	30.13	5.59	18.50	7.44	35.75	23.46	7.97	2.39	1.34	37.36	26.33	1422.85	81.75	8.3
189	140.75	150.63	31.48	5.79	18.25	7.95	34.00	25.84	8.12	2.27	1.35	39.63	26.40	1462.93	100.75	8.7
190	143.00	163.38	37.23	5.66	18.25	6.79	27.25	26.18	8.75	2.19	1.20	42.61	25.25	1767.38	90.25	9.1
191	140.25	120.63	32.00	4.51	17.75	5.35	27.75	23.48	7.01	1.93	1.08	37.59	22.70	1684.92	83.75	9.0
192	137.25	138.38	36.90	5.73	17.00	7.35	31.75	24.12	8.32	2.11	1.04	32.94	29.95	1096.07	77.75	9.7
193	133.25	170.50	28.95	4.24	18.75	4.74	44.75	23.12	7.43	2.78	1.73	39.46	27.60	1413.30	81.50	8.7
194	147.00	145.25	34.33	4.66	17.36	5.15	25.25	28.32	8.90	1.87	1.16	40.66	27.08	1387.74	74.50	11.
195	143.75	161.35	33.95	5.50	19.50	6.18	32.50	27.20	8.36	2.25	1.44	47.54	27.35	1797.79	76.00	9.9
196	134.00	136.13	26.03	4.20	17.00	5.55	35.00	21.66	7.32	1.91	1.09	30.69	26.60	1126.57	81.75	8.2
197	138.75	151.60	35.05	5.69	17.75	6.39	34.00	24.26	8.38	2.49	1.50	46.04	27.10	1700.58	77.25	8.9
198	146.50	160.35	34.20	5.31	17.50	4.79	31.75	23.38	6.28	2.19	1.29	33.63	26.85	1252.12	82.30	9.5
199	140.75	150.75	31.48	4.91	18.25	6.28	37.25	20.61	7.84	2.40	1.35	35.87	26.10	1400.68	74.25	9.0
200	144.50	125.03	25.45	3.80	18.25	6.25	28.25	25.48	8.62	2.00	1.21	42.86	26.08	1675.26	82.50	9.1
201	139.25	161.88	31.98	4.27	19.75	4.97	34.00	21.92	7.10	2.76	1.58	48.13	28.53	1747.60	84.00	9.0
202	141.00	160.00	31.15	4.86	17.25	5.42	25.50	26.07	8.00	2.00	1.16	43.45	27.38	1594.06	80.00	8.6
202	143.25	184.38	30.10	4.40	20.50	6.63	41.00	25.19	8.91	3.43	2.10	51.66	26.25	1948.92	78.75	9.5
204	141.50	170.00	31.68	4.50	18.75	4.63	34.75	26.04	7.22	2.18	1.21	35.40	30.13	1253.95	82.00	8.8
205	137.00	147.85	31.73	5.13	20.25	5.61	42.75	23.20	8.67	3.20	1.79	41.42	26.00	1597.84	83.25	9.5

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
206	145.00	158.63	32.88	5.06	18.00	6.45	32.75	24.31	8.58	2.13	1.30	39.42	29.58	1309.62	79.75	9.43
207	135.75	159.88	30.75	5.36	20.00	5.17	41.50	26.27	8.67	2.95	1.67	41.08	27.03	1519.75	82.75	10.08
208	137.75	159.75	28.28	5.34	19.75	8.09	35.25	25.80	7.68	2.33	1.42	40.19	28.38	1435.39	66.25	9.15
209	146.00	133.30	32.78	5.30	18.25	6.08	31.50	23.35	8.20	1.54	0.86	26.26	26.73	959.71	71.75	10.10
210	141.50	158.78	30.10	4.00	17.50	8.26	30.00	21.70	8.17	1.96	1.18	30.85	26.28	1675.72	92.50	8.38
211	137.75	152.55	30.13	4.12	18.75	7.46	38.25	23.54	8.57	2.28	1.32	34.17	22.38	1576.90	87.50	9.55
212	147.75	177.75	32.10	4.30	16.75	8.31	16.75	28.65	8.95	1.35	0.61	37.39	27.58	1300.48	89.75	8.28
213	141.75	150.93	35.08	4.83	19.00	8.13	36.50	27.07	9.68	2.54	1.41	36.90	22.58	1593.21	73.75	10.65
214	140.25	150.13	27.88	4.91	18.50	9.08	28.50	25.90	8.41	1.99	1.27	42.77	26.20	1627.81	82.00	9.80
215	142.50	146.60	30.63	4.47	19.25	5.37	26.00	25.17	9.20	2.33	1.39	58.42	27.40	2163.57	79.25	11.78
216	136.50	171.13	33.73	4.74	19.00	5.44	30.00	27.56	9.67	2.63	1.43	47.83	25.53	1868.15	77.75	10.53
217	140.00	182.75	30.98	4.71	18.25	7.74	23.00	28.04	9.90	1.93	1.01	42.20	24.05	1770.46	81.75	9.63
218	141.00	147.85	26.35	4.16	18.25	8.22	30.50	24.26	8.34	2.07	1.23	39.28	24.23	1650.64	83.50	8.85
219	143.50	168.30	31.78	4.83	18.75	4.83	29.75	26.00	7.33	1.77	0.97	34.87	28.18	1238.63	84.75	8.38
220	140.75	191.38	32.60	4.80	19.50	5.93	36.00	24.92	7.84	3.01	1.85	51.55	26.88	1923.79	83.00	8.81
221	137.50	197.25	32.03	5.21	18.75	5.38	32.25	27.28	8.64	2.76	1.43	44.86	29.38	1531.20	97.50	9.35
222	139.25	167.25	31.09	4.51	19.00	4.10	40.25	20.54	6.64	2.97	1.69	35.56	25.55	1404.63	83.75	8.75
223	139.25	133.05	25.10	3.89	16.25	8.36	28.00	22.62	8.09	1.91	1.17	42.01	24.53	1745.37	68.75	7.88
224	147.00	126.00	36.90	5.49	19.75	4.68	28.75	26.67	7.15	1.71	1.01	34.90	24.63	1453.26	78.50	9.28
225	135.75	180.25	27.35	3.91	19.75	5.28	33.50	33.81	10.87	2.58	1.36	43.89	27.93	1511.38	34.25	8.83
226	143.25	151.15	27.78	4.15	17.25	4.27	40.50	24.72	8.70	2.31	1.34	33.32	24.23	1227.91	93.75	8.90

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
227	139.50	153.50	37.20	5.23	20.25	4.28	29.25	22.73	8.99	2.40	1.27	46.76	27.53	1677.14	84.00	10.10
228	135.75	137.38	29.08	4.57	18.25	4.69	40.50	24.93	9.16	2.73	1.46	35.18	27.18	1288.32	80.00	10.33
229	141.25	16.10	37.05	5.31	19.75	3.71	29.00	25.95	7.85	2.37	1.41	50.26	23.20	2247.78	93.75	8.70
230	135.25	144.40	30.58	4.69	8.25	6.10	26.25	25.19	9.66	2.40	1.48	59.85	27.35	2180.07	76.75	10.80
231	138.75	170.38	34.63	5.16	18.50	7.20	32.00	25.63	8.55	2.59	1.54	46.30	26.40	1741.32	86.25	8.98
232	143.25	167.38	38.83	6.45	18.50	7.76	26.25	28.50	9.14	2.45	1.40	57.22	29.05	1993.26	86.25	9.28
233	140.50	138.63	32.60	4.80	17.00	10.18	23.00	27.50	8.99	2.23	1.22	52.79	28.85	1943.90	83.75	9.48
234	137.75	173.38	29.50	4.98	17.00	5.38	33.25	23.36	7.61	2.27	1.36	39.66	27.45	1443.05	84.75	9. 3
235	141.00	224.25	34.08	4.86	19.75	5.52	38.00	29.59	8.97	2.89	1.51	41.66	29.15	1414.48	86.50	9.18
236	141.75	191.63	39.00	4.99	19.25	6.88	38.75	24.71	8.34	2.25	1.36	47.62	26.60	1790.32	76.00	9.00
237	143.50	157.08	28.83	4.17	19.25	7.23	31.25	29.02	9.07	2.32	1.22	38.36	28.80	1354.18	82.25	10.05
238	133.75	138.50	32.15	4.66	18.75	10.58	38.25	25.77	8.11	2.57	1.45	36.25	25.25	1425.68	78.75	8.93
239	*139.25*	*127.88*	*33.10*	*9.18*	*20.00*	*5.26*	*35.25*	*25.29*	7.83	2.61	1.59	51.60	25.60	*2036.18*	84.00	10.70
240	138.25	167.88	32.78	5.26	18.25	6.47	31.00	27.44	6.99	2.32	1.07	32.67	26.23	1246.87	82.00	9.18
241	137.25	180.38	33.81	4.73	19.25	5.54	31.00	29.00	8.94	2.46	1.39	17.52	27.93	1909.17	84.25	10.47
242	139.00	157.13	30.50	4.68	18.25	5.19	33.00	27.09	8.13	2.32	1.31	40.86	27.33	1481.14	87.50	9.05
243	141.00	141.65	36.63	5.56	19.75	3.95	32.25	28.89	8.90	2.63	1.51	45.95	27.63	1726.44	95.25	9.78
244	138.00	170.88	33.05	5.11	17.75	6.27	35.25	29.73	10.28	2.75	1.67	47.42	27.48	1728.93	74.00	10.30
245	140.00	168.25	30.15	4.70	19.00	5.83	33.75	25.06	8.38	2.62	1.33	38.50	28.43	1372.36	75.75	9.40

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V_{14}
227	139.50	153.50	37.20	5.23	20.25	4.28	29.25	22.73	8.99	2.40	1.27	46.76	27.53	1677.14	84.00	10.10
228	135.75	137.38	29.08	4.57	18.25	4.69	40.50	24.93	9.16	2.73	1.46	35.18	27.18	1288.32	80.00	10.33
229	141.25	16.10	37.05	5.31	19.75	3.71	29.00	25.95	7.85	2.37	1.41	50.26	23.20	2247.78	93.75	8.70
230	135.25	144.40	30.58	4.69	8.25	6.10	26.25	25.19	9.66	2.40	1.48	59.85	27.35	2180.07	76.75	10.80
231	138.75	170.38	34.63	5.16	18.50	7.20	32.00	25.63	8.55	2.59	1.54	46.30	26.40	1741.32	86.25	8.98
232	143.25	167.38	38.83	6.45	18.50	7.76	26.25	28.50	9.14	2.45	1.40	57.22	29.05	1993.26	86.25	9.28
233	140.50	138.63	32.60	4.80	17.00	10.18	23.00	27.50	8.99	2.23	1.22	52.79	28.85	1943.90	83.75	9.48
234	137.75	173.38	29.50	4.98	17.00	5.38	33.25	23.36	7.61	2.27	1.36	39.66	27.45	1443.05	84.75	9. 3
235	141.00	224.25	34.08	4.86	19.75	5.52	38.00	29.59	8.97	2.89	1.51	41.66	29.15	1414.48	86.50	9.18
236	141.75	191.63	39.00	4.99	19.25	6.88	38.75	24.71	8.34	2.25	1.36	47.62	26.60	1790.32	76.00	9.00
237	143.50	157.08	28.83	4.17	19.25	7.23	31.25	29.02	9.07	2.32	1.22	38.36	28.80	1354.18	82.25	10.05
238	133.75	138.50	32.15	4.66	18.75	10.58	38.25	25.77	8.11	2.57	1.45	36.25	25.25	1425.68	78.75	8.93
239	139.25	127.88	33.10	9.18	20.00	5.26	35.25	25.29	7.83	2.61	1.59	51.60	25.60	2036.18	84.00	10.70
240	138.25	167.88	32.78	5.26	18.25	6.47	31.00	27.44	6.99	2.32	1.07	32.67	26.23	1246.87	82.00	9.18
241	137.25	180.38	33.81	4.73	19.25	5.54	31.00	29.00	8.94	2.46	1.39	17.52	27.93	1909.17	84.25	10.47
242	139.00	157.13	30.50	4.68	18.25	5.19	33.00	27.09	8.13	2.32	1.31	40.86	27.33	1481.14	87.50	9.05
243	141.00	141.65	36.63	5.56	19.75	3.95	32.25	28.89	8.90	2.63	1.51	45.95	27.63	1726.44	95.25	9.78
244	138.00	170.88	33.05	5.11	17.75	6.27	35.25	29.73	10.28	2.75	1.67	47.42	27.48	1728.93	74.00	10.30
245	140.00	168.25	30.15	4.70	19.00	5.83	33.75	25.06	8.38	2.62	1.33	38.50	28.43	1372.36	75.75	9.40

	V_1	V_2	V_9	V_{10}	V_8	V_{11}	V_4	V_3	V_{12}	V_5	V_6	V_7	V_{15}	V_{16}	V_{13}	V
246	135.00	178.75	32.93	5.71	18.75	6.38	44.00	27.20	9.10	3.19	2.01	47.04	26.35	1785.42	90.00	9.
247	138.25	176.15	31.18	5.40	16.75	4.39	31.25	24.66	9.03	2.55	1.19	36.19	24.83	1514.42	89.75	8.
248	142.50	163.63	33.73	4.41	18.00	4.51	29.75	30.46	8.53	1.82	0.97	37.27	27.73	1163.51	83.75	10
249	141.50	156.13	36.08	5.36	18.00	5.71	24.25	28.54	8.13	2.03	1.07	44.15	28.28	1578.08	100.00	9.
250	139.75	175.83	31.80	4.60	20.00	6.69	28.50	28.22	9.17	1.99	1.06	37.78	25.33	1526.51	81.25	9.