21114

NATIONAL LIBRARY
OTTAWA

CANADA

BIBLIOTHÈQUE NATIONALE
OTTAWA

NAME OF AUTHOR...BARKAT ALI SOOMRO

TITLE OF THESIS...A BIOMETRICAL-GENETIC ANALYSIS OF SOME QUANTITATIVE CHARACTERS IN A FIVE-PARENT DIALLEL CROSS OF COMMON WHEAT (Triticum aestivum L.)

UNIVERSITY...THE UNIVERSITY OF ALBERTA

DEGREE FOR WHICH THESIS WAS PRESENTED...Ph. D.

YEAR THIS DEGREE GRANTED...1974

Permission is hereby granted to THE NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

(Signed)...Barkat Ali Soomro

PERMANENT ADDRESS:

P.O. SIJAWAL
TAHSIL MIROKHAN
DISTRICT LARKANA (SIND)
PAKISTAN

DATED...January 17...1974

NL-91 (10-68)

THE UNIVERSITY OF ALBERTA

A BIOMETRICAL-GENETIC ANALYSIS OF SOME QUANTITATIVE CHARACTERS IN A FIVE-PARENT DIALLEL CROSS OF COMMON WHEAT (*TRITICUM AESTIVUM* L.)

by

© BARKAT ALI SOOMRO

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GENETICS

EDMONTON, ALBERTA

SPRING, 1974

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled A Biometrical-Genetic Analysis of Some Quantitative Characters in a Five-Parent Diallel Cross of Common Wheat (*Triticum aestivum* L.) submitted by Barkat Ali Soomro in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Supervisor

External Examiner

Date January 14, 1974

To Mämtaaz Khàtoon Soomro.

ABSTRACT

Common wheat (*Triticum aestivum L.*) cultivars Marquis, Chinook, Khush-hal, Ciano-67 and Inia-66 were used as parents of a five-parent diallel cross. The F_1, F_2, backcross and selfed backcross generations of this diallel cross were used as materials in this study. The experimental data were investigated by means of principal factor analysis, general and specific combining ability analysis, diallel cross analysis for genetic components of variation and genotype-environment interaction analysis. The data on ten characters were recorded from materials grown at Ellerslie and Parkland. The characters considered were: onset-of-heading, final heading, heading-span, plant height, number of tillers per plant, number of spikelets per spike, number of seeds per spike, weight of seeds per spike, 1000-kernel weight and yield per plant.

In the factor analyses, correlation matrices indicated that early maturing varieties were high yielding. Yield per plant was positively correlated with its subcharacters or components. There was no correlation between yield and plant height. Varimax rotated factor matrices for each generation of the diallel cross constituted five principal factors which were named according to the magnitude of the factor loading on the characters. The results of the factor analyses confirmed the conclusions drawn from correlation analyses. The scores of factor loadings on various characters were different for two locations but the generations appeared not to affect them significantly.

The general and specific combining ability analyses indicated that parental lines possessing high GCA's usually produced hybrids with low SCA's and therefore general combining ability of the parents does not necessarily constitute a criterion for evolving hybrids with high specific combining ability. The variances for GCA's were usually greater than those for SCA's for all the characters, and in those cases where SCA-variances were larger, the importance of non-additive gene effects for the characters concerned has been emphasized. SCA-variances significantly higher than GCA variances indicated instabilities of the cultivar for the character concerned and therefore these differences may be used as criteria for the selection in pedigree-record breeding. Mean squares for GCA's were in general all significant. Analysis also showed that GCA's were not significantly affected either by generations of the diallel set or by locations. The stability of the response of each cultivar with respect to its GCA was consistent over two locations.

The mean degree of dominance with respect to different characters ranged from partial to over-dominance. The proportions of alleles with positive and negative effects were not the same for all the characters: complete symmetry was observed for some and asymmetry for others. For some characters dominant and recessive genes in the parents were in equal proportions and for others either there was a preponderance of dominants or of recessives. Character differences were found to be controlled by at least one to three groups of genes. The analyses for the characters considered have shown that the genetic components of variation were relatively stable over the generations. They were more consistent when estimated from the variances and covariances of adjusted treatment means (from *ANOVA* of partially balanced lattice design) than when estimated from unadjusted means (experiments treated as randomized blocks).

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Dr. Rüstem Aksel for guiding the project. His formative criticism and invaluable suggestions gave this manuscript a final shape. Painstaking editing without demur, of the draft by Dr. G.W.R. Walker is gratefully acknowledged.

Seed of Pakistani and Mexican introductions was obtained through the courtesy of (Late) Mr. B.G. Shaikh, Wheat Botanist, Agricultural Research Station, Dera Ismail Khan, Pakistan, and Dr. Norman E. Bourlaug of CIMMYT, Mexico, respectively.

The author is also grateful to Dr. K.G. Briggs and Mr. J.E. Fitzsimmons of the Department of Plant Science, The University of Alberta, for lending a piece of land at Parkland Farm and extending full facilities for seeding the replicated trial. Voluntary help in seeding the experimental material and weeding the plots by Messrs. Bruce Hobin, Peter Vermier, Peter Conway and my colleagues in the Department of Genetics is gratefully appreciated. Mrs. Neli Farolan typed my thesis for which I am indebted to her.

The author's stay in Canada was under the auspices of Government of Canada, through the Commonwealth Scholarship and Fellowship Administration. Financial support by them for the present studies deserves a special note of gratitude.

TABLE OF CONTENTS

LIST OF TABLES

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_2 diallel set at two locations for:

Table Page

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from backcross diallel set at two locations for:

Table Page

Table Page

LIST OF FIGURES

Figure Page

Figure Page

Figure Page

LIST OF APPENDICES

INTRODUCTION

The degree to which a quantitative or metrical trait is phenotypically expressed in individuals depends on their genotype and the environmental conditions under which they are grown. It is assumed, and the experimental data seems to confirm it in most of the cases, that the genotype considered with respect to a metrical character is a set of genes referred to by Mather individually as polygenes and collectively as a polygenic system (Mather, 1949). These genes are often interdependent both in their action and transmission. In a polygenic system underlying a quantitative character, the allelic and non-allelic interactions are the most usual forms of manifestation of gene effects and inheritance pattern. The interaction of alleles at a given locus is known as dominance, while non-allelic interaction, viz., interaction between the genes at different loci, may take the form of complementary-gene, duplicate-gene or other classical relationships. All these effects are referred to generally as 'epistasis' in biometrical genetics.

Different genotypes defined with reference to a metrical character do not react alike to a given change in environment. This means that genotype and environment are not independent in their action in producing the phenotype. Consequently the variation in the degree of expression of the character is assumed to consist of genotypic, environmental and genotype-environment interaction components which may respectively be partitioned in a biometrically defined experimental design. The measurement of genotype-environment interaction in the diallel cross is quite efficient and informative, since a number of parental strains can be assessed together with their hybrid generations.

The diallel cross technique is one of the conventional approaches used in biometrical genetics to obtain adequate information regarding the inheritance of a quantitative character. The procedure, first introduced by Schmidt (1919) involves crossing a set of parental lines in all possible combinations, including their reciprocals, in order to obtain an estimation of the magnitude of genetic variability ascribable to the differences among the parental lines. The quantitative genetic analysis of a diallel cross based on a set of postulated assumptions is presented and discussed in detail by Jinks and Hayman (1953), Hayman (1954a, 1954b, 1958 and 1960), Jinks (1954 and 1956) and Kempthorne (1956). means of pertinent parameters obtainable from the analysis of the diallel cross, the mean degree of dominance, the proportion of positive to negative alleles at loci exhibiting dominance the proportion of dominant to recessive genes in the parents, and the correlation between the parental order of dominance and parental measurements can be determined. In addition, the graphical analysis of the regression of array covariances (W_r) on array variances (V_r) permits the separation of true dominance from the spurious one caused by non-allelic interaction and categorizes the parents according to their degree of dominance.

The analysis of genotype-environment interaction by means of a diallel cross replicated in time, in space or in both time and space, provides information on the pattern of reaction of homozygous parents and their hybrids to environmental variation. The value of such an analysis is that the significant inter-environmental differences characteristic of different genotypes are reflected in the array variances and co-variances by their effects on the relative magnitude of components of these statistics. The project reported in this thesis deals with this type of analysis of genotype-environment interaction in a five-parent diallel cross in common wheat (*Triticum aestivum* L.). The purpose of the investigation was to obtain information regarding the extent to which the genetic components of variation and the combining abilities of the parental lines are affected by environmental changes.

REVIEW OF LITERATURE

General background

A diallel cross involves the mating of n genotypes, individual clones or homozygous lines in all possible combinations to give $[n(n-1)]$ crosses, including reciprocals. The total number of such combinations comes to n^2 if the parents are also included as selfs. The n^2 combinations may be arranged in the form of a square matrix, the rows and columns of which correspond to the offspring of each parent, the n parents themselves occupying the main diagonal. Such an arrangement of arrays, known as a diallel table, may be complete or incomplete. Complete tables consist of all n^2 entries, while in incomplete ones the parental or reciprocal entries may be absent. Griffing (1956) has developed four possible methods of constructing a diallel table, together with the corresponding forms of analysis. These are: (1) the parents, all the F_1's and their reciprocals are included (n^2 combinations); (2) the parents and one set of F_1's are included but not the reciprocals [$\frac{1}{2}n(n+1)$ combinations]; (3) one set of F_1's and reciprocals are included but parents are not [$n(n-1)$ combinations]; and (4) one set of F_1's is included but the reciprocal crosses and the parents are not [$\frac{1}{2}n(n-1)$ combinations]. For each of these combinations, Griffing has developed two kinds of statistical analyses, arising from different assumptions regarding the sampling nature of the experimental material; either it is assumed to be a random sample from the population or it is assumed to be deliberately chosen, and therefore not a random sample.

The biometrical-genetic analysis of a diallel cross as formulated by Hayman (1954b) is based on the following set of assumptions:

1. Homozygous parents
2. Normal diploid segregation
3. No differences between reciprocal crosses
4. Independent action of non-allelic genes
5. No multiple allelism
6. Genes independently distributed between the parents.

The genetic analysis, discussed by different authors (Hull 1945; Hayman 1954a, 1954b, 1958, 1960; Jinks 1954, 1956 and Jinks and Hayman 1953) implies the estimation of genetic components of variation from the following second degree statistics:

V_{0L0} = Variance of the parents

W_r = Covariance between the parents and their offspring in one array (rth array)

W_{0L01} = Mean covariance between the parents and their offspring over the arrays

$V_{r.}$ = Variance of the rth array

V_{1L1} = Mean variance of the arrays

$(M_{L1}-M_{L0})$ = Difference between the mean of the parents and the mean of their n^2 progeny

The description of the genetic components of variation is given below:

D = Component of variation due to additive gene effects

H_1 = Component of variation due to dominance effects of the genes

H_2 = Component of variation due to dominance effects, corrected for gene distribution

F = Covariation between additive and dominance effects over all the arrays. Thus F could be used to determine the relative proportion of dominant to recessive alleles in the parents involved.

The expected values of these genetic components of variation in terms of variances and covariances have been described by Mather (1949), Hayman (1954b, 1958), Jinks (1954, 1956) and Mather and Jinks (1971).

The relationship between the array variances and covariances, expressed graphically, shows the overall genetic situation with respect to the inheritance-pattern of a particular character. When the set of assumptions described earlier are valid, the W_r-V_r differences are constant over the arrays, the regression of covariance on the array variance is a straight line of unit slope and all the points of W_r, V_r intercepts lie on this line. The upper and the lower limits where the W_r, V_r intercepts can lie are the points where the regression line intersects the limiting parabola. These points correspond respectively to the completely recessive and completely dominant parents, and thus show the possible limits of selection.

A deviation from the expected regression line of unit slope indicates the presence of non-allelic interaction. Any type of non-allelic interaction affecting the crosses in an array will inflate the variance of that array and reduce the parent-offspring covariance. Such an increase in variance relative to covariance will move the W_r, V_r graph towards the right, giving an apparent increase in dominance, and will cause the slope of the regression line to be less than unity. Thus, with $H_1 = D$ (complete dominance), $V_{1L1} + W_{0L01} = 1$ and the line of unit slope will pass through the origin; with $H_1 > D$ (over-dominance), $V_{1L1} \div W_{0L01} > 1$ and the line will cross the ordinate below the origin; and with $H_1 < D$ (partial dominance), $V_{1L1} \div W_{0L01} < 1$ and the regression line will pass above the origin. If, of course, $H_1 = 0$ there is no regression. The mean degree of dominance is measured by $(H_1 \div D)^{1/2}$. The ratio $(H_2 \div 4H_1)$ provides an estimate of the proportion of genes with positive and negative effects in the parents. The proportion of dominant to recessive genes in the parents is given by $[(4DH_1)^{1/2}+F] \div [(4DH_1)^{1/2}-F]$ and the number of groups of genes controlling the character and showing dominance can be determined by the formula $[h^2/H_2]$.

The failure of any one of the six postulated assumptions invalidates the analysis to a certain extent. The effects of the failure of these assumptions are discussed by Hayman (1954b). The methods of analysis of complete diallel tables as developed by Yates (1947), Hayman (1954a), Durrant (1965) and Jinks *et al* (1972) allow, among others, for the detection and testing of 'reciprocal differences'. Significance of the c pertaining to reciprocal differences in Hayman's analysis implies the expectation of two values for each of the genetic components of variation, D, H_1, H_2 and F from the diallel table; one from the use of column arrays and the other from the use of row arrays. This ambiguity may be removed by replacing the off-diagonal cells of the diallel table by the common mean for the cross and its reciprocal. However, with significant c, the errors of the parameters will be inflated. Departure from independent action of non-allelic genes may be checked by examining the $W_r - V_r$ values for homogeneity. Heterogeneity of $W_r - V_r$ differences indicates failure of the assumptions postulated. If this is the case, the inspection of the V_r, W_r graph would show which of the arrays contribute mostly to this failure. The disparate arrays may be eliminated, leaving a sub-diallel table for analysis that satisfies the null hypothesis. The results of the analysis would be valid, of course, for the remaining arrays.

Manifestations of 'non-allelic interaction', 'multiple allelism' and 'correlated gene distribution' introduce serious complications into the diallel analysis. They disturb the direction and mean degree of dominance, inflate the estimated proportion of dominant to recessive genes in the parents and reduce the estimate of the number of genes controlling a particular character. A test of homogeneity of variances of $W_r - V_r$ values has been advocated as an appropriate method for their detection.

Application of diallel cross analysis

The literature pertinent to diallel cross analysis as applied to plant breeding programmes is fairly impressive. In non-cereal crop plants, the technique has been widely used in the study of various quantitative characters. Thus this technique has been applied to bromegrass (Knowles 1950; Greesom and Kalton 1956; Neilson and Kalton 1959; Dunn and Wright 1970), alfalfa (Kehr 1961; Theurer and Elling 1963a, b; Wilcox and Wilsie 1964), flax (Carnahan 1947; Durrant and Tyson 1964; Murty *et al* 1967; Anand and Murty 1968, 1969), cotton (Turner 1953; Marani 1963;

White and Richmond 1963; Marani 1964; Miller and Marani 1963; White and Kohel 1964), tobacco (Jinks 1954, 1956; Matzinger *et al* 1962; Marani and Sachs 1966; Povilaitis 1966; Legg *et al* 1970; Povilaitis 1970), strawberry (Morrow *et al* 1958; Aalders and Craig 1968; Watkins and Spangello 1968; Spangello *et al* 1971) and *brassica* (Johnston 1968a, b; Chiang 1969).

In cereals, a considerable number of studies using diallel analysis have been made with rice (Mohammad and Hanna 1965; Athwal and Singh 1966a, b; Wu 1968a, b; Cheng and Chang 1970), maize (Kinman and Sprague 1945; Sprague and Federer 1951; Bauman 1959; Matzinger *et al* 1959; Sprague 1964; Troyer and Hallauer 1968; Eberhart and Russell 1969; Poneilet and Bauman 1970), barley (Johnson and Aksel 1959; Aksel and Johnson 1961; Eunis *et al* 1962; Fasoulas and Allard 1962; Aksel and Johnson 1963; Johnson and Aksel 1964; Norington 1967, 1968; Persson 1969; Yap and Harvey 1971; Riggs and Hayter 1972, 1973) and *sorghum* (Chiang and Smith 1967a, b; Liang 1967; Liang *et al* 1968).

In wheat, the first report on the use of diallel analysis is that of Whitehouse and co-workers (1958). Of the five characters studied by them in a 4 x 4 diallel cross, viz., single kernel weight, grains per spikelet, spikelets per spike, ears per plant and yield per plant, all except yield per plant were found to be under additive genic control. For total yield, a generalized type of gene action was found in the F_1 but the F_2 generation exhibited a localized multiplicative type of gene action.

Lupton (1961) performed a diallel analysis of the yield of winter wheats. Though there was no non-allelic interaction (as revealed by W_r, V_r graphs) in either the drilled or space-planted experiments, the position of the parents with respect to dominance was significantly changed in the two environments. The highest yielding parent, Capelle, exhibited dominance in the space-seeded trial and was reported to be the most recessive in the drilled trial. This change in yield inheritance was attributed to environmental differences of the inter-plant competition type which appeared to affect drill plantings more than space-seedings. In a later study (Lupton 1965), an incomplete diallel system, where reciprocals were excluded, was used to study the yield of spring wheat varieties replicated both in space and time, for F_1, F_2 and F_3 generations. In all cases, interaction of over-dominance with site was highly significant, establishing consistency in the performance of the parents and their hybrid combinations.

Crumpacker and Allard (1962) analysed heading date in ten spring wheat varieties in a complete diallel test, replicated over three years. The results indicated substantial differences among the parents, generally categorized as highly dominant, moderately dominant, moderately recessive and highly recessive. The genetic system governing the maturation time of the parents, F_1's and F_2-generation hybrids consisted of a very few major genes showing dominance and was reported to be operating consistently in different years.

Fonseca (1965) studied the inheritance of yield and yield-components in a seven-parent diallel cross of wheat. The author reported significant differences among the parental lin used. The graphical analysis revealed partial dominance to slight over-dominance for all the characters studied. Since all the F_1's yielded higher than either of their respective parents, the author proposed a new term, heterobeltiosis, to describe the better performance of the F_1 over the better parent in the cross.

Bagnara (1967) performed a diallel analysis on normal and radiation-induced mutant lines of durum wheat. The results revealed significant differences between the lines and the mutants derived from them with regard to the expression of the degree of dominance. All the characters under study except spikelets per spike exhibited partial dominance.

Fonseca and Patterson (1968) studied hybrid vigour in a seven-parent wheat diallel to determine the diversity of germ-plasms in hill-planting experiments. The authors reported significant heterobeltiosis for yield and kernel-weight in half of the F_1 hybrids. The yield and kernel-weight estimates, were respectively 100% and 101 to 115% greater than either parent in hilled as against experimental nursery plots.

Walton (1969) studied the association of several morphological characters with yield in a seven-parent spring wheat diallel. He reported that the distance of the spike above the leaf-sheath at maturity and flag-leaf area were directly proportional to yield, and that yield, flag-leaf area and spike length were partially dominant.

Paroda and Joshi (1970) performed a genetic analysis of a complete 6 x 6 wheat diallel test for yield and its principal components: 1000-kernel weight, kernels per spike and tillers per plant. Yield and

1000-kernel weight exhibited non-allelic interaction of the duplicate-gene and complementary-gene type, respectively. For both characters, the variances for additive gene effects were significant.

Hsu and Walton (1970) studied gene action for yield and its components (spikes per plant, spikelets per spike, kernels per spike and 1000-kernel weight) in a 5 x 5 wheat diallel. For all the characters studied, the genetic variation was reported to be due to additive and dominance gene effects. Yield per plant exhibited complete, and its components partial, dominance.

Bitzer *et al* (1971) reported gene action and hybrid vigour in a six-parent wheat diallel. The results of two years of study revealed that the yield of the F_1 hybrids was not significantly higher than that of the parental strains. However, according to the graphical analysis of regression of W_r on V_r, plant height, kernel weight and spikelets per spike exhibited partial dominance while yield per plant showed over-dominance.

Kaltsikes and Lee (1971) estimated the genetic parameters for degree of dominance, ratio of total number of dominant to recessive parental genes and heritability for yield and its components in a 6 x 6 diallel of durum wheat. The average degree of dominance ranged from incomplete dominance to over-dominance and an excess of dominant over recessive alleles in the parents was found for all the characters studied. Since the heritability estimates for yield were as high as 61%, the authors suggested a pedigree selection procedure in breeding for yield characters in durum wheat.

General and specific combining ability

In quantitative genetics two types of combining ability, viz., general combining ability and specific combining ability are considered. General combining ability (GCA) refers to the average performance of a parental line as reflected in its hybrid combinations, while specific combining ability (SCA) refers to the performance of a particular cross. According to Sprague and Tatum (1942), GCA is due to genes which are largely additive, and SCA to genes showing non-additive effects. Nakamura (1956) considers GCA as 'an index of the number of effective genes' and SCA as 'an index of the number of common genes and the interaction between their alleles'. According to Fryxel *et al* (1958), GCA is the ability of a parental strain to produce promising or non-promising genotypes in its hybrids, regardless of the other parent involved, while SCA refers to this ability in hybrid combinations with certain other parental strains.

In a detailed examination of combining ability in the diallel cross, by Griffing (1956), eight procedures of statistical analysis have been proposed. These have been developed for four different diallel crossing schemes and for two alternative assumptions regarding sampling nature.

Kronstad and Foote (1964) using Griffing's diallel analysis for estimating GCA and SCA effects in ten winter wheat varieties found that a large portion of the total genetic variation for yield and yield components was associated with significant GCA effects. SCA effects were significant for yield per plant and plant height but not for yield components.

Fonseca (1965) studied the performance of F_1 hybrids for yield and yield components in a 7 x 7 diallel cross using Griffing's method 4 (one set of F_1's is included in the diallel table but the reciprocal crosses and the parents are not) with fixed model. The results revealed that all the mean squares for GCA and some of the mean squares for SCA were significant.

Brown *et al* (1966) found that most of the variation in yield and other characters among F_1 wheat hybrids was associated with high GCA rather than with SCA variances.

Singh *et al* (1969) in an analysis of a 7 x 7 wheat diallel for combining ability and genetic parameters for yield and its components, reported importance of additive gene effects for general over the non-additive ones of specific combining ability for yield components. The variances for GCA and SCA in the case of yield were of the same order of magnitude, implying additive as well as non-additive effects.

Bhatt (1971) reported combining ability estimates for earliness, plant height and four yield components in a 5 x 5 wheat diallel. The analysis of GCA indicated that the larger portion of the genetic variation, for six out of seven characters considered, was associated with additive gene effects. The estimates of SCA's were highly significant but lower than GCA's for five characters.

Bitzer *et al* (1971) performed a combining ability analysis in a 6 x 6 diallel and found that GCA mean squares were significant for earliness, plant height and kernels per spike whereas SCA mean squares were not. The average yield of the F_1's was 28.1% higher than that of the highest yielding parent.

Paroda and Joshi (1970a) compared the combining ability variances of F_1 and F_2 generations for yield and other characters in a 6 x 6 wheat diallel. The GCA effects were high in the F_1's and F_2's but SCA effects were high only in F_1's. Similar results were also reported by Niehaus and Pickett (1966) in a *sorghum* diallel.

In some of the papers it has been reported that the parents with high GCA values do not necessarily produce hybrids with high SCA values (Larson, 1941 in tomatoes; Crumpacker and Urquhart, 1962 in wheat; Walker 1963, Chang 1967, Soomro 1967, Baluch and Soomro 1969 and Soomro and Baluch 1969 in cotton). It follows, therefore, that the general combining ability should not be taken as a criterion for predicting high specific combining ability.

Genotype-environment interaction

Finlay and Wilkinson's (1963) regression analysis technique permitted for the first time a satisfactory assessment of the performance stability of a strain or cultivar over the range of environments in which it is grown. According to these authors, a regression of varietal-mean-yield on location-mean-yield with a regression coefficient of less than unity indicates that the variety has an above-average stability in its response to environmental influences. Regression coefficients equal to and greater than unity indicate average and less-than-average stabilit respectively. Eberhart and Russell (1966) interpreted stability in a different manner, stating that the Finlay-Wilkinson model implies that a stable variety is one which performs relatively well in a poor environment and relatively poor in a favourable one. They proposed that the criteria for stability should be a regression coefficient of unity and minimum deviation from the unit slope. According to them a variety with high mean yield and fulfilling these two criteria would perform well in all the environments.

Another method of genotype-environment interaction analysis, in terms of biometrical genetics, has been developed by Bucio Alanis (1966) and applied to data for two inbred lines of *Nicotiana rustica* grown over a period of sixteen years at two locations. The analysis has shown that the effects of the genotype-environment interaction are linearly related to a particular environmental effect of the genotype. The model, which is essentially an extension of Mather's model (Mather, 1949), was later extended by Bucio Alanis (1966a) to apply to F_1's with identical and consistent results for this generation also.

For the analysis of genotype-environment interaction by means of the diallel cross, three papers have appeared, one theoretical (Perkins, 1970) and two experimental (Allard, 1956; Crumpacker and Allard, 1962) and are concerned with assessing the stability of genetic components of variation under different environments.

Crumpacker and Allard (1962) studied genotype-environment interaction for heading date in a 10 x 10 wheat diallel over three years. The analysis of variance of heading time for parental genotypes indicated different additive and/or epistatic effects in different years. Because of the homozygosity of the parents, the epistatic effects attributable to parents were defined by the authors as the result of interaction between homozygous loci, that is, additive x additive type of interaction. Stability of average degree of dominance was tested by the variance ratio for the dominance x year interaction. This was highly significant and showed that the mean degree of dominance for heading date varied from partial to complete dominance in consecutive years.

Porceddu (1968) in a yield test of three wheat varieties over twenty consecutive years at one location showed significant differences between varieties in different years. The results established that the performance of an individual genotype is a linear function of the environment, and that the major portion of the genotype-environment interaction could be accounted for by deviations from the linear response as estimated by the regression analysis.

Baker (1969), analysing the yield of six wheat varieties grown at nine locations over five years, subdivided the sum of squares for genotype-environment interaction into genotype x place, genotype x year and genotype x place x year interactions for each variety. Except for genotype x year, all interactions were highly significant, leading to the conclusion that the stability of performance of a particular cultivar over a range of environments is inversely proportional to the sum of squares for genotype-environment interaction for that particular variety.

Kaltsikes and Larter (1970) analysed genotype-environment interaction for height, maturity and yield in durum wheat. Five varieties grown over four to five years at five loctions, differed with different environments in all the characters studied. In their analysis, the major portion of the genotype-environment interaction effects was reported to be linearly correlated with the environment.

A considerable amount of work has been reported on genotype-environment interaction analysis with respect to a variety of quantitative characters in different crops (Allard 1961, Parson and Allard 1960, Allard and Workman 1963, in lima-beans; Eagles 1967, Knight 1965, 1970 and Breese 1969, in grasses; Westerman 1970, 1971a, b, in *Arabidopsis*; Hill and Perkins 1969, Perkins and Jinks 1970, 1971a, b, in tobacco; Kaltsikes 1970, in winter rye; Liang and Walter 1966, in *sorghum* and Qualset 1968, and Paroda and Hayes 1957, in barley). In each of these papers, the behaviour of a particular genotype when grown in a particular environment, and when grown with other genotypes over a wide range of environments, is studied using linear regression analysis to measure the environmental effect. The implication of these studies is that the linear regressions of individual genotypic values on the mean values of all genotypes for each of the environments provide measures of the response that are useful in predicting the relative performance of the genotype in question over the range of environmental conditions. The conclusion of these reports focuses on one point: that the performance of an individual genotype in a particular environment is a linear function of the over-all environmental mean in regression analysis, where the slope of regression measures the sensitivity of the genotype to the totality of the environmental factors.

MATERIAL AND METHODS

Five cultivars of common wheat (*Triticum aestivum* L.) described in Appedix I, were used in the diallel study. These varieties were selected on the basis of their diversity of origin, different spike and seed characteristics and their yield performances. The parental material was sown in September 1969 in the green-house to check its trueness to type. Fifteen to twenty phenotypically identical healthy heads were selected from each variety and their seed formed the basis of the present investigations. The parent lines were sown in the green house in January 1970. Crosses were made in all possible combinations, including reciprocals. During summer 1970, the parent material was again seeded at Parkland farm to obtain more F_1 seed. Following the winter, some of the F_1 seeds together with their parents were sown in growth chambers to make backcrosses, reciprocal backcrosses, further F_1 combinations and to provide F_2 seed. During 1971's spring the same procedure was repeated to have sufficient number of seeds for every combination. In the fall of 1971, the backcrosses and their reciprocals were seeded in the growth chambers to obtain seed for their first selfed generation.

By spring 1972, the experimental material consisted of five parents, 20 F_1's, 20 F_2's, 80 backcrosses and the selfed generation of these backcrosses, amounting to 205 different entries. A 15 x 15 partially balanced lattice design was chosen for seeding the material in a replicated trial. To meet the requirements of the design, 20 more entries were needed and since the F_2 is the maximum segregation generation, each F_2 combination was represented twice in each replication to complete the required 225 entries. The names and numerical designations of the entries are given in Appendix II. On 9th and 11th May, 1972, the whole of the experimental material was space-seeded in three replications at two locations, viz., Department of Genetics Ellerslie Field Lab. and Department of Plant Science Parkland Farm, respectively. Each of the fifteen (15' x 15') blocks in a replication consisted of 15 rows of 30 seeds each, with a spacing of 30.48 cm between rows and 15.24 cm between seeds within a row. The following observations were recorded at each of the locations:

(1) Onset-of-heading: expressed as the number of days between seeding date and the date of appearance of the first head in the row (entry).

(2) Final heading: recorded in number of days from the date of seeding to the day when 75% of the plants in a row have headed.

(3) Heading-span: measured by the difference between (1) and (2).

(4) Plant height: measured in centimeters from the surface of the soil to the tip of the spike on the highest tiller (excluding awns). Ten consecutive plants per row were recorded for height irrespective of their growth performance, leaving the first plant because of susceptibility to border effects, except in those rows where the number of surviving plants was reduced to ten or less. At maturity only those

plants that had been recorded for height were harvested. The following observations for yield and yield components were recorded on the harvested material.

(5) Number of productive tillers per plant.

(6) Number of spikelets per spike: Three spikes were taken at random from each plant and their spikelets counted.

(7) Number of seeds per spike.

(8) Weight of seeds per spike (in grams): spikes randomly sampled for spikelet-counts were threshed separately and their seeds counted and weighed.

(9) 1000-kernel weight (in grams): computed from observations (7) and (8).

(10) Yield per plant (in grams): expressed as total seed weight of all the spikes including those used for (6), (7), and (8).

Statistical analysis

The means were calculated for all the characters except onset-of-heading, final heading and heading-span. For observations (6), (7) and (8) means of three readings were calculated first and treated as individual variables for the calculation of entry means. Missing entries were calculated according to Cochran and Cox's (1957) formula for the randomized block design, except for (1) to (4) at Parkland. Here, since the number of missing entries was less than three, the procedure for the partially balanced lattice design was used. The complete set of data was subjected to analysis of variance for a partially balanced lattice design. This provided a single set of adjusted treatment means at each location. However, unadjusted treatment means (original entry means as treated in randomized block design) were used for most of the analyses. These were categorized into four diallel sets, viz., F_1's, F_2's, backcrosses and selfed backcrosses. The following analyses were performed on each of the sets for all the characters under study.

1. Correlation and factor analyses. Simple correlation coefficients were computed for each of the characters and arranged in the form of a matrix to permit the simultaneous comparison of one character with the other. Factor analysis was performed according to Hotelling's (1933) principal factor method as explained by Harman (1960) and Lawley and Maxwell (1963). The factor analysis approach aims at resolving the covariation into simpler relations in the form of a few factors which explain the larger portion of the variation in the original data. Statistically speaking, it reduces a large number of correlated variables to a small number of uncorrelated variables called factors, each of which proportionally accounts for the variability in the original observations.

The procedure for the principal factor method used in the present study was based on the following linear model (Harman, 1960):

$$z_j = a_{j1}F_1 + a_{j2}F_2 + \ldots\ldots + a_{jm}F_m + d_ju_j \quad (j = 1, 2, \ldots., n)$$

where z_j represents a character variable in terms of several underlying factors and each of the 'n' observed variables is described linearly in terms of 'm' common factors and the residual error (d_ju_j). The coefficients of these factors are referred to as factor loadings. A symmetrical correlation matrix produced from all possible [1/2n(n - 1)] combinations is resolved into an 'nk' factor matrix, where the number of factors 'k' is usually smaller than 'n', the number of variables.

In the correlation matrix, the leading diagonal elements have values of unity and since they are meaningless (the correlation of each variable with itself means nothing) they are replaced by 'communalities' (the approximate values in terms of amount of variance accounted for by the common factors). In the present case the highest correlation value in each column of the correlation matrix was substituted for unity in the diagonal cells because the variance-covariance ratio of the column for that character is expected to be nearer to unity. With these communalities as the approximate values, the correlation matrix was factored by iteration to give a new resultant set of approximations to communalities that are more convergent. The factor matrix was then rotated (in this case by the varimax method) with every new set of communalities produced, till off-the-diagonal elements of the residual matrix were not significantly different from zero.

2. Combining ability analysis. General and specific combining ability analyses were performed following Griffing's (1956) method 1 (where all the n^2 entries of the diallel table are included), model 1 (where the experimental material is not regarded as a random sample from the population). Model 1 was chosen against model 2 (where the experimental material is regarded as a random sample from the population) because the parental lines, producing all the entries in the form of various combinations, were deliberately chosen on the basis of their diversity of origin and yielding capacities.

3. Diallel cross analysis. Diallel analysis was performed in two steps,

viz., diallel analysis for genetic components of variation and graphical analysis of regression of W_r (parent-offspring covariance of the rth. array) on V_r (variance of the rth. array) to complement the former via graphical representation. In the diallel analysis for genetic components of variation, each diallel table was subjected to tests of validity of the following assumptions (Hayman, 1954b):

(1) Homozygous parents
(2) Normal diploid segregation
(3) No differences between the reciprocal crosses
(4) No multiple allelism
(5) Independent action of non-allelic genes
(6) Uncorrelated gene distribution.

The condition of 'homozygous parents' in the present studies could be satisfied, as the parent material was sown preceding crossing and found to be true to type. 'Normal diploid segregation' may be assured from the pedigree-record of the organism used as experimental material. Wheat, though an amphi-diploid derivative of *Triticum monococcum* for the 'A' genome (Melburne and Thompson, 1927; Zohary and Feldman, 1962), *Aegilops speltoides* for the 'B' genome (Sarkar and Stebbins, 1956; Riley *et al*, 1958; Sears and Okamoto, 1958) and *Aegilops squarrosa* for the 'D' genome (Kihara, 1944; McFadden and Sears, 1944, 1946; Kihara and Lilienfeld, 1949) behaves cytogenetically as a normal diploid (Sears, 1948; Riley *et al*, 1961). It follows therefore, that, the assumption of normal diploid segregation could be considered valid. 'No reciprocal differences' were checked after Hayman's (1954a) procedure of analysis of variance for diallel tables, where significance of the 'c' component indicates failure of this hypothesis. The remaining three conditions, 'no multiple allelism', 'independent action of non-allelic genes' and 'uncorrelated gene distribution' were checked through the analysis of variance of $W_r - V_r$ values for the arrays of each diallel table. Heterogeneity of $W_r - V_r$ variances will reveal non-validity of these assumptions.

After the validity checks for the above-mentioned conditions, the diallel analysis for genetic components of variation (Hayman 1954b, 1958 and Jinks 1954, 1956) was performed, on each of the diallel tables for all the characters under study, by replacing the off-diagonal cells of the diallel table with the common mean of the relevant cross and its reciprocal irrespective of the significance of Hayman's (1954a) 'c' component. In the F_2-generation diallel, the estimates of genetic components of variation from the second degree statistics were computed after Johnson and Aksel's (1959) notation describing the average effect of *Aa* in different filial generations. According to their formula:

$$\text{effect of } Aa = [(1/2)^{fn-1}\ h]$$

where fn = nth filial generation

$$\text{thus in } F_2\text{, effect of } Aa = [(1/2)^{2-1}\ h]$$

$$\text{and in } F_3\text{, the effect of } Aa = [(1/2)^{3-1}\ h] \text{ and so on.}$$

From the genetic components of variation, various parameters such as the mean degree of dominance, the proportion of positive to negative alleles at loci exhibiting dominance, the ratio of dominant to recessive genes in the parents and the number of groups of genes controlling the particular character were estimated. The heritability estimates were calculated after Crumpacker and Allard (1962) using the formula $[D \div (D + H_1 - F + 4E)]$.

The graphical analysis of regression of W_r on V_r was performed after Hayman (1954b) by plotting the regression line and the limiting parabola constructed by calculating its points $(W_r2 = V_r \times V_{OLO})$ and plotting the V_r, $(W_r \times V_{OLO})^{1/2}$ points. The W_r, V_r graphs were supplemented with Johnson and Aksel's (1959) standardized deviation graphs of parental measurements (Y_r) and parental order of dominance $(W_r + V_r)$ where the deviations of the Y_r's and $W_r + V_r$'s from their respective means were standardized by dividing them by their respective standard deviations. An abscissa (Y_r) and an ordinate $(W_r + V_r)$ intersecting each other produce four quadrants of the graph, classified as (+,+), (-,+), (-,-) and (+,-). The plus and minus signs for $(W_r + V_r)$ denote 'recessive' and 'dominant' and for Y_r, they refer to 'high' and 'low' performances respectively.

4. Analysis of genotype-environment interaction. The constancy of principal factors with respect to loadings in four generations of diallel cross was studied by means of *factorial ANOVA* where locations, principal factors and generations were treated as main source of variation. The *ANOVA* was based on fixed-effect-model as described by Scheffe (1959) because the set of parents in all the diallel tables could not be regarded as random sample and the two locations at which the materials were grown could not be considered as representing

random sample of the environments. Their choice was dictated by the limitations imposed both by time and facilities available.

The differences between the two locations with respect to general combining ability were also studied by *factorial ANOVA*. Stability of each cultivar was determined by regressing its GCA at Parkland upon that at Ellerslie. The regression analysis used was as given by Mather (1951).

The genotype-environment interaction with respect to D, H_1 and F considered as variables was investigated by using factorial analysis of variance. The concordance of the components in the two locations was studied by regressing the values of D, H_1 and F estimated from Parkland data upon those of Ellerslie and partitioning the total sum of squares into sum of squares due to regression and due to deviation from regression (error). Diallel analysis for genetic components of variation from adjusted treatment means (balanced lattice design) was compared with that of unadjusted treatment means (experiment treated as a randomized block design). The differences between the parameter estimates would reflect the effect of the adjustment factor characteristic of partially balanced lattice design. The regression analysis [illegible]er, 1951) applied to D, H_1 and F obtained from both the adjusted and unadjusted treatment means, will reveal the degree of concordance between the parameters characteristic of each treatment.

EXPERIMENTAL RESULTS

The experimental data for the two locations; (1) Ellerslie and (2) Parkland, are given in Appendices III to XXII inclusive. Table 1 shows the results of the analysis of variance of the partially balanced lattice design and its efficiency as compared to the analysis as a randomized block. The mean squares of the adjusted treatments except for number of tillers per plant and yield per plant, both at Parkland, all showed significant differences among the entries. The relative efficiency of the balanced lattice design at Parkland over the randomized block design was greater than that at Ellerslie.

ANALYSIS OF F_1 DATA

Simple correlations were computed for all the characters under study and are given in Table 2. As shown in the table:

Onset-of-heading was positively correlated with plant height and number of spikelets per spike and negatively correlated with weight of seeds per spike and 1000-kernel weight at both locations. At Ellerslie, it was positively correlated with final heading and negatively with yield per plant, while at Parkland, it showed positive correlation with number of tillers per plant and number of seeds per spike. The negative correlation of onset-of-heading with yield, weight of seeds per spike and 1000-kernel weight indicates that the longer the period between seeding and the appearance of the first head for a particular entry, the lower will be its yield and 1000-kernel weight. Correlations of final heading and heading-span with other characters may be interpreted in the same fashion.

TABLE 1

Mean-square values from the analysis of variance of partially balanced triple lattice design with respect to ten characters at two locations

Character	Replication	Blocks within replications	Treatments (adjusted)	Error	Total sum of squares	% Efficiency over randomized block
†D.F.	2	42	224	406	674	
Onset-of-heading	5.7305 19.8980	4.9140** 18.1369**	10.3581** 18.2897**	1.0209 2.5313	2948.5180 5921.1450	119.205 127.013
Final heading	14.4640 204.9375	8.0242** 14.7080**	17.3218** 19.2502**	1.4999 3.1787	4849.0160 6601.6170	118.699 108.332
Heading-span	24.0635 137.0770	2.8539* 6.6719**	3.1996* 4.6495**	1.6111 2.6398	1532.3940 2662.3760	95.829 107.162
Plant height	273.8125 1017.5480	566.9384** 524.6927**	543.1358** 738.0608**	41.0030 129.1721	162503.6250 241583.5620	121.334 99.301
Number of tillers per plant	0.9950 133.0380	4.8374 10.5493**	4.6147 6.0799**	5.6567 3.0278	3495.9080 3288.2760	87.318 109.575
Number of spikelets per spike	10.8070 19.9485	2.5932** 4.1922**	1.8178* 2.2189**	1.3783 1.0273	1087.8420 1125.9980	85.553 109.766
Number of seeds per spike	10.0065 180.0355	50.2140** 36.4799**	39.1424** 25.7529**	18.5529 11.9034	18299.5550 12446.094	91.021 100.465
Weight of seeds per spike	0.0060 0.0940	0.0995** 0.0942**	0.0843* 0.0586*	0.0455 0.0321	41.2460 30.2060	90.426 104.704
1000-kernel weight	12.2045 35.3210	21.8132** 25.9427**	18.7903** 17.5137**	8.4791 7.8801	8616.7660 8251.1520	90.954 104.127
Yield per plant	16.1310 153.8140	20.8652* 18.2453**	10.3075 8.3171*	15.8876 6.2202	9556.6840 5431.8160	86.462 104.334

First reading under each column refers to Ellerslie and the second to Parkland.

* Significant at 5% level

** Significant at 1% level

† Corresponding to the missing values in the different characters, the number of degrees of freedom have been subtracted from error D.F. in calculating mean squares.

Plant height was positively correlated with number of spikelets per spike and negatively correlated with weight of seeds per spike and 1000-kernel weight at both locations. It was positively correlated with number of tillers per plant at Ellerslie while at Parkland the correlation coefficient was not significant.

Number of tillers per plant was positively correlated with yield per plant at both locations and with number of spikelets per spike at Ellerslie. Correlation of number of tillers per plant with number of seeds per spike, weight of seeds per spike and 1000-kernel weight was not significant at either location. The correlation coefficients of other components of yield, viz., number of spikelets per spike, number of seeds per spike, weight of seeds per spike and 1000-kernel weight could be explained in the same manner.

As far as yield is concerned, it was highly and positively correlated with 1000-kernel weight, weight of seeds per spike and number of tillers per plant at both locations, but negatively correlated with onset-of-heading and final heading at Ellerslie.

Factor analysis

In the factor analysis, the symmetrical correlation matrix produced for all the characters under study was resolved into a varimax-rotated factor matrix. As suggested by Cattel (1965), if the number of factors is kept equal to that of the variables, 100% of the covariation in the data could be accounted for by these factors. In the present case the data was computerized for five factors which explained 92% of the

TABLE 2

Simple correlation coefficients between ten characters from F_1 diallel set at two locations.

Character	2	3	4	5	6	7	8	9	10
1. Onset-of-heading	0.916** 0.082	0.196 0.028	0.723** 0.821**	0.145 0.291**	0.313** 0.545**	0.191 0.246**	-0.324** -0.304**	-0.615** -0.612**	-0.281** -0.150
2. Final heading	-	0.548** 0.618**	0.744** 0.790**	0.196 0.358**	0.257** 0.588**	0.150 0.267*	-0.331** -0.240*	-0.574** -0.547**	-0.278** -0.058
3. Heading-span		-	0.316** 0.241*	0.166 0.219	-0.022 0.270*	-0.012 0.122	-0.135 -0.006	-0.146 -0.114	-0.147 0.105
4. Plant height			-	0.365** 0.239	0.416** 0.601**	0.149 0.106	-0.250* -0.402**	-0.474** -0.612**	-0.026 -0.162
5. Number of tillers per plant				-	0.272* 0.194	-0.014 0.085	0.059 -0.039	0.117 -0.121	0.574** 0.320**
6. Number of spikelets per spike					-	0.582** 0.556**	0.280* 0.206	-0.225 -0.207	0.154 0.184
7. Number of seeds per spike						-	0.663** 0.659**	-0.165 -0.014	0.144 0.211
8. Weight of seeds per spike							-	0.624** 0.740**	0.502** 0.506**
9. 1000-kernel weight								-	0.512** 0.500**
10. Yield per plant									-

First reading under each column refers to Ellerslie and the second to Parkland.

* Significant at 5% level
**Significant at 1% level

total variability with respect to all the characters at respective locations. The values of the rotated factor matrix in terms of the factor loadings together with the communalities for ten characters are given in Table 3.

The first factor was termed *lateness* because it carried the highest loadings for onset-of-heading and final heading at both locations and explained 28% and 32% of the variation in the data at Ellerslie and Parkland. Yield per plant was negatively affected by this factor showing thus that higher the number of days taken by a particular entry to head the larger will be its contribution to *lateness* and lower will be its yield and 1000-kernel weight. Plant height was one of the major contributors to *lateness* as it carried high loadings at both locations. This corresponds proportionally to the positive association between days to head and height of the plant. Number of tillers per plant, number of spikelets per spike and number of seeds per spike contributed very little to this factor.

The second principal factor was termed *yielding ability* as it carried generally higher loadings for yield and yield components: spikelets per spike, number of seeds per spike and, (except at Ellerslie) 1000-kernel weight at both locations. This factor accounted for about 19% of the variation. The loadings on yield and its components for this factor, as against those of the first factor (*lateness*), support a negative relationship between lateness and yielding ability. There is very little contribution of plant height and number of tillers per plant for this factor at either location.

TABLE 3

Varimax rotated factor matrix for ten characters
from F_1 diallel-set at two locations

Character	Communalities	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Onset-of-heading	0.964 0.908	0.960 0.892	0.107 -0.242	-0.060 0.062	-0.167 -0.093	-0.010 0.205
Final heading	0.972 0.945	0.901 0.773	0.070 -0.173	-0.022 0.073	-0.153 0.516	0.363 0.212
Heading-span	0.994 1.000	0.215 0.123	-0.040 0.032	0.033 0.039	-0.032 0.987	0.972 0.086
Plant height	0.806 0.906	0.788 0.917	0.175 -0.174	0.294 -0.113	-0.224 0.132	0.139 0.066
Number of tillers per plant	0.886 0.961	0.182 0.177	0.038 0.126	0.915 0.807	-0.010 0.113	0.121 0.949
Number of spikelets per spike	0.867 0.824	0.188 0.756	0.847 0.199	0.282 0.431	-0.182 0.160	-0.047 -0.039
Number of seeds per spike	0.923 0.971	0.160 0.218	0.882 0.626	-0.133 0.957	0.321 0.050	0.005 0.061
Weight of seeds per spike	0.990 0.963	-0.249 -0.258	0.523 0.567	0.086 0.754	0.804 -0.012	-0.034 -0.088
1000-kernel weight	0.884 0.878	-0.486 -0.518	-0.227 0.747	0.268 0.143	0.724 -0.060	-0.030 -0.169
Yield per plant	0.851 0.863	-0.170 0.011	0.109 0.876	0.762 0.114	0.456 0.043	-0.145 0.282
Percent of total variability explained	91.396 92.187	28.203 32.355	18.808 18.226	16.589 17.273	16.165 13.131	11.361 11.202

First reading under each column refers to Ellerslie and the second to Parkland.

The term *tillering-capacity* was chosen for the third principal factor, as the number of tillers per plant contributed highest at both locations. The factor explains approximately 17% of the total variation and is supported by number of spikelets per spike, number of seeds per spike (at Parkland), weight of seeds per spike, 1000-kernel weight and yield per plant. Since this component is closely associated with the *yielding-ability*, the *lateness* factor shows negative effects for onset-of-heading and final heading. This kind of response seems to be logical since high tillering capacity results in higher yield per plant and is associated with earliness.

The fourth principal component, named *heading-period* at Parkland and *seed weight* at Ellerslie, accounted for 13% and 16% of the variation respectively. Different names were chosen for different locations because of the inconsistency between locations of factor loadings on various characters. At Ellerslie, the *seed-weight* component was affected by number of seeds per spike, 1000-kernel weight and yield per plant. The contribution of onset-of-heading, final heading, heading-span, plant height and number of tillers per plant towards this component was negative. At Parkland, *heading-period* was positively affected by final heading, plant height, number of tillers per plant and number of spikelets per spike.

The terms *heading-period* and *tillering-capacity* were also used for fifth principal component at Ellerslie and Parkland, respectively, because of their high contribution towards the loadings of this factor. Only 11% of the total variability was accounted for by this factor at both

TABLE 4

Estimates of general combining ability
of five parental lines used in F_1 diallel set
for ten characters at two locations

Character	Marquis	Chinook	Khush-hal	Ciano	Inia
Onset-of-heading	1.933	1.4667	-0.4666	-1.7334	-1.2000
	1.9867	2.3533	-0.8800	-2.2466	-1.2133
Final heading	2.1600	1.7934	-0.3733	-2.1066	-1.4733
	2.4800	2.9466	-1.0867	-2.4867	-1.8533
Heading-span	0.2600	0.3933	0.1267	-0.4400	-0.3400
	0.4800	0.5800	-0.2200	-0.2200	-0.6200
Plant height	13.7470	12.1740	-8.1473	-7.8220	-9.9516
	12.3968	13.4648	-8.7599	-7.9252	-9.1766
Number of tiller per plant	-0.0409	0.8629	0.6390	-0.3116	-1.1495
	0.3351	0.3316	0.5466	-0.1349	-1.0784
Number of spikelets per spike	0.5123	0.3536	-0.5752	-0.3151	0.0245
	0.6729	0.4595	-0.5058	-0.3616	-0.2650
Number of seeds per spike	2.8305	-1.5451	-1.1460	-1.9094	1.7700
	2.0515	-0.9495	0.3450	-2.4385	0.9916
Weight of seeds per spike	-0.0103	-0.1285	-0.0092	0.0008	0.1472
	-0.0326	-0.0958	0.0848	-0.0501	0.0938
1000-kernel weight	-2.4230	-1.5338	0.7291	1.7007	1.5269
	-2.3256	-1.3217	1.6523	0.8898	1.1052
Yield per plant	-0.1646	-1.2333	-0.0382	0.1903	1.2458
	-0.4672	-0.5154	0.3461	0.2629	0.3736

First reading under each column refers to Ellerslie and the second to Parkland.

locations. The factor was negatively affected by number of spikelets per spike, weight of seeds per spike and 1000-kernel weight.

Combining ability analysis

Estimates of general and specific combining ability for the F_1 diallel were obtained by Griffing's (1956) procedure following method 1, model 1. General combining ability (GCA) values for all the characters at both locations are given in Table 4. Marquis appeared to be the best combiner for onset-of-heading, final heading, plant height, number of spikelets per spike and number of seeds per spike at both locations. For tillering capacity Chinook exhibited the highest combining ability at Ellerslie while Khush-hal excelled Chinook at Parkland. Inia showed the highest general combining ability for yield per plant, 1000-kernel weight and weight of seeds per spike at both locations. It is interesting to note that Inia excelled Marquis and Chinook (both Canadian standard varieties) in general combining ability for yield in a foreign environment. This might be attributed to a better adaptability of Inia as compared to the other two introductions, viz., Khush-hal and Ciano, of Pakistan and Mexican origin. Generally it could be said that Canadian environments are less suitable for introductions like Khush-hal and Ciano as far as yield per plant is concerned.

The values of specific combining ability (SCA), reciprocal effects and variances for general and specific combining abilities for F_1 hybrids are given in Tables 5 to 15.

Cross (CxI) had the highest SCA for onset-of-heading (Table 5),

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_1 diallel set at two locations.

TABLE 5. Onset-of-heading

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	0.8667 0.6801	-0.5333 -0.0866	-1.1000 -0.8866	-1.2999 -1.2533	1.9333 1.9867	3.6535 3.7430	-0.2104 -0.5095
Chinook	Reciprocal effects	-0.3333 0.1667	-	-0.9000 0.3800	-0.4667 0.2467	-0.5000 -1.1200	1.4667 2.3533	2.0669 5.3343	0.0400 -0.3554
Khush-hal		0.0 -0.1667	-0.5000 0.0	-	0.1333 -0.6867	0.4333 -0.8867	-0.4666 -0.8800	0.1336 0.5705	0.1544 -0.4589
Ciano		-0.5000 -2.0000**	0.0 -0.1667	0.6667 0.0	-	1.0334 0.9800	-1.7334 -2.2466	2.9204 4.8435	0.2715 -0.0701
Inia		0.5000 1.0000	0.5000 0.1667	0.8333* -0.5000	-0.1667 1.0000	-	-1.2000 -1.2133	1.3558 1.2683	0.8548 1.0144

TABLE 6. Final heading

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	1.0733 2.9200	-0.9267 -1.7133	-1.3600 -1.4799	-1.6000 -1.4467	2.1600 2.4800	4.5722 5.8974	-0.2335 -0.6322
Chinook	Reciprocal effects	0.0 0.0	-	-0.8934 -1.6799	-0.3267 -1.2800	-0.2933 -2.0800	1.7934 2.9466	3.1227 8.4298	0.1505 2.2100
Khush-hal		-0.5000 0.3333	-0.5000 -0.1667	-	-0.4933 0.2534	-0.1266 0.6200	-0.3733 -1.0867	0.0459 0.9280	0.3187 1.2870
Ciano		-0.3333 -1.1667	0.0 -1.1667	0.0 0.0	-	0.9400 1.1867	-2.1066 -2.4867	4.3445 5.9306	0.4979 0.6653
Inia		0.8333 0.1667	0.0 0.0	0.0 0.0	0.0 -0.1667	-	-1.4733 -1.8533	2.0773 3.1819	0.5436 2.1050

First reading under each column refers to Ellerslie and the second to Parkland.
* Significant at 5% level
** Significant at 1% level

at both locations followed by hybrid (MxCH). This shows that hybrid (CxI) was latest in heading and implicitly in maturity. Cross (MxI) exhibited lowest SCA and hence could be regarded as the earliest of all the F_1's. It is interesting to note that for both locations, the best hybrid, with the highest SCA, had parents showing the lowest GCA's, while the poorest hybrid, with the lowest SCA, had the female parent with the highest GCA and the male parent with the lowest GCA. Thus it appears unlikely that the best performing parents (those with high GCA's) necessarily produce hybrids showing high SCA's. None of the hybrids showed significant reciprocal effects except (IxK) at Ellerslie and (CxM) at Parkland, and the parental variances for GCA were in general higher than for SCA.

With respect to final heading (Table 6) and heading-span (Table 7), although there are some differences in relative positions of the parents and hybrids concerned, the general conclusions are the same as for onset-of-heading.

With respect to highest SCA for plant height (Table 8) at both locations, the best hybrid was (MxCH) and the poorest (MxI). The parents of cross (MxCH) had the highest GCA at both locations while the poorest hybrid had Marquis as one parent, with the highest GCA and Inia as the other, with the lowest GCA. The parental GCA-variances were larger than their SCA-variances at both locations, suggesting a greater importance of additive gene effects for the parental lines than of non-additive ones for the hybrids, with respect to plant height. The reciprocal effects were significant for (CxM) at both locations and for (IxM) and (IxCH) at Ellerslie. In the case of (IxM), the reciprocal effects could be attributed

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_1 diallel set at two locations.

TABLE 7. Heading-span

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	2.2533 0.0400	-1.6133 -0.0267	-0.6133 -0.2933	-0.2133 0.1067	0.4800 0.2600	-0.0163 -0.1184	-0.2096 -0.8721
Chinook		-0.1667 0.3333	-	-2.0467 -0.1600	-1.5467 0.0733	-0.9800 0.1400	0.5800 0.3933	0.0709 -0.0124	-0.2091 0.8204
Khush-hal	Reciprocal effects	0.5000 0.0	-0.1667 0.0		0.9200 -0.6600	1.4867 -0.5933	-0.2200 0.1267	-0.0678 -0.3004	-0.2009 1.3018
Ciano		0.8333* 0.1667	0.0 0.0	0.0 -0.6667	-	0.3200 -0.0267	-0.2200 -0.4400	0.1097 -0.3004	-0.0340 -0.3328
Inia		-0.8333* 0.3333	-0.1667 -0.5000	0.5000 -0.8333	-1.3333** 0.1667	-	-0.6200 -0.3400	0.0317 0.0356	-0.0817 0.2341

TABLE 8. Plant height

		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	3.4117 3.6766	2.0390 2.7912	-2.3879 -1.9234	-4.1867 -4.4220	13.7470 12.3968	187.1822 151.7148	-4.4931 -4.9129
Chinook		0.2933 -0.1134	-	2.4237 1.5132	1.3784 3.0219	2.6996 -3.3567	12.1740 13.4648	146.4086 179.3356	-0.5994 -0.4071
Khush-hal	Reciprocal effects	-0.4766 1.2467	0.8250 1.8566	-	-1.9553 -0.1367	-0.0704 -0.0287	-8.1473 -8.7599	64.5814 74.7702	-1.1491 -1.5526
Ciano		-3.7717* -4.3133	-1.3083 -0.7933	0.9233 1.3100	-	1.3890 2.0900	-7.8220 -7.9252	59.3868 60.8436	-0.6846 -0.6295
Inia		5.1567** 3.3467	-4.5567* -1.4767	1.0980 2.1400	-2.0700 -0.5600	-	-9.9516 -9.1766	97.2374 82.2441	4.4238 6.8172

First reading under each column refers to Ellerslie and the second to Parkland.
* Significant at 5% level
**Significant at 1% level

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_1 diallel set at two locations.

TABLE 9. Number of tillers per plant

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chincok	Khush-hal	Ciano	Inia			
Marquis		-	-0.0903 -0.8068	-0.7628 -1.2051	0.5342 -0.3143	-0.1946 -1.1968	-0.0409 0.3351	-0.3273 -0.1992	-0.8224 -0.7787
Chinook	Reciprocal effects	1.1667 0.0667	-	1.8354 0.5318	-0.1528 -0.5535	-0.4983 -0.3683	0.0629 0.3316	0.4155 -0.2015	-0.8197 -0.5617
Khush-hal		-0.4297 1.0167	0.1055 -0.6833	-	-0.3790 0.5982	-0.4183 -0.0249	0.6390 0.5466	0.0794 -0.0127	0.4944 -0.2004
Ciano		0.4833 0.1593	-0.5000 -1.1167	0.7833 0.6167	-	0.5094 1.0399	-0.3116 -0.1349	-0.2319 -0.2933	-0.6716 -0.5244
Inia		-0.4500 0.6000	-1.2500 0.4083	0.8227 0.4167	0.3500 -0.7333	-	-1.1495 -1.0784	0.9923 0.8513	-0.6077 0.1064

TABLE 10. Number of spikelets per spike

Marquis		-	-0.2740 1.1008	0.1741 -0.2395	-0.0388 -0.1238	-0.4728 -0.1136	0.5123 0.6729	0.1150 0.3652	-0.3687 -0.2192
Chinook	Reciprocal effects	-0.3333 0.2668	-	0.2618 0.1404	0.3642 -0.1925	-0.0032 -0.5073	0.3536 0.4595	-0.0224 0.1235	-0.3436 0.1847
Khush-hal		1.0593 -0.3278	-0.2623 -0.3167	-	-0.3403 0.1615	-0.1155 -0.3017	-0.5752 -0.5058	0.1834 0.1682	-0.3357 -0.1935
Ciano		-0.0778 -0.4012	-0.1002 -0.0277	0.4888 0.2057	-	0.2157 0.5208	-0.3151 -0.3616	-0.0482 0.0431	-0.2854 -0.1931
Inia		-0.4388 -0.2390	0.1947 0.3458	0.4692 0.1447	0.0222 -0.2168	-	0.0245 -0.2650	-0.1469 -0.0175	-0.2742 -0.0073

First reading under each column refers to Ellerslie and the second to Parkland.

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_1 diallel set at two locations.

TABLE 11. Number of seeds per spike

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	-1.9659 1.2486	2.2792 0.1486	0.9872 -1.2352	-3.1363 1.7185	2.8305 2.0515	6.6103 3.1165	-3.5029 -2.7300
Chinook	Reciprocal effects	-0.6665 0.1168	-	0.0151 0.1107	0.9075 -0.3172	2.0447 0.1696	-1.5451 -0.9495	0.9862 -0.1904	-2.2146 -2.2104
Khush-hal		3.1140 1.5667	-1.3513 -0.7168	-	-2.5752 -0.1725	-0.3525 -2.4527	-1.1460 0.3450	-0.0878 -0.9730	-1.7712 -2.2186
Ciano		4.5557** 0.4772	1.7223 0.5945	-0.6055 1.0333	-	2.9756 1.9031	-1.9094 -2.4385	2.2449 4.8542	-0.6930 -2.1780
Inia		-1.5222 -1.1278	0.0723 1.5223	-0.7965 -0.8835	-2.2833 -1.1335	-	1.7700 0.9916	1.7317 -0.1088	4.1624 1.4764

TABLE 12. Weight of seeds per spike

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	-0.0905 0.0512	0.0739 -0.0038	0.1517 0.0746	-0.1100 0.0983	-0.0103 -0.0326	-0.0032 -0.0027	-0.0083 -0.0095
Chinook	Reciprocal effects	-0.0175 -0.0320	-	0.0364 0.0194	0.0412 -0.0762	0.0439 0.0399	-0.1285 -0.0958	0.0132 0.0054	-0.0056 -0.0087
Khush-hal		0.1782* -0.0287	-0.0768 -0.0527	-	-0.1029 0.0249	0.0727 -0.0356	-0.0092 0.0846	-0.0033 0.0034	-0.0061 -0.0094
Ciano		0.2843** 0.0622	0.0267 0.0268	-0.0705 0.1142	-	0.0391 0.0487	0.0008 -0.0501	-0.0033 -0.0013	0.0036 -0.0055
Inia		-0.0590 -0.0805	-0.1433 -0.0038	0.0425 0.0427	-0.0505 -0.0460	-	0.1472 0.0938	0.0183 0.0050	-0.0014 -0.0046

First reading under each column refers to Ellerslie and the second to Parkland.

* Significant at 5% level

** Significant at 1% level

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_1 diallel set at two locations*

TABLE 13. 1000-kernel weight

♀ Parent	Specific combining ability					GCA	Variance of GCA	Variance of SCA
	Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis	-	-0.1201 0,0835	-0.5650 -0.2523	2,0236 2,6151	0.1734 0.8063	-2.4230 -2.3256	-1.0311 -0.2340	-2.6455 -1.2556
Chinook	0.2312 -0.7130	-	0.7965 0.3194	0.0375 -1.5360	-0.7600 0.9759	-1.5338 -1.3217	0.4628 -0.2366	-2.5316 -1.2425
Khush-hal	1.1725 -1.7405	-0.6182 -0.4882	-	0.0280 0.7257	1.8405 1.4420	0.7291 1.6523	-1.0567 -0.3825	-1.1211 -1.2450
Ciano	2.1175 1.0338	-0.9577 0.1613	-1.2283 1.7450	-	-1.5895 -0.4875	1.7007 0.8898	-1.0220 -0.4331	-0.6646 -0.9974
Inia	-0.0403 -1.0033	-3.1908* -1.3335	1.4478 1.8997	0.8910 0.0420	-	1.5269 1.1052	0.4939 -0.3636	-1.2788 -0.9555

Reciprocal effects

TABLE 14. Yield per plant

♀ Parent	Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis	-	-0.5845 -0.1980	-0.9024 0.1755	2.4220 0.8520	-0.3343 0.0911	-0.1646 -0.4672	-1.0311 -0.2840	-2.6455 -1.2556
Chinook	1.1575 -0.6980	-	1.9387 0.0337	0.0545 -0.2106	-0.7460 -0.6938	-1.2330 -0.5154	0.4628 -0.2366	-2.5316 -1.2425
Khush-hal	0.3260 -0.1923	-0.7188 -0.5447	-	-0.2716 -0.0804	1.6500 0.2976	-0.0382 0.3461	-1.0567 -0.3825	-1.1211 -1.2450
Ciano	2.5833 -2.0633*	-0.5388 -0.3382	0.8368 1.6012	-	-0.9329 0.5674	0.1903 0.2629	-1.0220 -0.4331	-0.6646 -0.9974
Inia	-0.2452 -1.0785	-3.2108* -0.0700	0.5890 2.5692*	0.5675 -0.4895	-	1.2458 0.3736	0.4939 -0.3626	-1.2788 -0.9555

Reciprocal effects

First reading under each column refers to Ellerslie and the second to Parkland.
*Significant at 5% level

to the female parent (Inia) while for (CxM) and (IxCH), the male parents Marquis and Chinook are responsible, because of the negative sign associated with the effects.

For number of tillers per plant (Table 9), the hybrids (CHxK) and (CxI) had the highest SCA's at Ellerslie and Parkland respectively. The parental GCA for (CHxK) at Ellerslie was highest whereas that for (CxI) at Parkland was the lowest. The poorest hybrid was (MxK) at both locations, having the lowest SCA value, although one of its parents (Khush-hal) showed high GCA. The variances for GCA were generally higher than those for SCA.

Hybrid (CHxC) at Ellerslie and (MxCH) at Parkland, respectively ranked highest for number of spikelets per spike with respect to their SCA's, whereas cross (MxI) at Ellerslie and (CxI) at Parkland ranked lowest. It could be argued that the hybrid (MxI) had one parent (Marquis) ranking highest in GCA and hybrid (CHxC) had one parent (Ciano) with a very low GCA which shows that high parental GCA's might not result in higher SCA's for the hybrids. In general, the variances for GCA, were higher than those for SCA. The reciprocal effects were non-significant for all crosses.

The interpretation of the results for general and specific combining ability and the reciprocal effects for number of seeds per spike (Table 11), weight of seeds per spike (Table 12), 1000-kernel weight (Table 13) and yield per plant (Table 14) follow the same pattern. Differences may be found with respect to relative positions of the parents and hybrids concerned but the general conclusions are the same.

TABLE 15

Analysis of variance of general and specific combining ability for ten characters from F_1 diallel set at two locations.

Character	M.S. for GCA	M.S. for SCA	M.S. for reciprocal effects	Error M.S.
D.F.	4	10	10	48
Onset-of-heading	26.3438** 41.9375**	1.9125** 2.2312**	0.4556 1.2722	0.3155 0.7640
Final heading	36.5000** 64.0469**	2.8562** 7.1312**	0.2611 0.3167	0.3504 0.9482
Heading-span	1.3688** 2.6199	0.4951 4.5816**	0.3333 0.7500	0.3144 1.3089
Plant height	1409.4062** 1396.7344**	22.8000** 22.6250**	14.1257* 8.6772	6.7393 7.3723
Number of tillers per plant	6.4326** 4.2588*	1.2214 2.6332*	1.0437 0.8791	1.2336 1.1674
Number of spikelets per spike	2.0459* 2.8027**	0.2086 0.5035	0.4016 0.1455	0.5531 0.3284
Number of seeds per spike	46.2188** 30.4062**	9.3219 4.4004	8.8449 2.0571	5.2554 4.0978
Weight of seeds per spike	0.0959** 0.0719**	0.0169 0.0137	0.0306* 0.0065	0.0124 0.0142
1000-kernel weight	34.9531** 29.7500**	3.0262 5.2500	4.3586 2.8623	3.2919 2.7816
Yield per plant	7.8486 2.0332	3.8079 0.6977	4.1329 3.1529	3.9663 1.8834

First reading under each column refers to Ellerslie and the second to Parkland.

* Significant at 5% level

**Significant at 1% level

A general review of the results of the combining ability analyses with respect to all the characters under study suggests that:

(i) The high GCA of the parents can not be taken as a criterion for the evolution of hybrids with high SCA's since the hybrids with high SCA's were associated with respective parents of low GCA's and *vice versa*.

(ii) Since the variances for GCA were usually larger than those for SCA, and since GCA is the result of additive, and SCA non-additive gene effects (Sprague and Tatum, 1942; Fryxel *et al* 1958 and Griffing 1956), the selection of the parental lines on the basis of their GCA's should be given priority over selection on the basis of their SCA's. This conclusion may also be supported from the analysis of variance for general and specific combining ability (Table 15). The results of Table 15 reveal that the variances for GCA were significant except for heading-span at Parkland and for yield per plant at both locations. The variances for SCA were significant only for onset-of-heading, final-heading and plant height (at both locations) and for heading-span and number of tillers per plant (at Parkland). Significance of variances for GCA thus suggests the importance of additive gene effects and emphasizes that substantial differences exist among the parental lines used in the study. (iii) The significant variances for SCA imply that non-additive gene effects for the particular characters are relatively more important and that the hybrids with highest SCA's may be selected for further breeding adaptability tests.

TABLE 16

Mean squares from the analysis of variance of the 5 x 5 F_1-diallel table for ten characters at two locations.

Source of variation	D.F.	Onset-of-heading	Final heading	Heading-span	Plant height	Number of tillers per plant	Number of spikelets per spike	Number of seeds per spike	Weight of seeds per spike	1000 kernel weight	Yield per plant
a	4	79.1719** 125.8750**	109.6875** 192.2500**	4.1074 7.8604	4228.0000** 4191.0000**	19.3008* 12.7686	6.1328* 8.4102**	138.7031* 91.2188	0.2877* 0.2156*	104.[illegible]* 88.2031**	23.5332 6.0947
b	10	5.7750 6.7125*	8.5250** 21.3812**	1.4852 13.7445*	68.4000 67.7000	3.6668 7.9043	0.6289 1.5145	28.0187 13.2562	0.0507 0.0413	9.0875 15.7437	11.4297 2.1000
b₁	1	16.3333 20.8033	38.1633 66.2700	5.8800 12.4033	67.5947 31.1918	0.7123 15.8674	0.1574 0.5796	4.1706 3.7705	0.0726 0.1749	10.4398* 66.0398	15.1135 2.0817
b₂	4	2.4219 4.7959	4.4375* 1.0469	1.8822 5.1289	112.5625 93.1719*	2.4049 13.1418*	0.7930 1.1104	14.0703 14.2686	0.0092 0.0390	5.3457 8.9922	5.1953 3.6924
b₃	5	6.3625** 5.4500*	5.8500** 28.6750**	0.2883 20.1060*	33.0125 54.8625**	5.2719 2.1195	0.5953 2.0281	43.9750 14.3625*	0.0796 0.0166	11.8000 11.1000	15.6836 0.8312
c	4	2.1333 4.1833	0.6167 0.5833	1.4333 2.4667	11.1538 6.6066	3.8020 1.9934	0.0725 0.4659	37.5303 4.6971	0.0977 0.0398	11.6772 14.9461	18.0605 12.4107
d	6	0.8556 3.5722*	0.8944 1.1944	0.7111 2.1056	63.1929* 38.9815**	2.6837 3.0668	1.9599 0.4170	19.2044 7.0210	0.0880* 0.0061	14.0084 4.3472	8.6244 7.4908
Blocks x *a*	8	1.0312 3.5937	0.6328 4.6406	2.2113 5.6348	17.7266 35.6094	4.7915 4.7622	1.7173 0.8608	25.6719 24.4531	0.0542 0.0572	20.7422 7.6406	7.8745 5.7969
Blocks x *b*	20	1.1312 2.5469	0.6406 3.6719	0.7294 5.1647	27.3656 24.7844	4.9238 4.9705	2.1734 0.9705	19.0937 6.5250	0.0398 0.0412	8.8656 10.3906	15.2057 5.3535
Blocks x *b₁*	2	9.2467 8.8466	2.4866 15.8600	1.5800 6.2067	77.0164 270.1160	13.4714 38.0653	2.2294 0.0713	42.1510 6.3986	0.0717 0.1328	0.4583 33.9540	47.2437 1.2041
Blocks x *b₂*	8	1.0688 4.0024	0.9307 1.3726	1.0355 6.2955	31.9712 20.4922	4.3863 1.9459	1.3899 1.5215	16.33[illegible] 10.458[illegible]	0.0487 0.0377	8.8271 8.2334	8.9218 3.0371
Blocks x *b₃*	10	0.4750 0.9937	0.3000 4.6562	0.4725 4.6720	21.6625 6.1187	4.9898 2.8008	3.0066 0.7113	20.9125 4.0633	0.0335 0.0390	10.6437 10.8035	18.5426 8.1539
Blocks x *c*	8	0.8333 2.1833	1.4667 0.4083	1.0583 2.1417	16.0278 24.9243	3.1607 3.1579	1.2033 1.3036	12.4407 17.3466	0.0273 0.0666	6.5340 7.7739	8.6371 8.0467
Blocks x *d*	12	0.6389 1.0722	1.7444 1.8944	0.3778 1.9056	13.0140 6.9826	1.3007 1.9370	1.0707 0.8900	5.8792 10.4261	0.0293 0.0204	6.5789 5.8304	11.2731 4.4533
Error	48	0.9418 2.2921	1.0529 2.8450	0.9433 3.9244	20.2814 22.1612	3.7021 3.5057	1.6601 0.9876	15.7776 12.2919	0.0375 0.0429	9.8848 8.354	11.9059 5.6517

*Significant at 5% level

** Significant at 1% level

First reading under each column refers to Ellerslie and second to Parkland. Error D.F. comprises of block interaction with D.F. of (*a*+*b*+*c*+*d*).

Each component has been tested against its own block interaction.

Diallel cross analysis

F_1 entries from Appendices III to XXII were sorted out and complete diallel tables were constructed for each replication with respect to all the characters at both locations. All the entries were subjected to Hayman's (1954a) analysis of variance. The results of this analysis are presented in Table 16. In this table component a tests the significance of additive effects and b the dominance effects of genes, while b_1 tests the mean deviations of F_1's from their mid-parent values. The dominance-deviations, if predominantly in one direction, may result in significance of b_1 in an analysis of variance. The component b_2 indicates the extent to which the mean dominance deviations within a given array of the diallel table differ from those of the other arrays. A significant b_2 thus implies that some of the parents contain an excess of dominant alleles. The b_3 component tests the portion of the dominance deviations attributable to individual F_1's. The difference between the reciprocal crosses is assessed by the significance of the c component and maternal effects not ascribable to c are reflected by d. In Table 16 each of the components has been tested for significance against its own block-interaction mean-square. The c was not significantly different from zero at either location for any of the characters studied. Substantial differences among the parents are suggested by the significance of the a component (additive gene effects) for onset-of-heading, final heading, plant height, number of spikeletes per spike and 1000-kernel weight at both locations and number of tillers per plant and number of seeds per spike at Ellerslie. Item b was significant for final heading at both locations and for onset-of-heading and heading-span at Parkland.

TABLE 17

Analysis of variance of W_r-V_r differences for ten characters from F_1 diallel set at two locations.

Character	Block M.S.	Entry M.S.	Error M.S.	F for Entries
Onset-of-heading	9.2560 18.9050	0.5815 0.0396	0.1617 0.2974	3.4689 0.1332
Final heading	5.1354 73.2777	1.4540 11.9745	0.4502 4.6422	3.2297 2.5795
Heading-span	0.9138 31.5321	0.1887 18.5786	0.1845 11.9478	1.0227 1.5550
Plant height	17021.1562 4453.5938	344.3201 180.5625	200.6953 58.2656	1.7157 3.0990
Number of tillers per plant	37.6399 9.8207	6.5010 0.7379	3.5646 2.0809	1.8238 0.3546
Number of spikelets per spike	4.3689 0.5617	0.7859 0.1118	0.2638 0.1160	2.9796 0.9640
Number of seeds per spike	989.3882 24.4063	83.1030 23.2917	64.5087 12.2852	1.2882 1.8959
Weight of seeds per spike	0.0021 0.0041	0.0002 0.0002	0.0003 0.0002	0.5844 1.1813
1000-kernel weight	128.4015 134.1506	7.3713 21.2359	6.6094 7.2551	1.1153 2.9270
Yield per plant	102.4395 28.0996	13.8542 5.8340	11.9046 5.6502	1.1638 1.0325

First reading under each column refers to Ellerslie and the second to Parkland.

Directional dominance (significance of b_1) was exhibited by 1000-kernel weight at Ellerslie. Significance of b_2 for final heading at Ellerslie and for plant height and number of tillers per plant at Parkland indicates that some parents probably possess more dominant alleles than others for these characters.

The assumptions of no non-allelic interaction, no multiple allelism and uncorrelated parental gene distribution, were checked by analysis of the variance of W_r-V_r. The test of homogeneity of W_r-V_r is given in Table 17. None of the characters showed heterogeneity at either location and the conditions underlying the diallel cross analysis could therefore be accepted as valid. For analysis of the genetic components of variation, the offdiagonal values of the diallel table were replaced with the common mean of the corresponding cross and its reciprocal. The array variances (V_r) and parent-offspring covariances (W_r) over five arrays provided the basis for calculating other second degree statistics which are presented in Table 18. The estimates of genetic components of variation obtained from second degree statistics (Hayman 1954b) are presented in Table 19. Table 18 supplied 35 statistics [(15 V_r's of five arrays and three replications, 15 W_r's, V_{0L0}, $_{0L01}$, V_{0L1}, V_{1L1} and $(M_{L1} - M_{L0})^2$] and 10 constants were fitted to them (5 values, D, H_1, H_2, h and E; F was not considered, as it is the mean of five F_r's), leaving 25 degrees of freedom for error to test the significance of genetic components of variation. The proportional estimates of the genetic parameters from Table 19 for all the characters are given in Table 20. The results shown in Table 19 and 20 supported by the

TABLE 18

Estimates of second degree statistics parameters for ten characters from F_1 diallel set at two locations.

Character	V_{0L0}	W_{0L01}	V_{0L1}	V_{1L1}	$[M_{L1}-M_{L0}]^2$
Onset-of-heading	15.0000 15.7002	6.2693 7.8816	2.6367 4.1963	3.6055 5.3152	0.8710 1.1096
Final heading	16.9668 27.1514	7.6781 13.1479	3.6621 6.4092	5.0816 9.9770	2.0354 3.5344
Heading-span	0.5889 3.6111	0.1901 0.8584	0.1370 0.2621	0.3845 2.5528	0.3136 0.6614
Plant height	486.7744 518.4434	257.0203 264.6565	140.9746 139.7002	152.3508 150.9949	3.6043 1.6638
Number of tillers per plant	1.4343 5.4749	0.8816 1.1369	0.6432 0.4255	1.2544 1.7429	0.0379 0.8462
Number of spikelets per spike	1.2283 0.5749	0.4720 0.3638	0.2047 0.2805	0.3093 0.5328	0.0083 0.0309
Number of seeds per spike	28.9980 12.2275	11.1666 5.3820	4.6221 3.0371	9.2889 5.2459	0.2224 0.2010
Weight of seeds per spike	0.0384 0.0360	0.0187 0.0142	0.0096 0.0072	0.0180 0.0141	0.0038 0.0093
1000-kernel weight	16.7744 13.1670	7.4203 5.8156	3.4941 2.9736	5.0057 5.5967	0.5568 3.5220
Yield per plant	5.4558 0.8875	1.8886 0.2405	0.7846 0.2034	2.6896 0.5532	0.8060 0.1110

First reading under each column refers to Ellerslie and the second to Parkland.

TABLE 19

Estimates of components of variation
for ten characters from F_1 diallel set at two locations.

Character	D	F	H_1	H_2	h^2	
Onset-of-heading	14.6845 ± 0.3196** 14.9359 ± 0.4053**	4.5440 ± 0.7983** -1.0433 ± 1.0125	3.5241 ± 0.8630** 3.4473 ± 1.0946**	3.2439 ± 0.7828** 2.9471 ± 0.9924**	3.2826 ± 0.5285** 3.9492 ± 0.6703**	0.3155 ± 0.1305 0.7643 ± 0.1655**
Final heading	16.6165 ± 0.5209** 26.2030 ± 1.0947**	2.8008 ± 1.3011* 0.5733 ± 2.7346	5.6702 ± 1.4066** 12.0021 ± 2.9564**	4.9776 ± 1.2758** 12.3744 ± 2.6815**	7.9178 ± 0.8614** 13.5304 ± 1.8104**	0.3503 ± 0.2126 0.9484 ± 0.4469*
Heading-span	0.2745 ± 0.1321* 2,3939 ± 1.1997*	0.0402 ± 0.3300 2.2189 ± 2.7495	0.5491 ± 0.3568 6.9876 ± 2.9726**	0.3612 ± 0.3236 6.5466 ± 2.6962**	1.0532 ± 0.2185** 1.8088 ± 1.8203	0.3144 ± 0.0539** 1.3018 ± 0.4494**
Plant height	480.0347 ± 4.6656** 511.0740 ± 6.7585**	-62.6197 ± 11.6546** -30.5825 ± 16.8827	50.5735 ± 12.5999** 44.6366 ± 18.2521*	32.0255 ± 11.4283** 30.4400 ± 16.5549	10.1059 ± 7.7158 1.9389 ± 11.1770	6.7396 ± 1.9047** 7.3694 ± 2.7591**
Number of tillers per plant	0.2006 ± 0.5712 4.3068 ± 0.3862**	-2.1333 ± 1.4269 5.005 ± 0.9648**	-0.2819 ± 1.5427 4.8621 ± 1.0430**	-0.0226 ± 1.3992 2.9335 ± 0.9460**	-0.6376 ± 0.9447 2.6375 ± 0.6387**	1.2336 ± 0.2332** 1.1618 ± 0.1577**
Number of spikelets per spike	0.6753 ± 0.0312** 0.2460 ± 0.2050	-0.0951 ± 0.0780 -0.7193 ± 0.5121	-0.8602 ± 0.0844** 0.3765 ± 0.5536	-0.6873 ± 0.0765** 0.3513 ± 0.5021	-0.3203 ± 0.0517** -0.0868 ± 0.3399	0.5530 ± 0.0128** 0.3289 ± 0.0837**
Number of seeds per spike	23.7437 ± 2.5748** 8.1325 ± 1.5171**	7.0245 ± 6.4318 -1.9871 ± 3.7897	7.8258 ± 6.9535 1.0359 ± 4.0970	8.1585 ± 6.3069 0.6450 ± 3.7161	-2.4732 ± 4.2581 -1.8166 ± 2.5089	5.2543 ± 1.0511** 4.0951 ± 0.6193
Weight of seeds per spike	0.0259 ± 0.0038** 0.0217 ± 0.0035**	-0.0132 ± 0.0096 -0.0021 ± 0.0086	0.0031 ± 0.0103 -0.0018 ± 0.0093	0.0088 ± 0.0096 -0.0011 ± 0.0085	0.0075 ± 0.0063 0.0282 ± 0.0057**	0.0125 ± 0.0016** 0.0143 ± 0.0014**
1000-kernel weight	13.4832 ± 0.7218** 10.3857 ± 1.0709**	-0.0819 ± 1.8030 -0.2660 ± 2.6750	-1.4414 ± 1.9492 5.0600 ± 2.8920	-0.5364 ± 1.7680 4.9297 ± 2.6231	0.1206 ± 1.1936 12.3080 ± 1.7710**	3.2912 ± 0.2947** 2.7812 ± 0.4372**
Yield per plant	1.4876 ± 0.2376** -0.9960 ± 0.2306**	-1.4048 ± 0.5936* -1.4472 ± 0.5761*	-1.6575 ± 0.6418* -2.7585 ± 0.6229**	-0.3163 ± 0.5821 -2.3675 ± 0.5649**	0.6845 ± 0.3930 -0.7613 ± 0.3814	3.9682 ± 0.0970** 1.8834 ± 0.0942**

First reading under each column refers to Ellerslie and second to Parkland.
* Significant at 5% level
** Significant at 1% level

graphical analysis of regression of W_r upon V_r lead to the following conclusions:

At both locations, onset-of-heading as inherited as a partially dominant trait, as shown by the mean degree of dominance $[(H_1 \div D)^{1/2} = 0.48]$ and regression line (b_{W_r/V_r}) which passes above the origin (Figure 1). The proportion of genes with positive and negative effects in the parents $[H_2 \div 4H_1]$ is 0.23 at Ellerslie and 0.21 at Parkland, suggesting a slight asymmetry of alleles at the loci exhibiting dominance. The proportion of dominant to recessive genes in the parents $[(4DH_1)^{1/2} + F] \div [(4DH_1)^{1/2} - F]$ is 1.92 at Ellerslie and 0.86 at Parkland, suggesting a preponderance of dominant genes in the parents at Ellerslie and equal proportions of dominant and recessive genes at Parkland. The coefficient of correlation between the parental order of dominance, i.e. $(W_r + V_r)$ and the parental measurements $[(Y_r)$; the corresponding values of the main diagonal of the diallel table] are 0.97 and 0.66 at Ellerslie and Parkland respectively. High positive correlation at both locations suggests an association between recessive genes with late heading and dominant genes contributing towards early heading. This situation is reflected in the standardized deviation graph (Figure 2) where all the Y_r, $(W_r + V_r)$ parental intercepts occupy (+,+) and (-,-) quadrants, except Khush-hal at Parkland. Figure 1 classifies Marquis as the highly recessive and Inia as the highly dominant parents at both locations, since they lie, respectively, farthest and nearest to the point of intersect of regression line and limiting parabola. Figure 2 supplements this conclusion by revealing

TABLE 20

Proportional values of the estimates of genetic parameters for ten characters from F_1 diallel set at two locations.

Character	$[H_1 + D]^{1/2}$	$[H_2 + 4H_1]$	$\left[\frac{(4DH_1)^{1/2} + F}{(4DH_1)^{1/2} - F}\right]$	h^2/H_2	r_{Y_r, W_r+V_r}	Heritability
Onset-of-heading	0.4899* 0.4804*	0.2301* 0.2137*	1.9232* 0.8645*	1.0119* 1.3400*	0.9742 0.6627	0.9837 0.6642
Final heading	0.5842* 0.6768*	0.2195* 0.2578*	1.3372* 1.0329*	1.5907* 1.0934*	0.9712 0.9661	0.7955 0.6325
Heading-span	1.4144 1.7419*	0.1644 0.2342*	1.1093 1.7646 †	2.9160 0.2763	0.1322 0.7382	0.1344 0.1875
Plant height	0.3246* 0.2955*	-0.1583* 0.1705*	0.6654* 0.8161†	0.3156 0.0637	0.1720 0.0770	0.7740 0.8299
Number of tillers per plant	1.1855 1.0625*	0.0200 0.1508*	-0.6361 3.4090*	28.1984 0.8991*	0.8341 0.8924	0.0281 0.4885
Number of spikelets per spike	1.1286* 1.2370	0.1997* 0.2333	0.8826† -0.0833	0.4661* -0.2472	-0.2485 0.7543	0.3182 0.0925
Number of seeds per spike	0.5741* 0.3569	0.2606 0.1557	1.6942 0.4900	-0.3031 -2.8162	-0.3653 -0.0519	0.5211 0.2953
Weight of seeds per spike	0.3484 0.2912	0.7000 0.1445	0.1561 0.7188	0.8524 -26.4099	-1.1500 -0.8890	0.2809 0.2739
1000-kernel weight	0.3270 0.6980	0.0930 0.2436	0.9816 0.9640	-0.2248 2.4967	-0.7287 -0.9252	0.5331 0.3869
Yield per plant	1.0556 1.6642	0.0477 0.2146	0.3819 0.3922	-2.1646 0.3216	-0.0082 -0.8646	0.0869 -0.1905

First reading under each column refers to Ellerslie and second to Parkland.
*Genetic component of variation for characters significantly different from zero at $P \leq 0.05$.
†Components D and H_1 significant, F non-significant ($P > 0.05$).

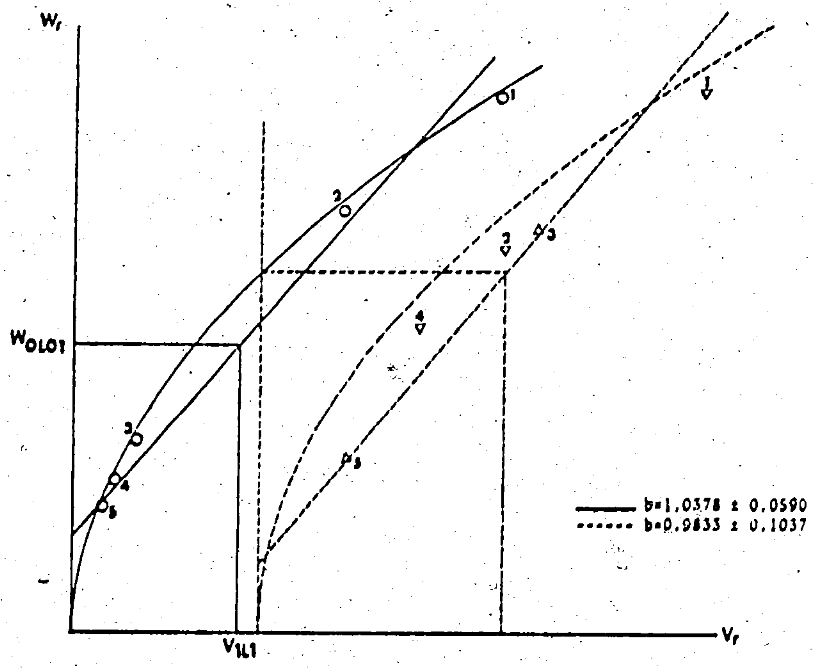

Figure 1. W_r, V_r graph for onset-of- heading from F_1 diallel set.

— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

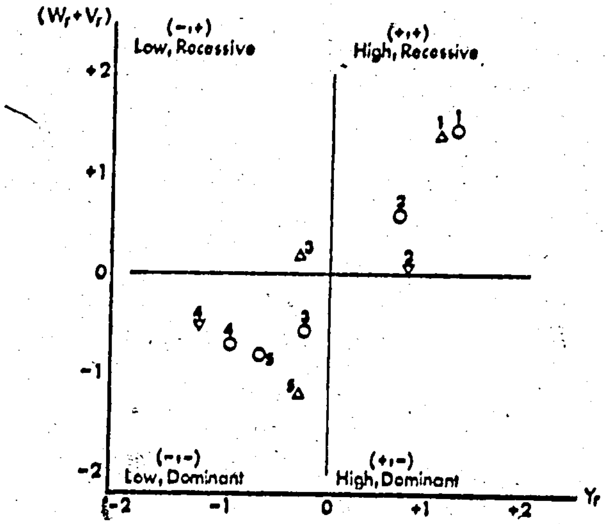

Figure 2. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for onset-of-heading from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

that at both locations the highly recessive parent contributes towards late heading (+,+ quadrant) and the highly dominant one towards early heading (-,- quadrant). As far as other parents are concerned, Chinook and Ciano, lying in (+,+) and (-,-) quadrants, may be classified as recessive late headers and dominant early headers. Khush-hal's order of dominance seems to be affected by the environmental influence, being a dominant early header at Ellerslie (-,- quadrant) and a recessive medium-early he[illegible] quadrant) at Parkland. The number of groups of genes (h [illegible] at both locations, suggests that at least one group of genes control onset-of-heading and exhibit dominance. The heritability estimates of 98.37% at Ellerlie and 66.42% at Parkland show that the character is highly heritable.

The results from Table 19 and 20 for final heading (Figures 3, 4) and heding-span (Figures 5,6) are subject to the same kind of interpretation as for onset-of-heading except for changes in the relative positions of the parents with respect to their ranking order for dominance, and therefore they are not discussed separately.

For plant height, the mean degree of dominance of 0.3 at both locations shows that height is inherited as a partially dominant character. The W_r, V_r graph (Figure 7) with a regression line intersecting the limiting parabola above its origin supports the above conclusion . The proportion of genes with positive and negative effects in the parents is approximately the same for both locations (0.158 at Ellerslie and 0.170 at Parkland), indicating asymmetry in the distribution of alleles at loci exhibiting dominance. The ratio of dominant to recessive

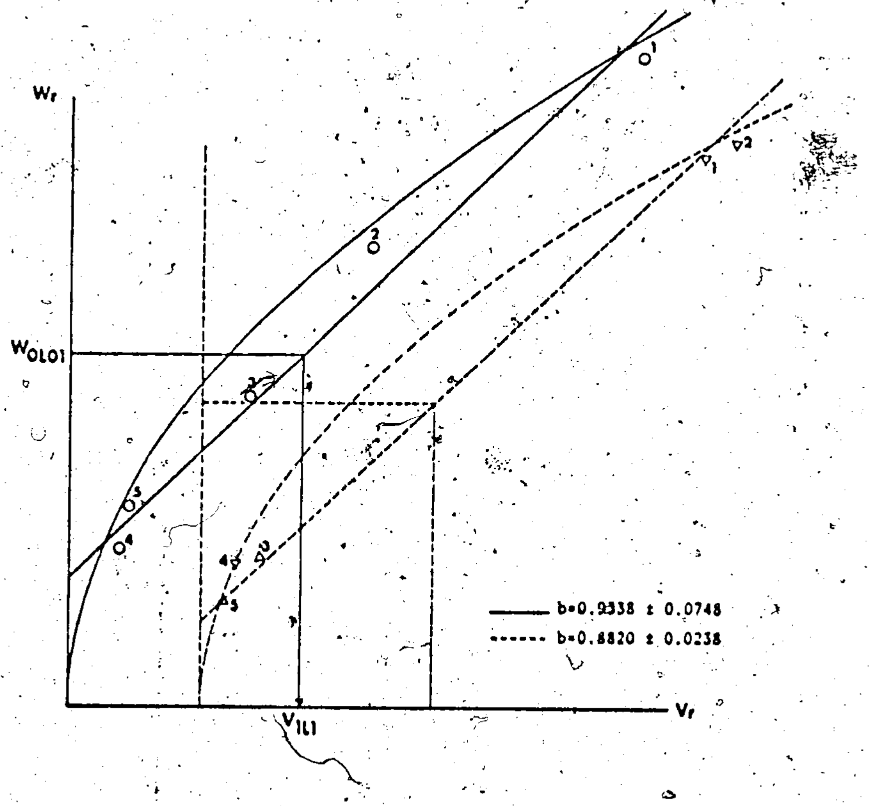

Figure 3. W_r, V_r graph for final heading from F_1 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

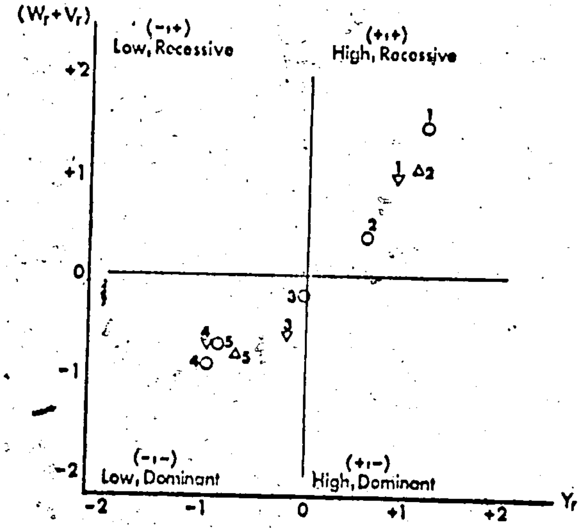

Figure 4. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for final heading from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

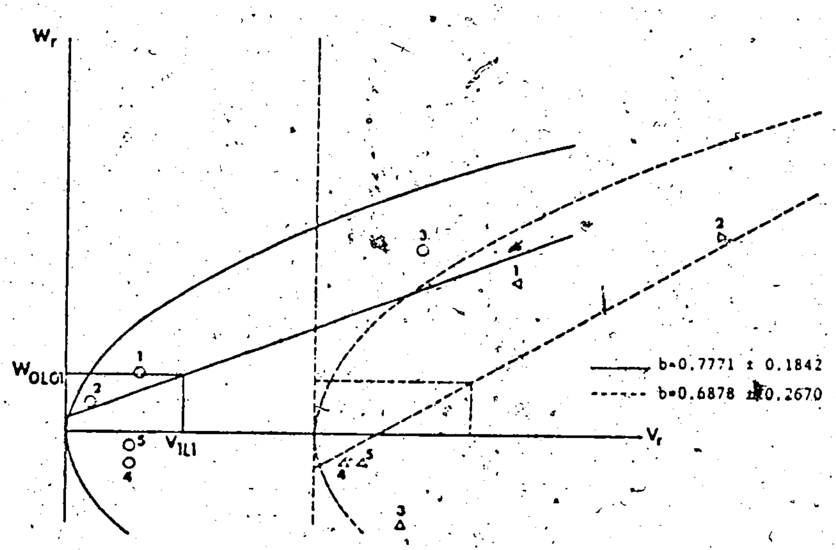

Figure 5. W_r, V_r graph for heading-span from F_1 diallel set.

—— o = W_r, V_r intercepts at Ellers[illegible]e

--- Δ = W_r, V_r intercepts at Parkland

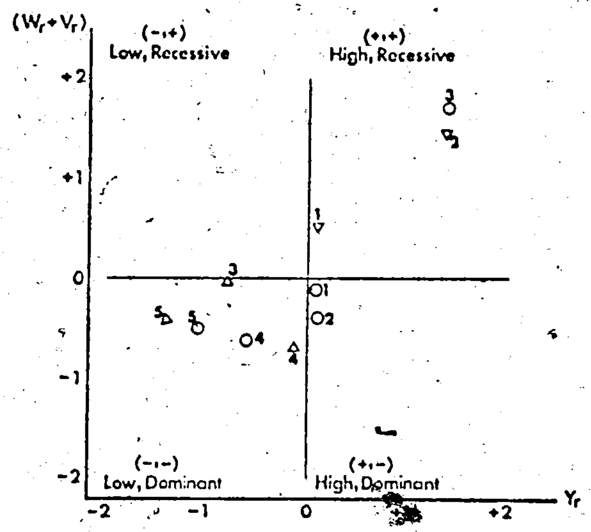

Figure 6. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for heading-span from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

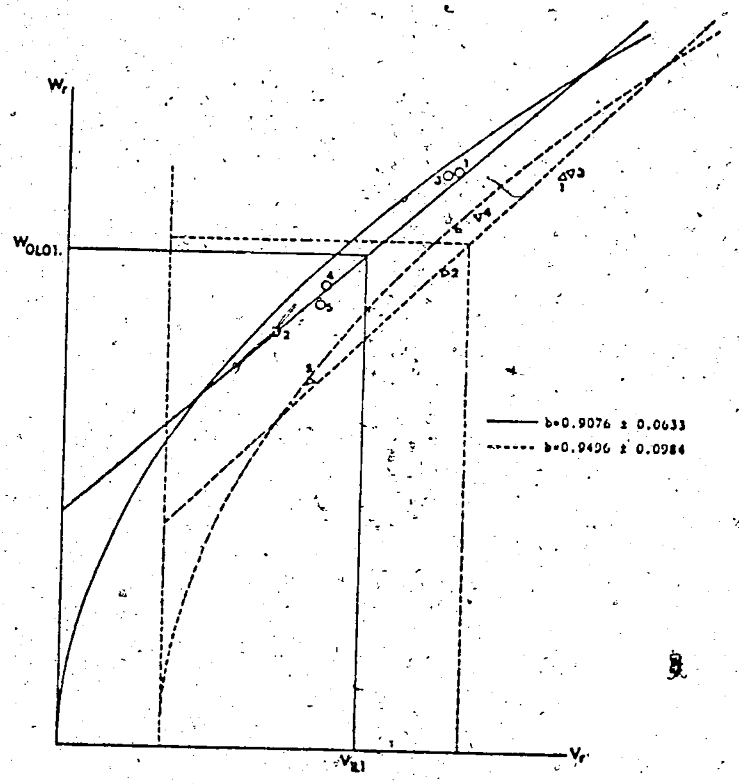

Figure 7. W_r, V_r graph for plant height from F_1 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

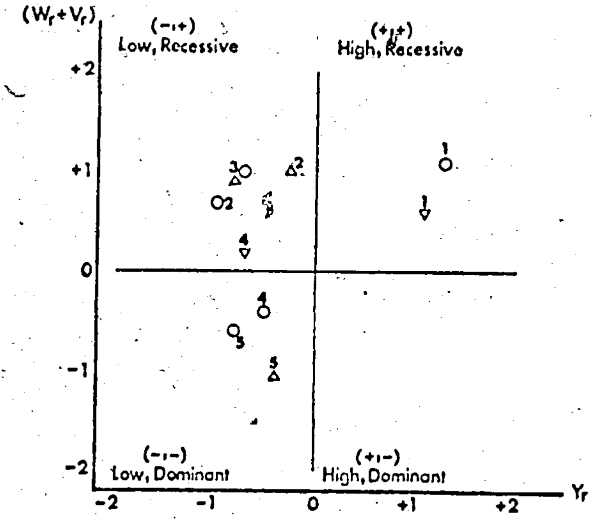

Figure 8. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for plant height from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

genes in the parents is approximately equal to one at both locations, suggesting that the parents contain equal numbers of dominant and recessive genes. The coefficient of correlation between the parental order of dominance and parental measurements is 0.17 at Ellerslie and 0.07 at Parkland, indicating weak association between the measurements of the parents and their order of dominance. Figure 7 indicates that Marquis at Ellerslie and Khush-hal at Parkland are the most recessive parents while Inia at both the locations is the most dominant parent. Figure 8 classifies the parental order of dominance together with their height performance. It places highly recessive parents Marquis (at Ellerslie) and Khush-hal (at Parkland) into (+,+) and (-,+) quadrants, showing that recessiveness of the former is responsible for tallness, while the recessive genes of the latter carry effects decreasing height. The position of Inia in the (-,-) quadrant of the graph (Figure 8) at both locations suggests that it contains a preponderance of dominant genes contributing towards shortness. The ranking order of Ciano appears to be influenced by location effects. At Ellerslie, it is highly dominant, contributing towards reduced height while at Parkland it has an excess of recessive genes, again responsible for shortness. The character seems to be consistently highly heritable over the locations (77.40% heritability at Ellerslie and 82.99% at Parkland).

The genetic components of variation, D, F, H_1 and H_2 are not significant for number of tillers per plant at Ellerslie and therefore estimates of mean degree of dominance, proportion of dominant to

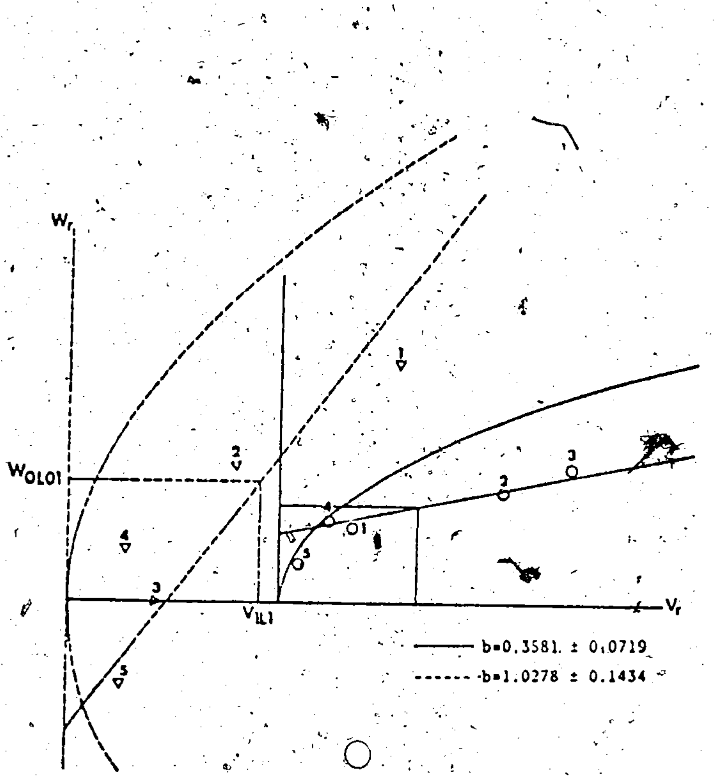

Figure 9. W_r, V_r graph for number of tillers per plant from F_1 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

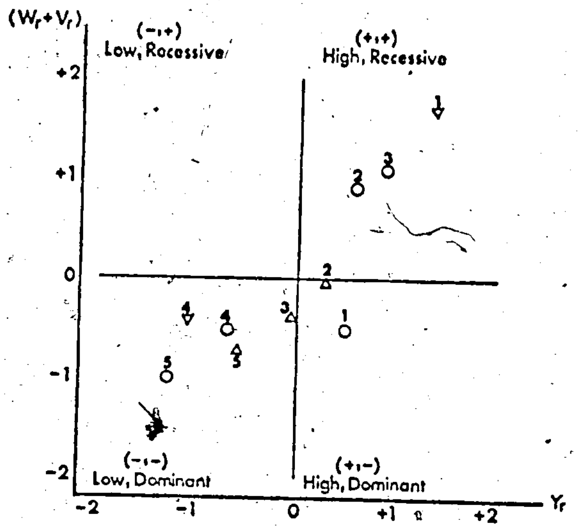

Figure 10. Standardized deviation graph of $[Y_r]$ $[W_r + V_r]$ for number of tillers per plant from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

recessive genes in the parents etc. should be meaningless (as suggested by Hayman, 1954b). Moreover, the W_r, V_r graph (Figure 9) for Ellerslie is distorted. The mean degree of dominance at Parkland (1.06) indicates over-dominance. This is supported by Figure 9 in which the regression line intersects the limiting parabola above its origin. The proportion of genes with negative and positive alleles at loci exhibiting dominance is 0.15 revealing asymmetry in distribution of alleles. The proportion of dominant to recessive genes in the parents is 3.409 which indicates an excess of dominant genes in the parents. Consequently Khush-hal, Ciano and Inia are categorized as parents with a preponderance of dominant genes, and of these Inia is the most dominant one as it lies closest to the point of intersection of the regression line with the limiting parabola (Figure 9). The significant positive correlation between the parental order of dominance and the parental measurements (0.80) shows that the genes with negative effects for number of tillers per plant are mostly dominant and those with positive effects are mostly recessive. This is shown graphically in Figure 10 where parental Y_r, $(W_r + V_r)$ intercepts occupy only the (+,+) and (-,-) quadrants. Ciano and Inia contain an excess of dominant genes (-,- quadrant) with lower tillering capacity. Chinook appears to be recessive, with a higher number of tillers per plant at Ellerslie, but shows an equal number of recessive and dominant genes at Parkland. Marquis and Khush-hal appear to be inconsistent with respect to order of dominance. At Ellerslie, Marquis has an excess of dominant genes but at Parkland it has become highly recessive. The reverse situation exists with Khush-hal which is placed in the (+,+)

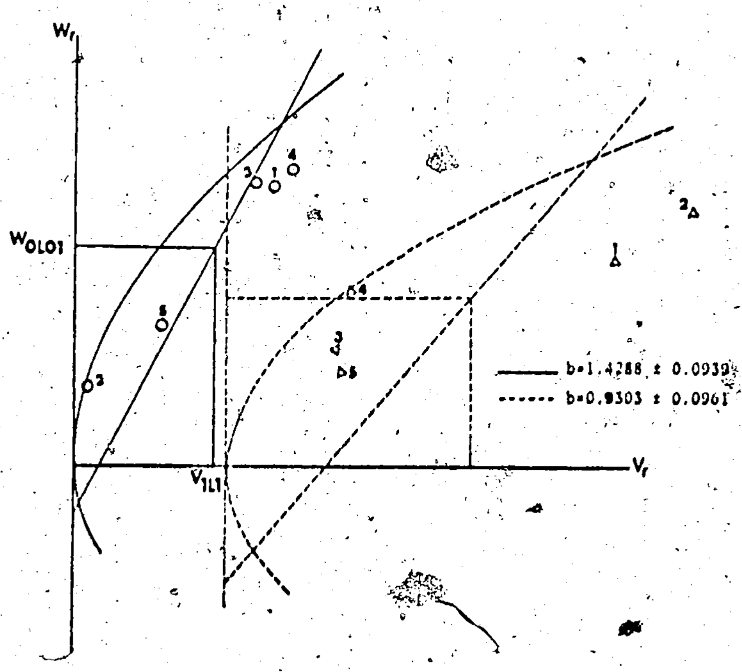

Figure 11. W_r, V_r graph for number of spikelets per spike from F_1 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

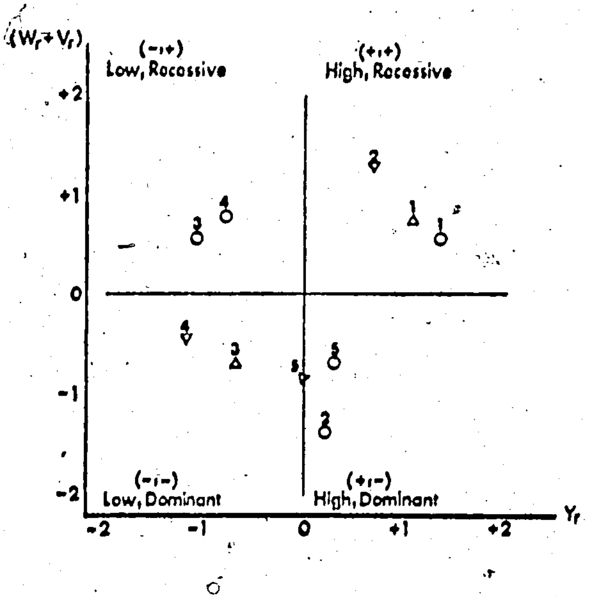

Figure 12. Standardized deviation graphs of $[Y_r]$ and $[W_r + V_r]$ for number of spikelets per spike from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

quadrant at Ellerslie and in the (-,-) quadrant at Parkland. The estimate for the number of groups of genes controlling tiller number seems to be questionable for Ellerslie (Table 20) where the relevant components of variation were nonsignificant (Table 19). However it is approximately equal to one at Parkland, showing that at least one group of genes exhibiting dominance controls tillering. The heritability of this character, low at Ellerslie (2.86%) and relatively high at Parkland (48.85%) seems to be affected by environmental differences.

With regard to number of spikelets per spike, there was over-dominance at both locations, since $[H_1/D]^{1/2} > 1$ and the W_r/V_r regression line intersects the limiting parabola below its origin (Figure 11). The genetic components of variation were not significant for Parkland and the proportional estimates of genetic parameters given in Table 20 have therefore to be ignored. For Ellerslie, the proportion of genes with positive and negative alleles at loci exhibiting dominance is approximately 0.2, indicating a slight asymmetry in distribution. The proportion of dominant to recessive genes in the parents is 0.99, suggesting approximately equal proportions of dominant and recessive genes. Figure 11 classifies Marquis, Khush-hal and Ciano as having an excess of recessive genes. The correlation coefficient $(r_{Y_r, W_r + V_r})$ of -0.2 at Ellerslie suggests that parental measurements are not related with their order of dominance, while $r = 0.75$ at Parkland suggests that genes for lower spikelet number per spike are dominant. Order of dominance of the parents (Figure 12) seems to be inconsistent for the two locations except Marquis and Inia. Chinook, the highly recessive parent at Parkland

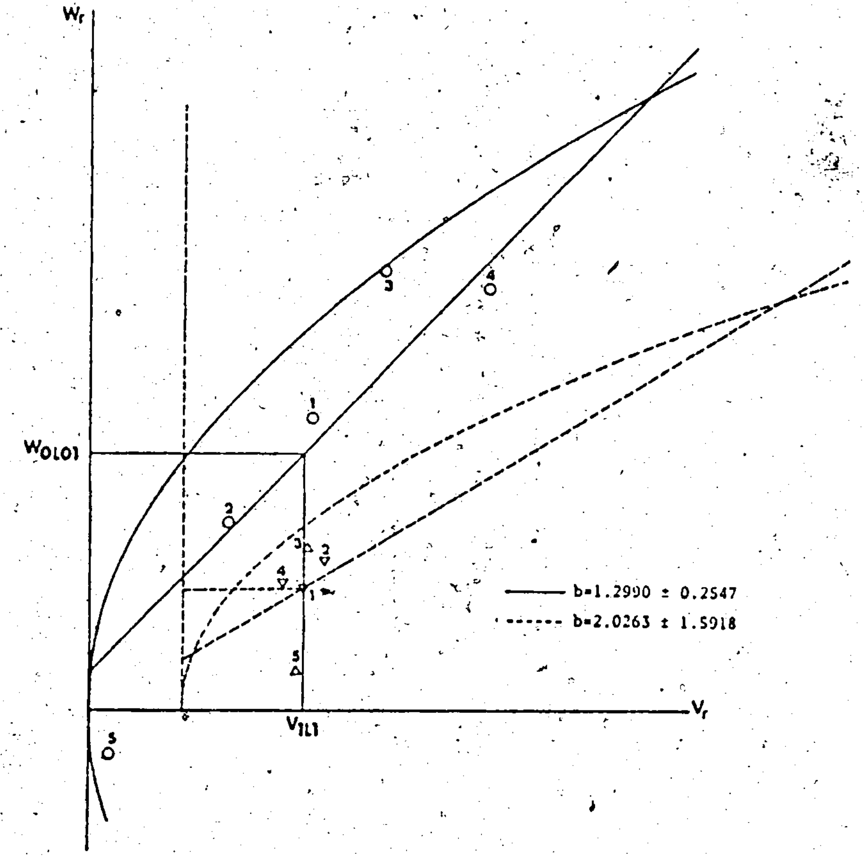

Figure 13. W_r, V_r graph for number of seeds per spike from F_1 diallel set.

— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

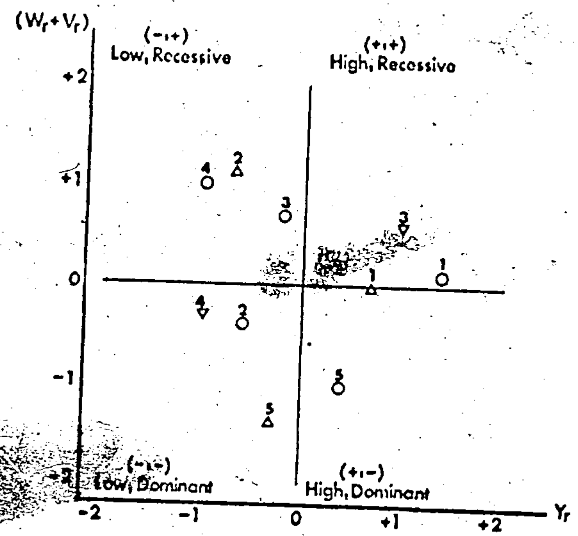

Figure 14. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of seeds per spike from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

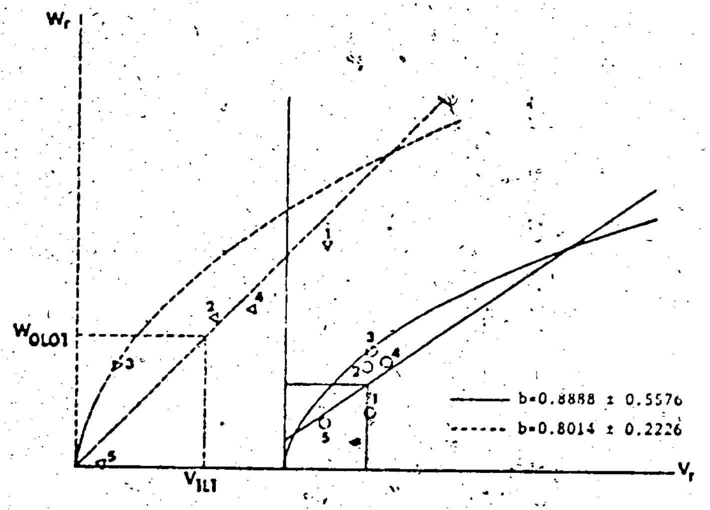

Figure 15. W_r, V_r graph for weight of seeds per spike from F_1 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

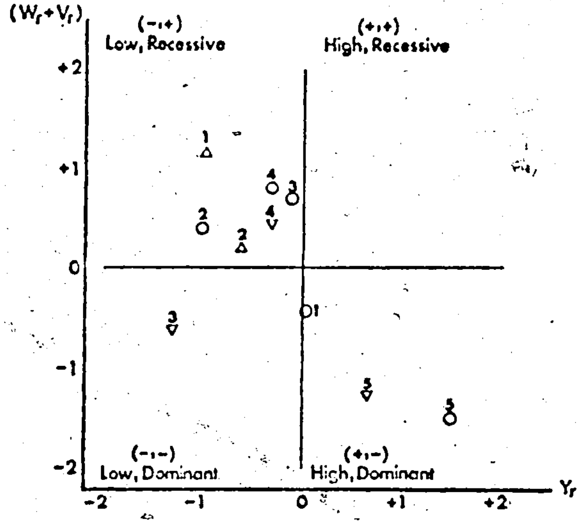

Figure 16. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for weight of seeds per spike from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

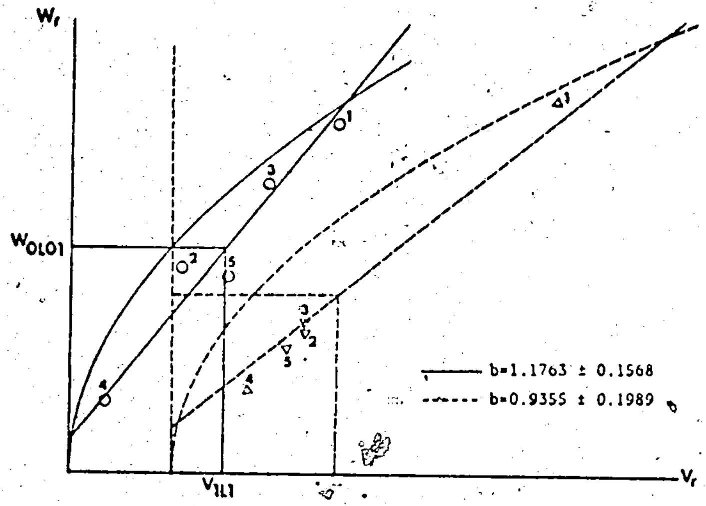

Figure 17. W_r, V_r graph for 1000-kernel weight from F_1 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Ellerslie

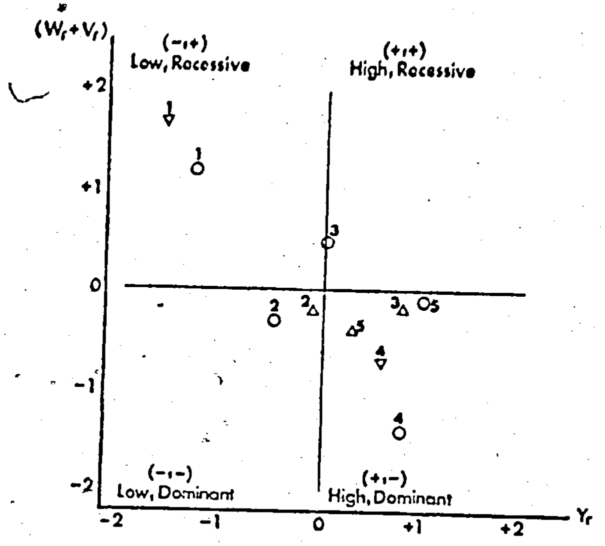

Figure 18. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for 1000-kernel weight from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

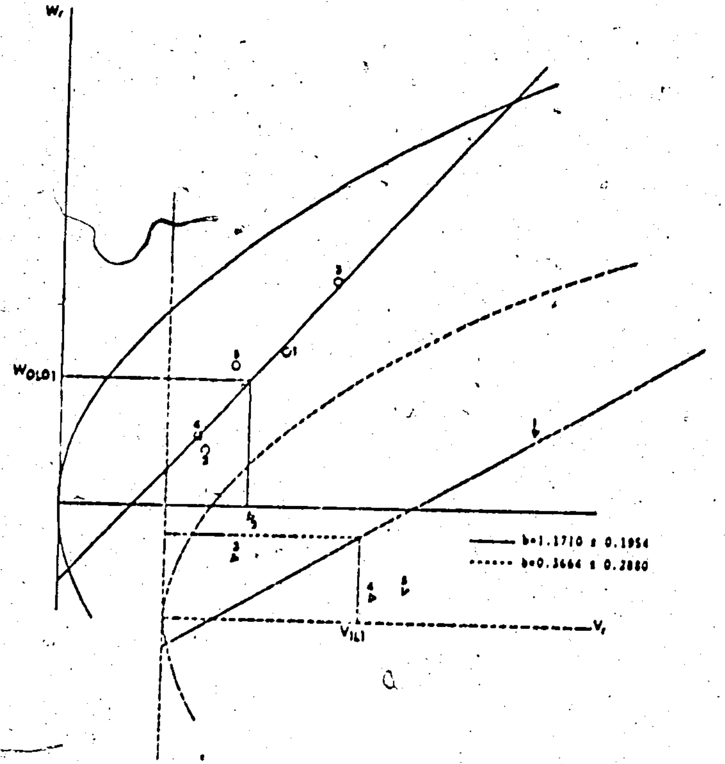

Figure 19. W_r, V_r graph for yield per plant from F_1 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

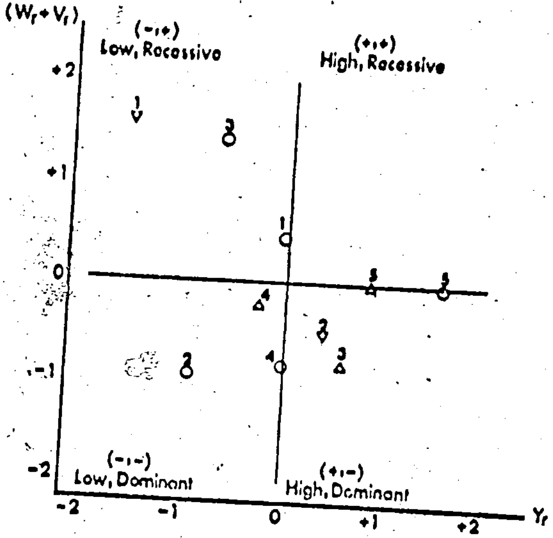

Figure 20. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for yield per plant from F_1 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

appeared highly dominant at Ellerslie. Khush-hal and Ciano with a preponderance of recessive genes at Ellerslie (-,+ quadrant) contained mostly dominant genes at Parkland (-,+ quadrant). The ratio $h^2/H_2 = 0.46$ suggests that possibly one group of dominant genes is controlling the number of spikelets per spike. Heritability estimates of 31.82% at Ellerslie and 9.25% at Parkland suggest that not only the character is low heritable but inconsistent over the locations also.

As far as the other components of yield i.e. number of seeds per spike (Table 19, 20 and Figure 13, 14), weight of seeds per spike (Table 19, 20 and Figure 15, 16) and 1000-kernel weight (Table 19, 20 and Figure 17, 18) are concerned, the interpretation of the results from relevant tables and figures will be similar. The changes in the relative positions of the parents for their order of dominance may be encountered which may be interpreted accordingly.

The results of diallel cross analysis for yield per plant are meaningless both for Ellerslie and Parkland data. Paradoxically, H_1 for Ellerslie and D, H_1 and H_2 for Parkland have negative values significantly different from zero. Consequently the V_r, W_r graph (Figure 19) for Parkland appears to be severely distorted. The respective graph for Ellerslie does not seem to be distorted and suggests the validity of the hypotheses underlying the diallel analysis. However, a significant negative H_1 invalidates the interpretation of the graph. The same objection applies to standardized deviation graph (Figure 20) also.

ANALYSIS OF F_2 DATA

It will not be out of place to mention again that the F_2 generation hybrids were duplicated in each replication at both locations,

TABLE 21

Simple correlation coefficients between ten characters from F_2 diallel set at two locations.

Character	1	2	3	4	5	6	7	8	9	10
1. Onset-of-heading	-	0.382** 0.831**	0.115 -0.040	0.763** 0.798**	0.196 0.522**	0.433** 0.536**	0.275* 0.306**	-0.274* -0.4[illegible]0**	-0.610** -0.686**	-0.249* -0.126
2. Final heading		-	0.025 0.522**	0.253* 0.750**	0.176 0.556**	0.142 0.516**	0.087 0.234*	-0.114 -0.398**	-0.229* -0.638**	-0.021 -0.089
3. Heading-span			-	0.302** 0.122	0.166 0.205	0.027 0.102	-0.074 -0.049	-0.299** -0.102	-0.322** -0.095	-0.201 0.037
4. Plant height				-	0.394** 0.506**	0.575** 0.652**	0.263* 0.248*	-0.287* -0.412**	-0.633** -0.687**	0.009 -0.034
5. Number of tillers per plant					-	0.204 0.353**	0.081 0.060	-0.032 -0.278*	-0.113 -0.505**	0.565** 0.238*
6. Number of spikelets per spike						-	0.625** 0.444**	0.218 0.192	-0.346** -0.349**	0.267* 0.329**
7. Number of seeds per spike							-	0.657** 0.160	-0.130 -0.141	0.259* 0.065
8. Weight of seeds per spike								-	0.650** 0.701**	0.392** 0.473**
9. 1000-kernel weight									-	0.252* 0.265*
10. Yield per plant										-

First reading under each column refers to Ellerslie and second to Parkland.
* Significant at 5% level
**Significant at 1% level

partly to meet the entry requirements of the partially balanced lattice design, and partly to reduce the genetic sampling error inherent in the segregating generation. Though the heading data and yield observations were recorded separately for the two repetitions, the analysis of the data is based on their average.

Simple correlation coefficients for all the characters are shown in Table 21. The results reveal that:

Onset-of-heading was positively correlated with final heading, plant height, number of spikelets per spike, number of seeds per spike, and negatively correlated with weight of seeds per spike, 1000-kernel weight and yield per plant at both locations. Correlation with number of tillers per plant was only exhibited at Parkland. The negative association of onset-of-heading with yield and its two components, weight of seeds per spike and 1000-kernel weight, suggests that early maturing varieties are higher yielders and consequently their seed weighs more than the late maturing ones. This kind of relationship was also noticed for F_1 hybrids. Correlation of final heading and heading-span with other characters has the same kind of interpretation.

Plant height exhibited significant positive correlation with number of tillers per plant, number of spikelets per spike, number of seeds per spike and 1000-kernel weight at both locations. Correlation with yield per plant was not significant.

Number of tillers per plant exhibited positive correlation with yield per plant at both locations and with number of spikelets per spike at Parkland but was negatively associated with weight of seeds per

TABLE 22

Varimax rotated factor matrix for ton characters from F_2 diallol set at two locations.

Character	Communality	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Onset-of-heading	0.977 0.886	0.958 0.896	0.149 0.023	-0.047 0.253	-0.178 -0.116	-0.055 -0.075
Final heading	0.981 0.940	0.895 0.794	0.129 0.001	-0.029 0.252	-0.208 -0.090	0.346 0.488
Heading-span	0.996 0.993	0.152 0.050	-0.051 -0.036	0.009 0.071	-0.140 0.019	0.975 0.992
Plant height	0.851 0.889	0.746 0.922	0.267 0.012	0.250 0.194	-0.372 -0.004	0.148 0.049
Number of tillers per plant	0.912 0.917	0.277 0.351	-0.039 0.013	0.903 0.848	-0.006 0.235	0.133 0.142
Number of spikelets per spike	0.834 0.883	0.288 0.688	0.811 0.590	0.162 0.046	-0.257 0.233	-0.022 0.071
Number of seeds per spike	0.903 0.981	0.186 0.156	0.904 0.967	0.039 0.098	0.221 0.049	-0.014 -0.050
Weight of seeds per spike	0.994 0.943	-0.234 -0.381	0.581 0.725	0.082 -0.346	0.760 0.391	-0.129 -0.024
1000-kernel weight	0.913 0.880	-0.462 -0.625	-0.155 0.059	0.072 -0.546	0.802 0.411	-0.162 -0.005
Yield per plant	0.898 0.929	-0.285 -0.045	0.278 0.252	0.839 0.129	0.105 0.920	-0.156 0.008
% of total variability explained	92.590 92.399	28.424 34.420	20.287 18.768	16.261 13.540	15.814 13.089	11.805 12.581

First reading under each column refers to Ellerslie and second to Parkland

spike and 1000-kernel weight at Parkland. Negative correlations with weight of seeds per spike and 1000-kernel weight establish an inverse relationship indicating that more the tillers per plant, the higher is the yield and the lower the weight of seeds per spike and 1000-kernel weight. The correlation coefficients of other components of yield, viz., number of spikelets per spike, number of seeds per spike, weight of seeds per spike and 1000-kernel weight may be explained in the same manner.

Yield per plant was positively correlated with its components, viz., number of tillers per plant, number of spikelets per spike, weight of seeds per spike and 1000-kernel weight. It was negatively associated with onset-of-heading at Ellerslie, while its correlation at Parkland was not significant. Negative correlation of yield with onset-of-heading indicates that high yielding varieties are usually early maturing.

Factor analysis was performed on the complete F_2 diallel data. Four principal factors, derived by factorizing correlation matrix into a varimax rotated factor matrix, accounted for 81.7% of the variability present in the data. Since it was thought that 82% of the variation (as explained by these four factors) was not sufficient the number of factors was raised to five and the procedure was repeated through computerization. The five factors were found to explain 92% of the variation in the data. A further six factor matrix explained 96% of the variability, it was not significantly different from the five factor-matrix which was therefore considered and the results are given in Table 22.

Since the first factor showed the highest loadings for onset-of-heading and final heading at both locations and accounted for 28% of variability at Ellerslie and 34% at Parkland, it was named *lateness*. It was positively affected by plant height and negatively by weight of seed per spike, 1000-kernel weight and yield per plant at both locations. This implies that a longer heading period causes the plants to grow taller but yield less, with lower seed weight per spike and consequently lower 1000-kernel weight. Number of tillers per plant, number of spikelets per spike and number of seeds per spike at both locations contributed very little to this factor.

The second principal component was termed *yield-components*. Although earlier the term *yielding-capacity* was applied in the F_1 factor analysis, the above term is considered more suitable because of the consistently higher loadings for yield components. Thus this component shows maximum loadings for number of spikelets per spike, number of seeds per spike and weight of seeds per spike at both locations. Negative contributions towards this factor due to heading-span at both locations and number of tillers per plant and 1000-kernel weight at Ellerslie reveal that varieties with longer maturing times yield less, produce fewer tillers per plant and show lower 1000-kernel weight.

The third principal component was named *tillering-capacity* as it provided the maximum contribution to number of tillers per plant at both locations. The factor accounted for 16% and 13.5% of the total variability in the data at Ellerslie and Parkland respectively. Yield was significantly affected at Ellerlie, but at Parkland, the contribution towards yield was comparatively low. Number of spikelets per spike,

TABLE 23

Estimates of general combining ability of five parental lines used in F_2 diallel set for ten characters at two locations.

Character	Marquis	Chinook	Khush-hal	Ciano	Inia
Onset-of-heading	1.8000 2.2267	1.3167 2.0267	-0.3667 -1.0900	-1.6833 -2.0066	-1.0667 -1.1566
Final heading	1.9767 2.0334	1.5767 2.5667	-0.0733 -0.9167	-1.9733 -2.0333	-1.5066 -1.6570
Heading-span	0.1500 -0.2033	0.3667 0.5467	0.2667 0.1800	-0.3167 -0.0367	-0.4667 -0.4867
Plant height	13.3708 12.9692	10.0921 12.0445	-6.7329 -7.7827	-7.3467 -9.2980	-9.3831 -8.9530
Number of tillers per plant	-0.0055 0.8860	0.4139 0.6827	0.4435 0.5310	-0.2707 -0.9973	-0.8512 -1.1023
Number of spikelets per spike	0.7264 0.6867	0.2257 0.4672	-0.6356 -0.3060	-0.4576 -0.7084	0.1412 -0.1394
Number of seeds per spike	3.1883 2.2384	-1.5763 -1.1155	-1.7061 0.2738	-2.1989 -2.4832	2.2930 1.0865
Weight of seeds per spike	0.0283 -0.0274	-0.1592 -0.1023	-0.0475 +0.0665	-0.0079 -0.0431	0.1863 0.1063
1000-kernel weight	-2.0321 -2.2536	-2.2150 -1.3656	0.4223 1.2445	1.7856 1.2144	2.0392 1.1603
Yield per plant	0.0508 -0.5307	-1.4712 0.1256	-0.7275 0.6319	0.6961 -0.5374	1.4518 0.3109

First reading under each column refers to Ellerslie and second to Parkland.

number of seeds per spike and heading-span at both locations, weight of seeds per spike and 1000-kernel weight at Ellerslie contributed positively to this factor.

The fourth principal factor, accounting for 15% and 13% variability at Ellerslie and Parkland and carrying the highest loadings for 1000-kernel weight at both locations, was called *kernel-weight*. The factor was contributed to by weight of seeds per spike and yield per plant at both locations, although the effect of number of seeds per spike appears to be slight. Other characters such as plant height, final heading and onset-of-heading at both locations were negatively affected.

The fifth principal factor, since it was termed *heading period*, was strongly affected by heading-span. It explained 12% of the total variation at both locations, and was adversely affected by yield and its components. Final heading, plant height and number of tillers per plant at both locations scored positively for this factor but their contribution was relatively low.

Combining ability analysis

Estimates of general combining ability for the five parental lines are presented in Table 23. Marquis scored highest for onset-of-heading and Ciano lowest at both locations. The same was true for final heading. For heading-span, Chinook ranked first and Ciano last. In plant height, Marquis excelled at both locations while Inia at Ellerslie and Ciano at Parkland were lowest. For number of tillers per plant, Khush-hal ranked first at Ellerslie and Chinook ranked first at Parkland.

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_2 diallel set at two locations.

TABLE 24 Onset-of-heading

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	-0.0500 1.2066	-1.1166 -0.2600	-0.7166 -1.5100	-0.9166 -1.1100	1.8000 2.2267	3.1762 4.8224	-0.1594 -0.3394
Chinook	Reciprocal effects	-0.3333 0.1667	-	-0.4667 -0.6434	-0.7333 0.1900	-0.5167 -1.8267	1.3167 2.0267	1.6699 3.9718	-0.1586 0.1459
Khush-hal		-0.4167 -0.4167	-0.4167 0.1667	-	0.1167 -0.3600	0.3334 -1.0434	-0.3667 -1.0900	0.0707 1.0522	0.3288 -1.1789
Ciano		0.0 -0.4167	0.8333* 0.2500	0.3333 -0.2500	-	0.5667 1.2066	-1.6833 -2.0066	2.7697 3.8908	0.1956 0.4759
Inia		0.0833 -0.6667	0.6667 -0.0833	0.3333 -0.2500	0.4167 -0.4167	-	-1.0067 -1.1556	1.0740 1.2020	0.3537 2.0317

TABLE 25 Final heading

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	0.2233 1.0167	-1.1267 -1.3833	-0.6434 -1.4333	-1.0267 -1.2333	1.9767 2.0334	3.8498 3.9308	-0.1441 -0.5093
Chinook	Reciprocal effects	-0.0833 0.5833	-	0.3566 -1.8333	-1.0767 -0.8000	-0.2100 -1.6833	1.5767 2.5667	2.4284 6.3842	-0.1275 -0.0158
Khush-hal		-0.0833 0.3333	-0.6667 0.2500	-	-0.3434 0.5167	-0.5600 0.3000	-0.0733 -0.9167	-0.0523 0.6366	0.3214 1.2490
Ciano		-0.6667 -0.1667	0.6667 -0.3333	0.4167 -0.6667	-	1.2567 1.0833	-1.9733 -2.0333	3.8362 3.9306	0.4196 0.4779
Inia		0.7500* -0.0833	0.6667	0.3333 0.3333	0.4167 -0.6667	-	-1.5066 -1.6500	2.2123 2.8188	0.8529 1.3635

First reading under each column refers to Ellerslie and the second to Parkland.
*Significant at 5% level

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_2 diallel set at two locations.

TABLE 26. Heading-span

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	0.1667 0.0200	0.0167 -1.1133	0.1000 0.0200	-0.0833 -0.1133	0.1500 -0.2033	-0.0443 -0.2013	-0.1671 -0.6067
Chinook	Reciprocal effects	0.2500 0.4167	-	0.7167 -1.1967	-0.4500 -0.9800	0.2000 0.1367	0.3667 0.5467	0.0676 0.0562	-0.1578 -0.6065
Khush-hal		0.3333 0.7500	-0.2500 0.0333	-	-0.4333 0.8867	-0.8667 1.3367	0.2667 0.1800	0.0043 -0.2103	0.0042 0.2838
Ciano		-0.6667 0.3333	-0.1667 -0.5833	0.0833 -0.4167	-	0.7167 -0.1133	-0.3167 -0.0367	0.0334 -0.2413	-0.0337 -0.0243
Inia		0.6667 0.5833	0.0 0.2500	0.0 0.5833	0.0 -0.2500	-	-0.4667 -0.4867	0.1509 -0.0058	0.2701 -0.0037

TABLE 27. Plant height

Marquis		-	2.8015 1.8702	0.0336 5.4357	-1.9122 -1.9114	-5.2829 -6.1106	13.3708 12.9892	177.5788 166.6538	-2.9988 -5.1606
Chinook	Reciprocal effects	-1.1342 2.0642	-	1.3486 1.2654	-3.5393 -1.3834	2.7586 0.2390	10.0921 13.0445	100.6507 168.0942	-0.9129 -3.9947
Khush-hal		3.3558* 0.8525	1.7808 3.4392	-	1.3133 0.1846	-0.2195 -2.8154	-6.7329 -7.7827	44.1325 58.5057	-2.3549 5.2222
Ciano		-0.8783 0.0633	3.8492* 5.0650*	0.0467 0.0592	-	1.0260 1.3933	-7.3467 -9.2980	52.7748 84.3886	2.9703 -3.2934
Inia		12.9255** 8.2025**	5.8667** 5.3258*	-0.2958 -0.4642	1.5775 -0.7742	-	-9.3831 -8.9530	86.8439 78.0926	9.5876 10.5941

First reading under each column refers to Ellerslie and the second to Parkland.
* Significant at 1% level
**Significant at 5% level

For number of spikelets per spike, Marquis was highest at both locations while Khush-hal at Ellerslie and Ciano at Parkland ranked lowest. For number of seeds per spike, Marquis ranked highest at both locations and Ciano was the lowest. For weight of seeds per spike and 1000-kernel weight, Inia ranked first at both locations, while Chinook ranked last for weight of seeds per spike; and for 1000-kernel weight, Marquis at Parkland and Chinook at Ellerslie ranked last. For yield, Inia at Ellerslie and Khush-hal at Parkland scored highest GCA and Khush-hal at Ellerslie and Ciano at Parkland ranked lowest.

Specific combining abilities of the F_2 hybrids, the reciprocal effects and the variances for general and specific combining abilities are given in Tables 24 to 33. These are discussed under individual characters.

Cross (CxI) had the highest SCA for onset-of-heading (Table 24) at both locations and (MxK) at Ellerslie and (MxI) at Parkland were the lowest. Hybrid (CxI) with the highest SCA had parents with the lowest GCA's at both locations. Similarly the lowest ranking hybrids (MxK) and (MxI) had one parent (Marquis) with the highest GCA at both locations. These kinds of results support those of the F_1 combining ability analyses. Thus it is seen that parental lines with high GCA's do not necessarily produce hybrids with high SCA's. The variances for GCA were usually larger than those for SCA except for Khush-hal at Ellerslie and Inia at Parkland. Relatively high SCA variances for Inia and Khush-hal imply an inconsistency in their SCA performance of their hybrids at both locations. Reciprocal effects were generally non-significant except for (CxCH) at Ellerslie which may be ascribed to the female parent of the hybrid.

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_2 diallel set at two locations.

TABLE 28. Number of tillers per plant

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	0.0155 -0.7810	-0.5067 -0.5043	0.05200 -0.6510	0.0377 -0.3043	-0.0055 0.8860	-0.1858 0.5798	-0.4646 -0.5129
Chinook	Reciprocal effects	-0.0833 -0.3583	-	0.4832 0.9407	-0.9860 -0.2310	0.7246 -0.2427	0.7246 0.6827	0.4139 0.2609	-0.4646 -0.3096
Khush-hal		0.7260 -1.0667	0.5167 [illegible]1750	-	0.8520 -0.2043	-0.7987 0.1827	0.4435 0.5310	0.0108 0.0768	-0.3012 -0.1332
Ciano		-0.4185 0.6250	0.3667 0.8583	0.5158 -0.0167	-	0.7167 0.3123	-0.2707 -0.9973	-0.1126 0.7895	0.1023 -0.3400
Inia		0.8230 0.0667	0.7500 0.1250	0.2437 0.0333	0.4908 -0.0500	-	-0.5812 -1.1023	0.1520 1.0100	0.0947 -0.4188

TABLE 29. Number of spikelets per spike

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	-0.0184 0.5606	0.3592 0.1479	-0.2315 0.1164	-0.0934 -0.1162	0.7264 0.6867	0.4810 0.4044	-0.1169 -0.1677
Chinook	Reciprocal effects	0.8083* 0.0222	-	-0.0646 0.4920	-0.1672 -0.3278	0.5422 -0.1107	0.2257 0.4672	0.0042 0.1512	-0.1168 -0.0629
Khush-hal		-0.2523 -0.0472	-0.0500 0.3832	-	0.3346 -0.3072	-0.5709 -0.1203	-0.6356 -0.3060	0.3537 0.0266	-0.0725 -0.0796
Ciano		-0.0117 -0.0870	0.1972 -0.2613	0.2123 0.2750	-	0.1788 0.2484	-0.4576 -0.7084	0.1626 0.4348	-0.0524 -0.0959
Inia		0.4678 0.3723	0.1057 0.0473	-0.3203 0.1305	-0.1243 0.0418	-	0.1412 -0.1394	-0.0268 -0.0476	0.1033 -0.1337

First reading under each column refers to Ellerslie and the second to Parkland.
*Significant at 5% level

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_2 diallel set at two locations.

TABLE 30. Number of seeds per spike

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	1.1545 0.2870	-0.7005 -0.0244	0.1160 1.3941	0.5999 0.6768	3.1883 2.2384	9.3728 4.0955	-1.9670 -2.2876
Chinook		1.7028 0.1278	-	0.0982 0.0492	-0.0284 -0.1192	2.0048 0.7419	-1.5763 -1.1155	1.6979 0.3293	-1.5227 -2.2601
Khush-hal	Reciprocal effects	0.1287 -1.2997	-1.4832 0.0360	-	0.2428 -1.8748	-1.4129 -0.5793	-1.7061 0.2738	2.1238 -0.8401	-1.8002 -2.2866
Ciano		0.7217 0.7168	0.9697 -1.2167	-0.1442 0.3277	-	1.3696 0.7678	-2.1989 -2.4832	4.0483 5.2511	-1.9426 -0.4635
Inia		1.7125 0.9752	-0.0612 0.4083	1.0087 -0.7652	0.5783 1.0390	-	2.2930 1.0865	4.4710 -0.2653	0.7809 -1.6431

TABLE 31. Weight of seeds per spike

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	-0.0530 0.0068	0.0072 -0.0384	0.0107 0.0898	0.1000 0.1372	0.0283 -0.0274	-0.0017 -0.0018	-0.0064 -0.0063
Chinook		0.0022 0.0172	-	-0.0560 -0.0018	0.0218 -0.006	0.0196 -0.0131	-0.1592 -0.1023	0.0228 0.0079	-0.0054 -0.0063
Khush-hal	Reciprocal effects	0.0283 -0.0558	-0.0740 -0.0208	-	0.0447 -0.0383	-0.0299 0.0114	-0.0475 0.0665	-0.0003 0.0019	-0.0053 -0.0058
Ciano		0.1072 0.0700	0.0355 -0.0573	-0.0413 -0.0225	-	-0.0030 0.0051	-0.0079 -0.0431	-0.0025 -0.0007	-0.0055 -0.0031
Inia		0.0237 0.0885	0.0072 -0.0143	-0.0377 -0.0503	-0.0052 0.0277	-	0.1863 0.1063	0.0322 0.0088	-0.0026 0.0001

First reading under each column refers to Ellerslie and the second to Parkland.

With respect to final heading (Table 25) and heading-span (Table 26), although there are some differences in relative positions of the parents and hybrids concerned, the general conclusions are the same as for onset-of-heading.

Cross (MxCH) at Ellerslie and (MxK) at Parkland ranked highest for plant height while (MxI) at both locations was the lowest (Table 27). Cross (MxCH) had both parents with highest GCA's at both locations while cross (MxK) with highest SCA at Parkland had one parent (Khush-hal) with a comparatively low GCA. Similarly (MxI) with lowest SCA at both locations had Marquis parent with highest GCA at both locations. In all cases the variances for GCA were greater than those for SCA. Crosses (CxCH), (IxM) and (IxCH) at both locations and (KxM) at Ellerslie showed significant reciprocal effects, which may be ascribed to the female parents because of the positive sign appended to each effect.

For number of tillers per plant (Table 28), crosses (KxC) at Ellerslie and (CHxK) at Parkland scored highest in SCA and (CHxC) at Ellerlie and (MxCH) at Parkland scored lowest. It is again noteworthy that one parent of the hybrids with high SCA (Ciano) had the second lowest GCA at both locations, while one parent of those scoring lowest in SCA (Chinook) had the highest GCA at both locations. The variances for GCA were, in general, greater than those for SCA and the reciprocal effects were non-significant.

The general interpretations for the remaining components of yield, viz., number of spikelets per spike (Table 29), number of seeds per spike (Table 30), weight of seeds per spike (Table 31) and 1000-kernel

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from F_2 diallel set at two locations.

TABLE 32. 1000-kernel weight

Reciprocal effects

♀ Parent	Specific combining ability Marquis	 Chinook	 Khush-hal	 Ciano	 Inia	GCA	Variance of GCA	Variance of SCA
Marquis	-	-0.0159 -0.2108	0.2364 -0.8323	-0.1336 1.4480	1.4490 2.2354	-2.0321 -2.2536	3.4447 4.5162	-1.7115 -1.4056
Chinook	-0.5203 0.2470	-	-1.4490 0.1446	0.4314 -0.2289	-1.1334 -0.7060	-2.2150 -1.3656	4.3318 1.3026	-1.7114 -1.3909
Khush-hal	-1.2750 -0.2907	-0.4182 -0.5318	-	0.9701 0.3904	0.9718 0.9605	0.4223 1.2445	-0.5063 0.9866	-0.9926 -1.1678
Ciano	1.6177 0.2192	0.0647 -0.3352	-1.0387 -0.0517	-	-1.8572 0.3992	1.7856 1.2144	2.5039 0.9125	-1.3299 -0.6385
Inia	-0.7592 1.0892	0.1358 -0.5033	-0.8753 -0.2993	-0.6647 -0.3512	-	2.0392 1.1603	3.4739 0.7840	0.3453 0.7868

TABLE 33. Yield per plant

Reciprocal effects

♀ Parent	Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis	-	0.5420 -0.8039	-0.8646 0.7455	1.1590 0.0267	-0.1661 0.7448	0.0508 -0.5307	-0.3966 -0.1445	-0.9980 -1.0655
Chinook	-0.4107 0.6045	-	0.1689 1.3541	-1.0782 -0.7700	0.1929 0.3538	-1.4712 0.1256	1.7653 -0.4104	-0.9001 -0.8501
Khush-hal	2.1502* -1.5562	0.5530 -0.0635	-	1.7764 0.0255	-0.4546 -1.2061	-0.7275 0.6319	0.1300 -0.0270	-0.7394 -0.2690
Ciano	-0.9003 1.3395	-0.1892 -0.1583	-0.4672 -0.2452	-	0.0659 0.1652	0.6961 -0.5374	0.0854 -0.1373	0.8891 -0.8674
Inia	1.0152 0.5628	1.1928 -0.4918	0.6962 -0.3988	-0.4528 -0.1468		1.4518 0.3109	1.7084 -0.3296	-0.9061 -0.3448

First reading under each column refers to Ellerslie and the second to Parkland.
*Significant at 5% level

weight (Table 32) and the conclusions derived therefrom with respect to SCA's do not differ from number of tillers per plant. Only the relative positions and respective ranking orders of the parents and hybrids are changed.

For yield per plant (Table 33), crosses (KxC) at Ellerslie and (CHxK) at Parkland, respectively scored highest in SCA while (CHxC) at Ellerslie and (KxI) at Parkland ranked lowest. One parent of (KxI), Inia, scored highest for GCA at both locations while one parent of (CHxC), Chinook, scored lowest at Ellerslie and other parent, Ciano, scored second highest at Ellerslie. (KxC) had one parent (Khush-hal) with the second lowest GCA at Ellerslie. The variances for GCA were greater than those for SCA except for Marquis and Ciano at both locations, and Chinook, Khush-hal and Inia at Parkland. The reciprocal effects were non-significant except for (KxM) at Ellerslie which may be ascribed to Khush-hal because of the positive sign appended to the effect.

The following conclusions may be drawn from the analysis of general and specific combining ability for all the characters considered: (1) In all cases, since hybrids with high SCA's were associated with the parents with low GCA's, the high GCA's of the parental lines may not be taken as criteria to predict high SCA's of their hybrids. (2) In most cases, the variances for GCA's were greater than those for SCA's. The analysis of variance for general and specific combining ability (Table 34) also supports this conclusion. In all cases, the mean squares for GCA in Table 34 are significant except for heading-span and yield per plant at Parkland. This implies that GCA which is largely due to

TABLE 34

Analysis of variance of general and specific combining ability and reciprocal effects from F_2 diallel set for ten characters at two locations.

Character	M.S. for GCA	M.S. for SCA	M.S. for reciprocal effects	Error M.S.
D.F.	4	10	10	48
Onset-of-heading	22.7031** 39.0469**	2.1187** 4.0062**	0.4000 0.2431	0.2390 0.5096
Final heading	31.3750** 46.0000**	2.3062** 5.6812**	0.5625* 0.3375	0.2126 0.7635
Heading-span	1.3652* 1.5268	0.5275* 1.9586*	0.2319 0.4347	0.2507 0.9094
Plant height	1169.9375** 1415.1094**	17.7062** 25.2250**	47.0742** 27.7873	4.4982 39.3587
Number of tillers per plant	1.9502* 9.3584**	0.8808 1.0986	0.5834 0.4896	0.6970 1.2179
Number of spikelets per spike	3.0322** 3.2627**	0.2066 0.2785	0.2304 0.0921	0.1753 0.9593
Number of seeds per spike	64.1406** 34.2031*	3.4828 2.9781	1.6961 1.3182	2.9497 10.7170
Weight of seeds per spike	0.1579** 0.0720*	0.0063 0.0126	0.0046 0.0048	0.0096 0.0163
1000-kernel weight	41.4063** 28.2812**	2.6574 3.3535	1.5148 0.4488	2.5674 6.8000
Yield per plant	13.2227** 2.7109	1.8699 1.3242	1.8725 1.0820	1.4968 2.2172

First reading under each column refers to Ellerslie and the second to Parkland.
* Significant at 5% level
** Significant at 1% level

TABLE 35

Mean squares from the analysis of variance of 5 x 5 F_2 diallel set for ten characters at two locations.

Source of variation	D.F.	Onset-of-heading	Final heading,	Heading-span	Plant height	Number of tillers per plant	Number of spikelets per spike	Number of seeds per spike	Weight of seeds per spike	1000 kernel weight	Yield per plant
a	4	68.0938** 117.0937**	73.1250 138.1719**	4.0957 4.5820	3510.5000** 4245.5000**	5.8467 20.0713**	9.0908** 0.7852*	192.3750** 190.9219*	0.4738** 0.2159**	124.1875** 84.8125**	39.6543** 8.1191
b	10	6.3812** 12.0687**	61.2437 17.0125**	1.5824 5.8754	53.0000** 75.7000*	2.6473 3.2988	0.6227 0.8395	10.5312 68.5313	0.0188 0.0377	7.9812 10.0750	5.6172 3.9770
b_1	1	36.7496 51.6675	79.5675 82.6875	0.0208 3.7408	6.4820 10.0833	1.0448 10.2491	0.2168 1.0195	3.8458 40.0176	0.0116 0.0698	0.0029 23.5447	5.3993 1.2118
b_2	4	4.1406 4.2607*	44.9219 5.1094	0.9528 7.6094	59.7031 93.1250*	1.0060 3.9525	0.0586 0.9189	17.0752 75.6230	0.0249 0.0582	9.5039 9.9443	4.0752 1.6973
b_3	5	2.1000** 10.3750**	70.6500* 13.4250**	2.3992 4.9156	56.9000** 74.6125*	4.2852* 1.3898	1.1625 0.7453	6.6250 68.5625	0.0156 0.0149	8.3625 7.5000	6.8937* 6.3586**
c	4	2.2541 1.1625	71.7542 0.5542	0.5375 2.0292	239.1536** 141.6374**	2.6807 1.7982	0.4980 0.1374	8.5938 93.4017	0.0072 0.0091	2.2230 1.3426	6.1870 1.2746
d	6	0.4972 0.4403	56.6431 1.3181	0.8014 0.8208	75.9351** 44.5118*	0.9963 1.2493	0.8198* 0.3691	2.7512 83.4116	0.0180 0.0178	6.0919 1.3408	5.2380 4.5601
Blocks x *a*	8	0.6094 2.6172	35.5859 2.0547	1.2484 5.3865	22.0469 59.4609	1.7603 3.1372	0.7969 1.4517	8.4609 30.6875	0.0289 0.0298	14.6484 7.3843	3.1318 12.6904
Blocks x *b*	20	0.8375 1.2875	42.0594 3.4312	0.8220 3.5931	14.4500 24.2156	2.9328 2.8902	0.6846 0.5980	12.5031 67.5125	0.0395 0.0373	7.5344 9.5287	4.9916 3.4434
Blocks x b_1	2	4.4151 7.9850	17.8850 19.1850	1.7017 3.0817	30.5184 181.8318	3.0592 30.4552	1.7195 0.1034	63.1927 34.0421	0.0729 0.1419	8.1275 51.5334	5.6767 10.2759
Blocks x b_2	8	1.2827 1.0347	23.4004 4.0889	1.2711 5.8356	22.0747 16.0625	5.5184 2.8100	0.8450 0.9053	15.7554 53.9883	0.0651 0.0589	11.1401 10.5664	9.3918 6.4728
Blocks x b_3	10	0.1875 0.9437	63.5938 1.6625	0.4566 2.2068	8.3312 16.0437	1.1415 0.4828	0.5141 0.4555	6.0937 88.4437	0.0196 0.0133	5.3578 5.4691	1.8984 0.6773
Blocks x *c*	8	0.9041 0.7812	71.3666 0.8979	0.4500 1.4104	9.2411 3.1023	1.2472 1.5910	0.2572 0.4212	4.8894 60.4627	0.0130 0.0084	3.9115 1.1626	3.0324 2.6685
Blocks x *d*	12	0.4597 1.6944	57.7347 1.5056	0.5056 0.4000	9.1118 11.1003	1.4759 1.2712	0.2664 0.7791	5.7155 94.8401	0.0207 0.0262	5.9257 3.7547	5.5405 3.2056
Error	48	0.7161 1.5265	49.7838 2.2982	0.7520 2.7299	13.5133 23.2919	2.0922 2.3101	0.5275 0.7561	8.8636 67.0319	0.0286 0.0285	7.7141 6.3335	4.4923 4.7959

*Significant at 5% level
**Significant at 1% level
First reading under each column refers to Ellerslie and second to Parkland. Error D.F. comprises of block interaction with D.F. of (*a+b+c+d*).
Each component has been tested against its own block interaction.

TABLE 36

Analysis of variance of $W_r - V_r$ from F_2 diallel set for ten characters at two locations.

Character	Block M.S.	Entry M.S.	Error M.S.
Onset-of-heading	7.3643 8.3904	0.2675 2.4463	0.3478 0.8515
Final heading	2.3424 35.5057	0.7644 5.2120	0.2218 3.7671
Heading-span	0.0046 6.1741	0.1472 4.4720	0.2028 2.0416
Plant height	10448.0312 4912.7812	155.1719 427.7812**	157.5547 38.5703
Number of tillers per plant	1.2452 0.8319	2.4152* 0.5920	0.5435 2.3435
Number of spikelets per spike	0.9966 0.0373	0.0884 0.1622	0.0807 0.0598
Number of seeds per spike	636.7512 180.8423	26.2899 15.5951	19.7865 6.5623
Weight of seeds per spike	0.0069 0.0025	0.0002 0.0004	0.0003 0.0003
1000-kernel weight	313.4819 2.6203	7.3413 11.5522	1.9490 18.5395
Yield per plant	61.8167 12.4054	9.5905 2.6444	3.0673 2.7121

First reading under each column refers to Ellerslie and second to Parkland.
* Significant at 5% level
**Significant at 1% level

TABLE 37

Estimates of second degree statistics parameters for ten characters from F_2 diallel set at two locations.

Character	V_{0L0}	W_{0L01}	V_{0L1}	V_{1L1}	$(M_{L1}-M_{L0})^2$
Onset-of-heading	15.0000 15.7002	5.8158 7.6168	2.2734 30.9072	3.3381 5.9146	1.9600 2.7759
Final heading	16.9668 27.1514	7.2016 11.1402	3.1475 4.6084	4.3006 7.4500	1.5891 4.4100
Heading-span	0.5889 3.6100	0.2362 0.6751	0.1367 0.1528	0.4003 1.1320	0.0011 0.1995
Plant height	486.7784 518.4434	235.7205 226.4807	117.0059 141.5420	125.8615 154.1387	0.3456 0.5377
Number of tillers per plant	1.4343 5.4749	0.5030 2.1069	0.1948 0.9358	0.6359 1.4856	0.0557 0.5465
Number of spikelets per spike	1.2283 0.5749	0.6072 0.4241	0.3030 0.3264	0.4072 0.4663	0.0115 0.0543
Number of seeds per spike	28.9930 12.2275	12.8064 5.6326	6.4111 3.4180	8.1627 4.9113	0.2050 0.2783
Weight of seeds per spike	0.0384 0.0360	0.0241 0.0133	0.0158 0.0072	0.0189 0.0135	0.0006 0.0037
1000-kernel weight	16.7744 13.1670	7.8586 5.6221	4.1396 2.8271	5.4666 4.5039	0.6001 1.2557
Yield per plant	5.4558 0.8875	2.4823 0.4078	1.3221 0.2711	2.2580 0.9338	0.4412 0.0646

First reading under each column refers to Ellerslie and the second to Parkland.

additive gene effects, is relatively more important than SCA, which is due to non-additive gene effects, as far as selection on the basis of these characters is concerned. (3) The significance of SCA variances implies that hybrids yield much less than would be expected on the basis of the GCA's of their parents. This suggests that character instability of a hybrid is largely due to high SCA variances associated with its parents.

Diallel cross analysis

The results of the analysis of variance performed after Hayman (1954a) on the F_2 diallel table are given in Table 35. The presence of additive gene effects is shown by significant a's for onset-of-heading, plant height, number of spikelets per spike, number of seeds per spike, weight of seeds per spike and 1000-kernel weight at both locations; also for yield per plant at Ellerslie and final heading and number of tillers per plant at Parkland. Significant additive gene effects for these characters suggest substantial differences among the parental lines used. Significant b's for onset-of-heading, final heading and plant height shows that dominance is present while significant b_2's indicate some asymmetry of loci exhibiting dominance for these characters, suggesting that some parents contain more dominant alleles than others. Significant b_3's for onset-of-heading, final heading, plant height and yield per plant at both locations, and for number of tillers per plant at Ellerlie, imply that specific combining ability for these characters is comparatively more important than general combining ability when a pedigree selection procedure is followed in a breeding programme (Mather and Jinks, 1971).

TABLE 30

Estimates of genetic components of variation and their standard errors from F_2 diallel set for ten characters at two locations.

Character	D	F	H_1	H_2	h^2	E
Onset-of-heading	14.6708 ± 0.2067** 15.1911 ± 0.6740**	6.4497 ± 0.5162** 0.3223 ± 1.6036	4.4673 ± 0.5581** 7.5679 ± 1.0202**	3.7801 ± 0.5062** 7.0114 ± 1.0509**	7.6875 ± 0.3418** 10.6973 ± 1.1146**	0.2391 ± 0.0644** 0.5091 ± 0.2752
Final heading	16.7506 ± 0.3746** 20.3875 ± 0.5310**	4.0680 ± 0.9356** 8.8251 ± 1.3263**	4.0009 ± 1.0115** 10.4043 ± 1.4339**	4.1002 ± 0.9175** 9.8386 ± 1.3006**	6.2127 ± 0.6194** 17.1511 ± 0.8781**	0.2161 ± 0.1529 0.7639 ± 0.2186**
Heading-span	0.3383 ± 0.1606* 2.7012 ± 0.7337**	-0.0677 ± 0.4012 3.4300 ± 1.8327	0.5938 ± 0.4337 3.0730 ± 1.9014	0.5534 ± 0.3934 2.0971 ± 1.7971	-0.1560 ± 0.2656 0.2157 ± 1.2133	0.2407 ± 0.0656** 0.9100 ± 0.2995**
Plant height	482.2761 ± 5.3403** 510.7024 ± 11.4837**	25.2691 ± 13.1401 -38.3252 ± 28.6862	35.6[illegible] ± 14.4221** 48.9489 ± 31.0130	26.4261 ± 13.0810* 34.9049 ± 28.1292	-1.4962 ± 8.8316 -2.8030 ± 18.9913	4.4903 ± 2.1802* 7.7409 ± 4.6882
Number of tillers per plant	0.7373 ± 0.1694** 4.7055 ± 0.1993**	0.0199 ± 0.4232 1.5989 ± 0.4978**	0.1536 ± 0.4575 0.9894 ± 0.5382	0.3705 ± 0.4150 0.6605 ± 0.4801	-0.2232 ± 0.2802 1.6941 ± 0.3296**	0.6970 ± 0.0692** 0.7694 ± 0.0814**
Number of spikelets per spike	1.0529 ± 0.0515** 0.3233 ± 0.1134**	-0.1027 ± 0.1287 -0.8483 ± 0.2834**	-0.0278 ± 0.1391 0.0896 ± 0.3064	0.0658 ± 0.1262 0.0562 ± 0.2779	-0.0660 ± 0.0852 0.0565 ± 0.1876	0.1753 ± 0.0210** 0.2516 ± 0.0463**
Number of seeds per spike	26.0475 ± 1.1122** 8.7961 ± 1.0111**	3.2297 ± 2.7783 -2.1931 ± 2.5257	2.7517 ± 3.0037 0.4207 ± 2.7306	1.1052 ± 2.7244 -0.8894 ± 2.4767	-1.0681 ± 1.8394 -1.0627 ± 1.6721	2.9505 ± 0.4541** 0.0095 ± 0.0021**
Weight of seeds per spike	0.0288 ± 0.0019** 0.0266 ± 0.0052**	-0.0113 ± 0.0047** 0.0075 ± 0.0130	-0.0073 ± 0.0050 0.0121 ± 0.0140	-0.0065 ± 0.0046 0.0062 ± 0.0127	-0.0036 ± 0.0031 0.0088 ± 0.0086	0.0095 ± 0.0008** 0.0095 ± 0.0021**
1000-kernel weight	14.2071 ± 0.8036** 11.0585 ± 1.3289**	-0.9663 ± 2.0075 1.3155 ± 3.3195	0.5315 ± 2.1703 3.2122 ± 3.5808	0.1733 ± 1.9685 2.4900 ± 3.2551	1.6424 ± 1.3290 3.6732 ± 2.1976	2.5673 ± 0.3281** 2.1085 ± 0.5425**
Yield per plant	3.9588 ± 0.7287** -0.7108 ± 0.3318*	-0.8142 ± 1.8203 -1.7740 ± 0.8287*	0.6660 ± 1.9679 -1.1636 ± 0.8960	0.7492 ± 1.7849 -0.5453 ± 0.0126	0.1937 ± 1.2051 -0.7644 ± 0.5487	1.4970 ± 0.2975** 1.5982 ± 0.1354**

First reading under each column refers to Ellerslie and second to Parkland.
* Significant at 5% level
**Significant at 1% level

TABLE 39

Proportional estimates of genetic parameters for ten characters from F_2 diallel set at two locations.

Character	$(H_1/D)^{1/2}$	$(H_2/4H_1)$	$\left[\frac{(4DH_1)^{1/2} + F}{(4DH_1)^{1/2} - F}\right]$	$r_{(Y_r/W_r+V_r)}$	$\left\lvert\frac{h^2}{H_2}\right\rvert$	(Heritability)
Onset-of-heading	0.5501* 0.7058*	0.2116* 0.2316*	2.3175* 1.0305†	0.9658 0.8792	2.0336* 1.5257*	1.0751 0.6206
Final heading	0.5354* 0.6279*	0.2177* 0.2364*	1.7451* 1.7279*	0.9906 0.9550	1.4862* 1.7432*	0.9545 0.8596
Heading-span	1.3249 1.0666	0.2330 0.1706	0.8596 3.9415	0.9362 0.2426	-0.2818 0.1028	0.1689 0.4513
Plant height	0.2719* 0.3096	0.1854* 0.1783	1.2131† 0.7838	0.7522 0.0827	-0.0566 -0.0803	0.9443 0.8120
Number of tillers per plant	0.4565 0.4585	0.6029 0.1669	1.0610 2.1772	-0.1501 0.9489	-0.6023 2.5648	0.2015 0.6559
Number of spikelets per spike	0.1626 0.5264	-0.5913 0.1569	0.3040 -0.4273	0.8604 -0.1745	-1.0027 1.0043	0.5515 0.1425
Number of seeds per spike	0.3250 0.2187	0.1004 -0.5285	1.4714 0.2739	0.0765 -0.1187	-0.9664 1.2174	0.6969 0.7683
Weight of seeds per spike	0.5034 0.6752	0.2241 0.1272	-0.0379 1.5290	-0.2629 -0.3126	0.5555 1.4330	0.3171 0.3843
1000-kernel weight	0.1934 0.5390	0.0815 0.1938	0.7009 1.2481	-0.5825 -0.8244	-9.4800 1.4752	0.5469 0.5170
Yield per plant	0.4102 1.2795	0.2812 0.1172	0.5991 0.0125	0.1919 -0.4069	0.2585 1.4016	0.3464 -0.1129

First reading under each column refers to Ellerslie and second to Parkland.
*Genetic components of variation for the characters significantly different from zero at $P < 0.05$
†Components D and H_1 significant, F non-significant ($P > 0.05$).

In regard to the testing of the assumptions underlying the analysis, significant c's for plant height at each of the two locations indicate that there are reciprocal differences for this character. The results of a test of other assumptions, by the analysis of variance of W_r-V_r differences are given in Table 36. Except for plant height at Parkland and number of tillers per plant at Ellerslie, the W_r-V_r differences were homogeneous and therefore these other assumptions were generally not invalidated by the data. Two exceptions (for plant height and number of tillers per plant) will be considered later.

Estimates of second degree statistics and components of genetic variation derived from the analysis of F_2 diallel table after replacement of off-the-diagonal cells with their corresponding common means, are given in Tables 37 and 38. In Table 38, component significances are tested with 25 D.F. (35 statistics provided by Table 37, with 10 constants fitted to them). Proportional values of the genetic parameters calculated from Table 38 are given in Table 39, which shows the over-all genetic situation with regard to the inheritance of each character. The results of Tables 38 and 39 together with W_r,V_r graphs and standardized deviation graphs of Y_r and (W_r+V_r) are discussed under each character.

All components of variation for onset-of-heading (Table 38) except F and E at Parkland were significant. The mean degree of dominance (0.55 at Ellerslie and 0.75 at Parkland) indicates that the character is partially dominant at both locations. This is also shown by the regression line in the W_r,V_r graph (Figure 21) which intersects the limiting parabola

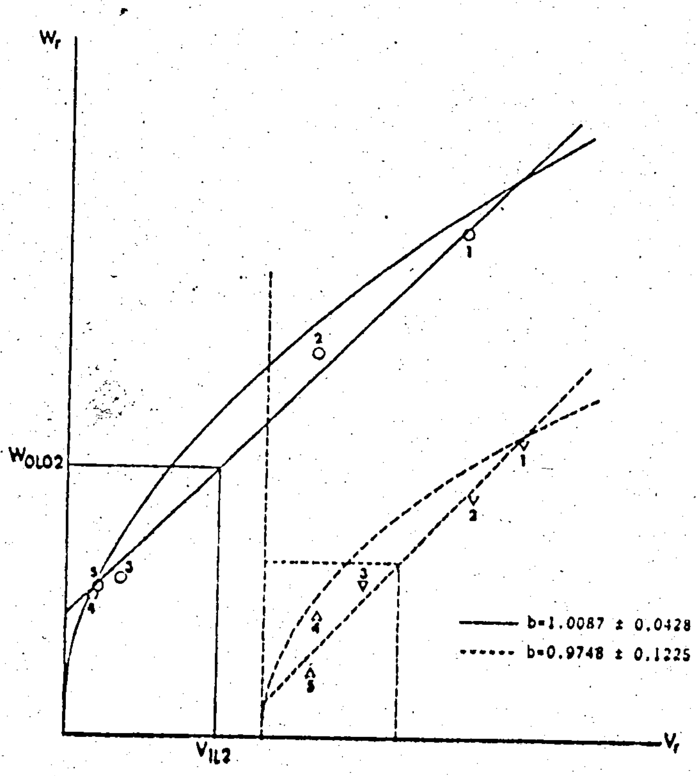

Figure 21. W_r, V_r graph for onset-of-heading from F_2 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

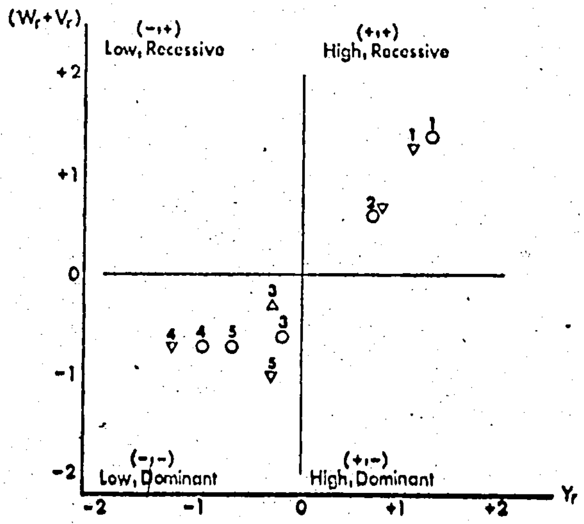

Figure 22. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for onset-of-heading from F_2 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

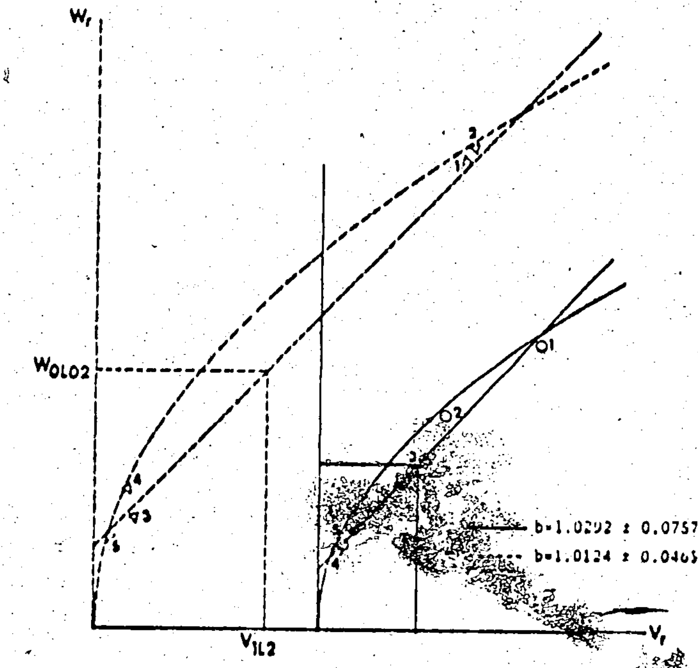

Figure 23. W_r, V_r graph for final heading from F_2 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

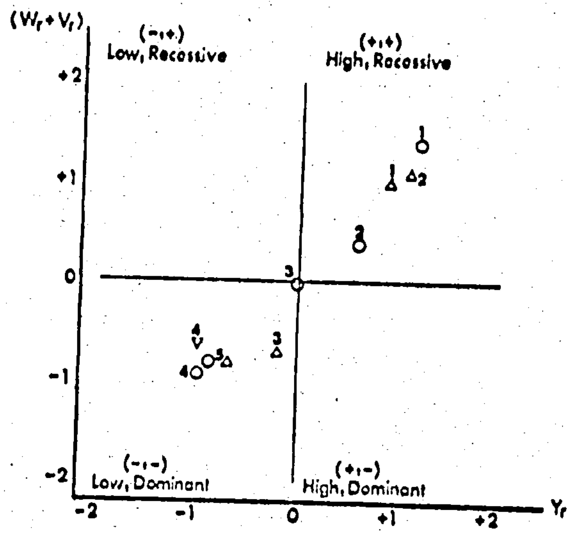

Figure 24. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for final heading from F_2 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

above the origin. The proportion of positive to negative alleles in the parents at loci exhibiting dominance is approximately 0.25, indicating equal proportions at both locations. The proportion of dominant to recessive genes in the parents is 2.3 and 1.03 for Ellerslie and Parkland, suggesting a preponderance of dominant genes in the parents. Figure 21 shows that Marquis is the highly recessive parent at both locations, as it lies farthest from the point of origin of the regression line. Ciano at Ellerslie and Inia at Parkland rank as the two most dominant parents because of their nearness to the point of origin of the regression line. The coefficient of correlation between parental order of dominance and parental measurements is 0.96 at Ellerslie and 0.87 at Parkland suggesting that most of the negative genes (for early maturing) are dominant. The distribution of parents with respect to order of dominance is shown in standardized deviation graph of Figure 22. Marquis and Chinook at both locations fall into the (+,+) quadrant indicating that they contain mostly recessive genes responsible for lateness while Khush-hal, Ciano and Inia fall into the (-,-) quadrant and are therefore early heading dominant parents. The number of groups of genes controlling onset-of-heading has been estimated as 2.03 for Ellerslie and 1.52 for Parkland indicating that at least two groups of genes exhibiting dominance control the onset-of-heading. The heritability estimates of 107.51% and 62.06% show that the character is highly heritable but with low stability under different environments.

The results of the analysis for final heading (Tables 38, 39; Figures 23, 24) and heading-span (Tables 38, 39; Figures 25, 26) are subject

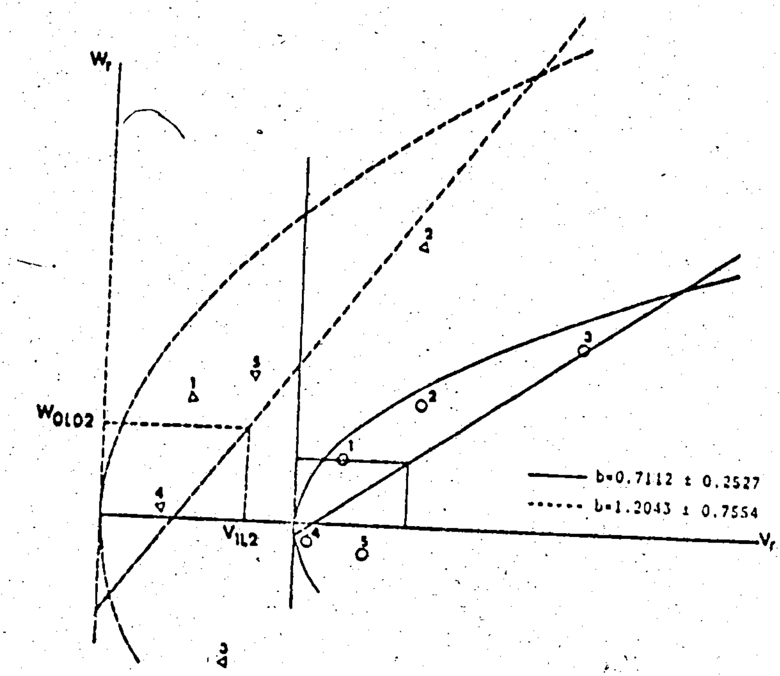

Figure 25. W_r, V_r graph for heading-span from F_2 diallel set.

— o = W_r, V_r intercepts at Ellerslie

--- $\Delta = W_r$, V_r intercepts at Parkland

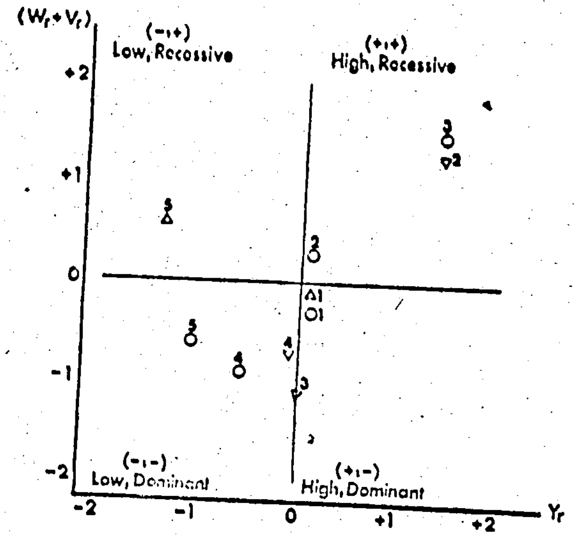

Figure 26. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for heading-span from F_2 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

$\Delta = Y_r$, $W_r + V_r]$ intercepts at Parkland to the same kind of interpretations as for onset-of-heading.

For plant height, the components of variation, D, H_1, H_2 and E were significant for Ellerslie but none except D were significant at Parkland. Heterogeneity of W_r-V_r values (Table 36) implies either non-allelic interaction, multiple allelism or correlated gene distribution. In the case of correlated gene distribution, the W_r, V_r curve is convex upwards and the mean degree of dominance is seriously inflated, giving an impression of apparent over-dominance (Hayman, 1954b) in a situation where, in fact, partial dominance exists. In the case of multiple allelism, the effects are extremely complicated. Models to explain the consequences in terms of W_r, V_r graphs, are pending. It might show spurious dominance (Hayman, 1954b) by scattering the W_r, V_r points and thus causing their mean (V_{1L2}, W_{0L02}) to lie inside, and not on the limiting parabola. Non-allelic interaction of the complementary type distorts the (W_r, V_r) graph, inflates the $(H_1 \div D)^{1/2}$ and depresses (h^2/H_2), but has very little effect on the estimator of gene frequency. A duplicate type of interaction depresses (h^2/H_2) by increasing the proportion of dominants, but does not alter $(H_1 \div D)^{1/2}$, $H_2/4H_1$ and the W_r, V_r graph.

Considering the various effects of the three above-mentioned conditions, and examining the W_r, V_r graph for plant height at Parkland (Figure 27) we come to the conclusion that there is actually no non-validity of any of the above-mentioned hypotheses. This is because the regression of W_r upon V_r is not significantly different from one, the array W_r, V_r intercepts do not show any convexity upwards or downwards

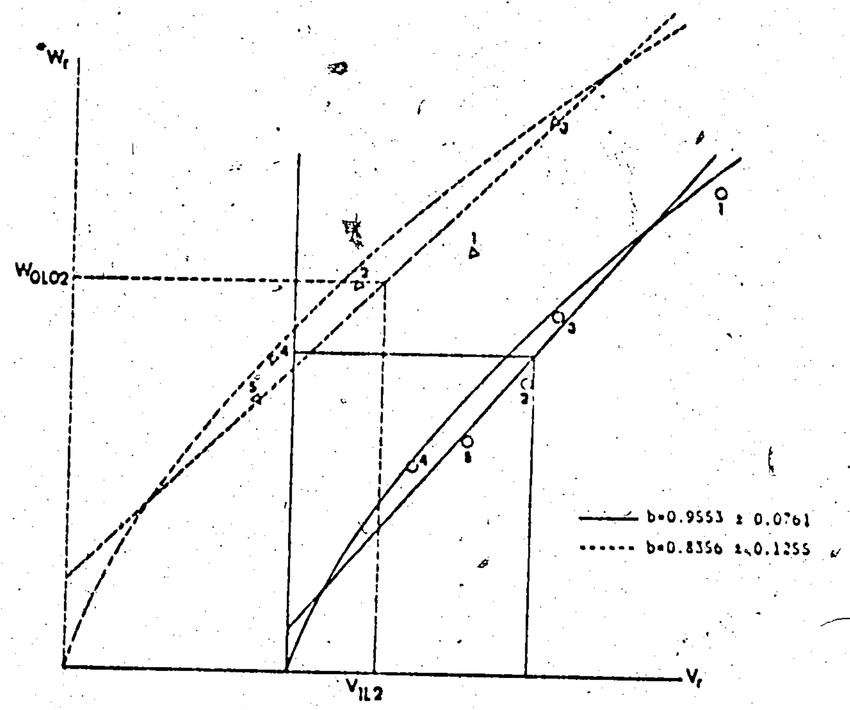

Figure 27. W_r, V_r graph for plant height from F_2 diallel set.

—— O = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

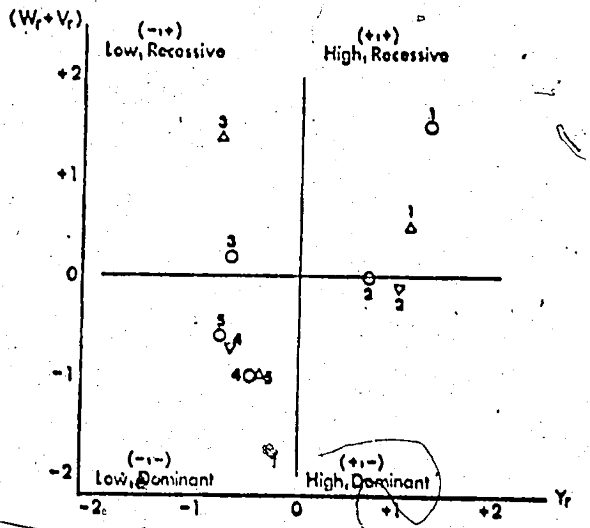

Figure 28. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for plant height from F_2 diallel set.

O = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $W_r + V_r]$ intercepts at Parkland

and there are no serious effects on the estimates of genetic parameters (Table 39). Our conclusion is supported by the fact that all the estimates of genetic components of variation at Parkland except D are non-significant (Table 38). The only reason we might give for the heterogeneity of W_r-V_r over the arrays is a strong environmental effect.

At Ellerslie, plant height is inherited as a partially dominant trait since the mean degree of dominance is 0.27 (See also Figure 27). The proportion of positive to negative alleles at loci exhibiting dominance is 0.18 indicating asymmetry, while the proportion of dominant to recessive genes in the parents is 1.2 (close to equality). The coefficient of correlation between the parental order of dominance and parental measurements is 0.75 at Ellerslie and 0.08 at Parkland, indicating that the genes contributing towards shortness are mostly dominant. With respect to parental order of dominance (Figure 27 and 28) Marquis rates as the highly recessive parent for tallness at Ellerslie and Khush-hal likewise at Parkland. Ciano ranks as the most dominant parent for shortness at Ellerslie and similarly Inia at Parkland. Examination of Figure 28 reveals that though Marquis and Khush-hal rank as the highly recessive parents, Khush-hal nevertheless contributes towards reduced expression of the character (-,+ quadrant) as compared to Marquis (+,+ quadrant). Ciano and Inia rank as the most dominant parents for shortness because of their position in the (-,-) quadrant. Chinook, contributing towards tallness, has recessive and dominant genes in equal proportions. The character has high heritability (94.43% at Ellerslie and 81.20% at Parkland) and thus seems to be little affected by environmental conditions.

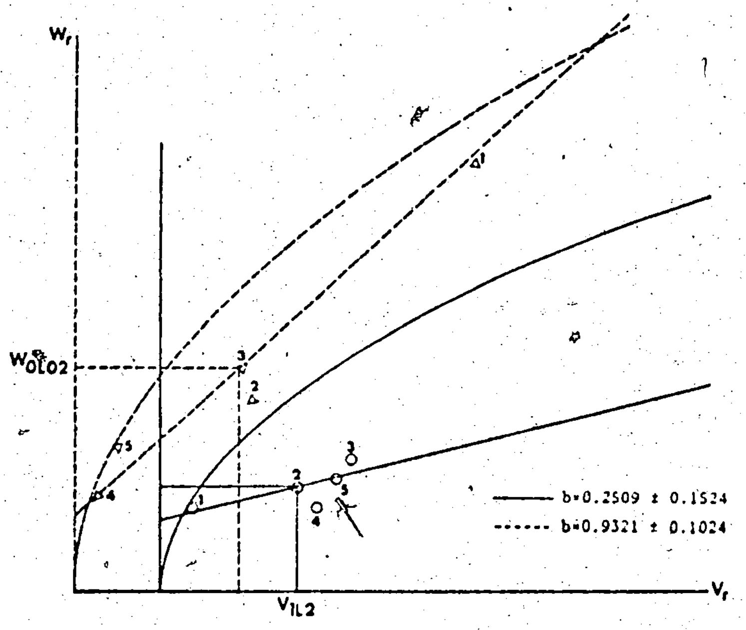

Figure 29. W_r, V_r graph for number of tillers per plant from F_2 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

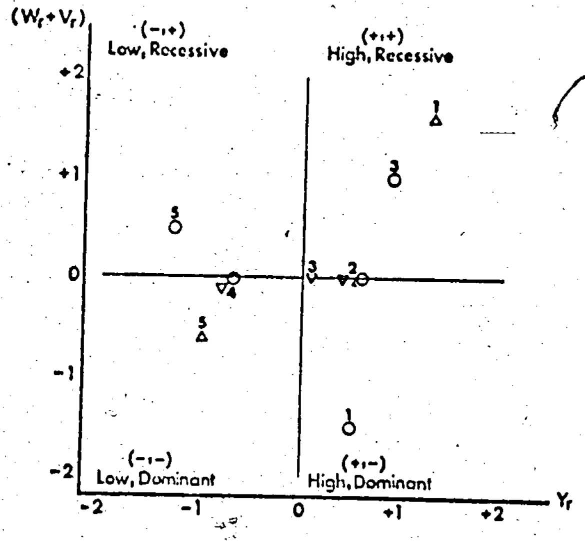

Figure 30. Standard deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of tillers per plant from F_2 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

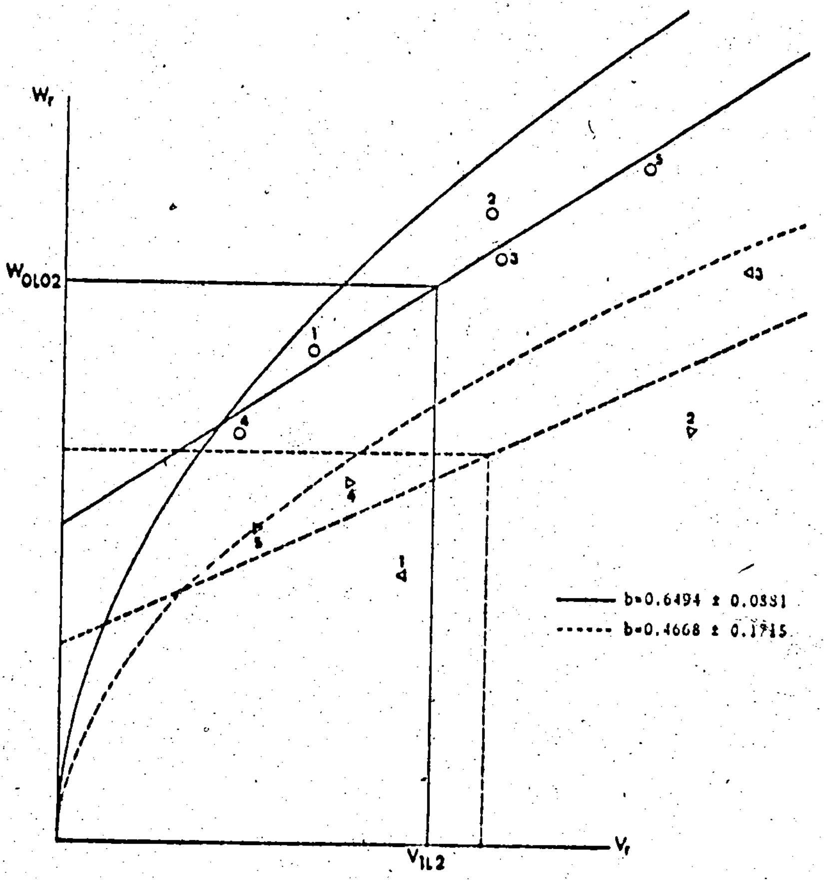

Figure 31. W_r, V_r graph for number of spikelets per spike from F_2 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

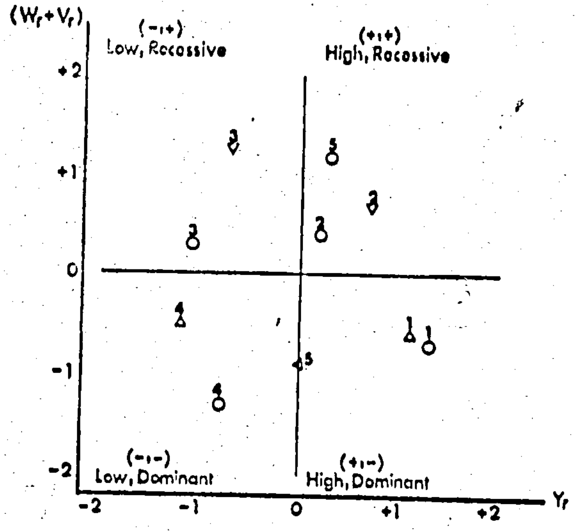

Figure 32. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of spikelets per spike from F_2 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

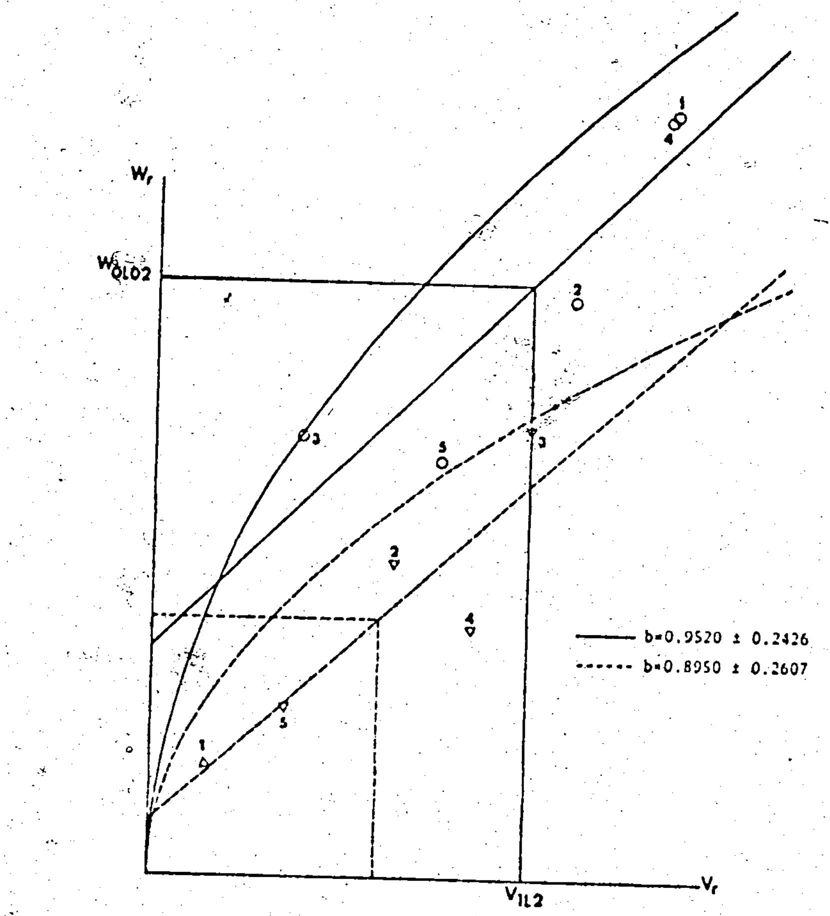

Figure 33. W_r, V_r graph for number of seeds per spike from F_2 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

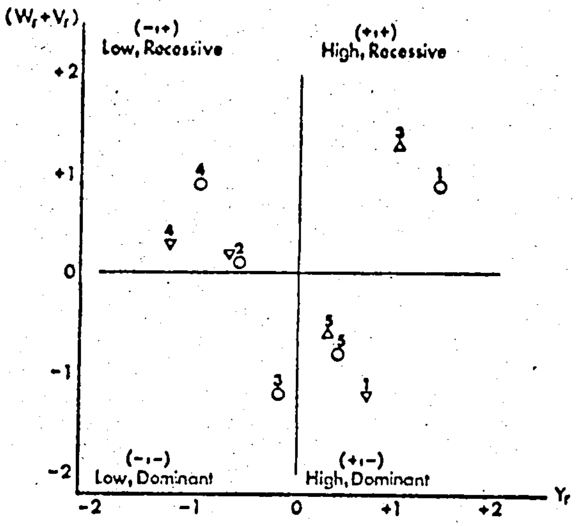

Figure 34. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of seeds per spike from F_2 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

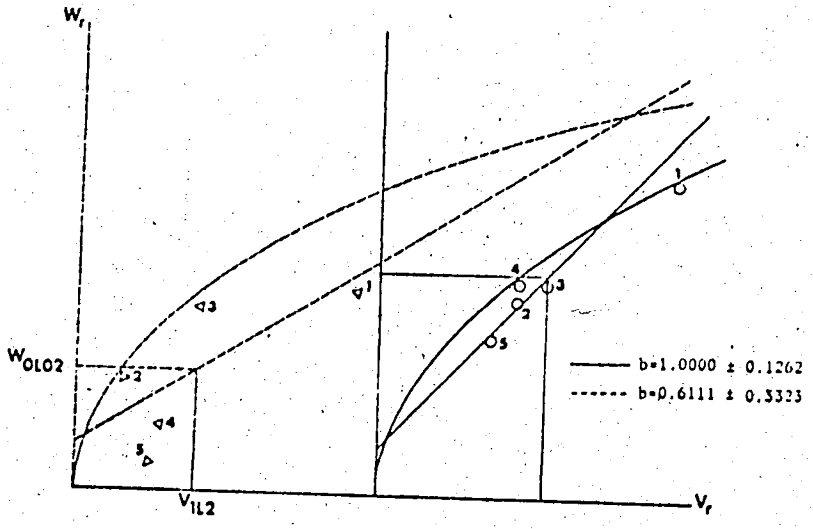

Figure 35. W_r, V_r graph for weight of seeds per spike from F_2 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

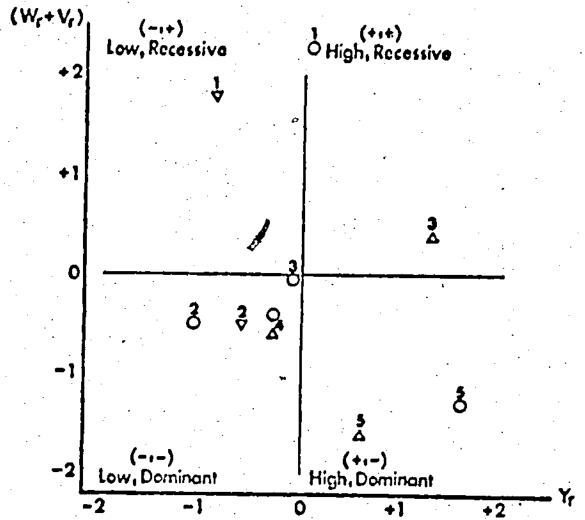

Figure 36. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for weight of seeds per spike from F_2 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

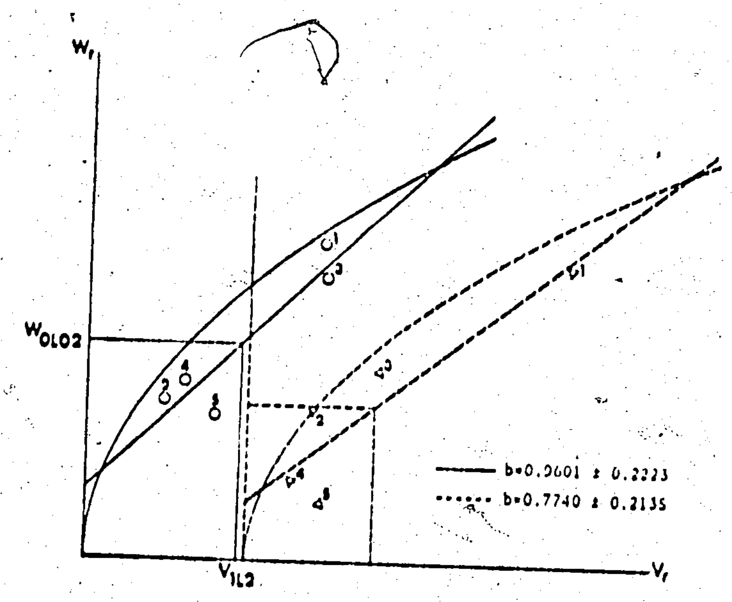

Figure 37. W_r, V_r graph for 1000-kernel weight from F_2 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

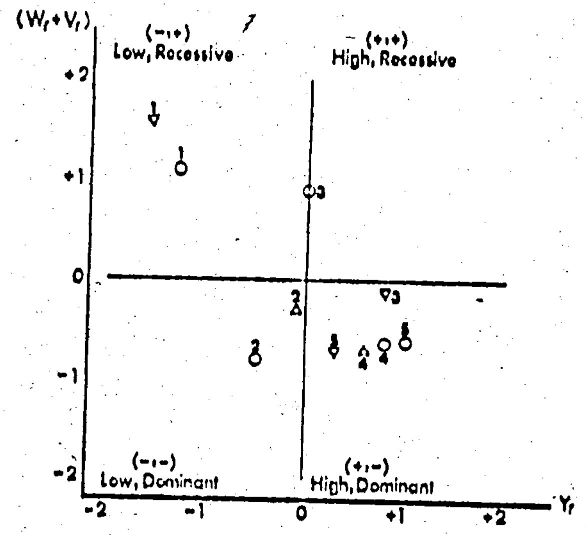

Figure 38. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for 1000-kernel weight from F_2 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

Number of tillers per plant showed heterogeneity of $W_r - V_r$ values (Table 36). Examination of the W_r, V_r graph (Figure 29) and a review of the effects of non-allelic gene interaction, multiple allelism and correlated gene distribution upon the analysis, reveals that none of these conditions invalidate the corresponding null hypotheses. Moreover, since at Ellerslie the environmental component of variation is highly significant and all other components of genetic variation but D non-significant, the environmental variation is the most probable reason for heterogeneity of $W_r - V_r$ values. Since the ratios (Table 39) expressing the mean degree of dominance, the proportion of alleles with positive and negative effects at loci exhibiting dominance, the proportion of dominant and recessive genes in the parents and the number of groups of genes controlling the character were based on parameters some of which were not significant (Table 38) their interpretation as well as the interpretation of the graphs is of little value.

The general features of the diallel analysis with respect to the interpretation of the results from Tables 38 and 39 for other yield components, viz., number of spikelets per spike (Figures 31, 32), number of seeds per spike (Figures 33, 34), weight of seeds per spike (Figures 35, 36) and 1000-kernel weight (Figures 37, 38) are the same. The conclusions drawn therefrom differ with respect to the relative position of the parents for their ranking order of dominance.

For yield per plant, only D and E components of variation

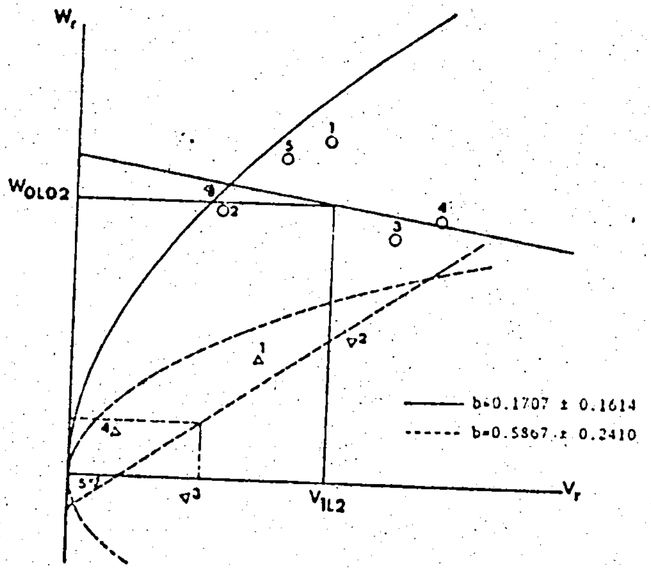

Figure 39. W_r, V_r graph for yield per plant from F_2 diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

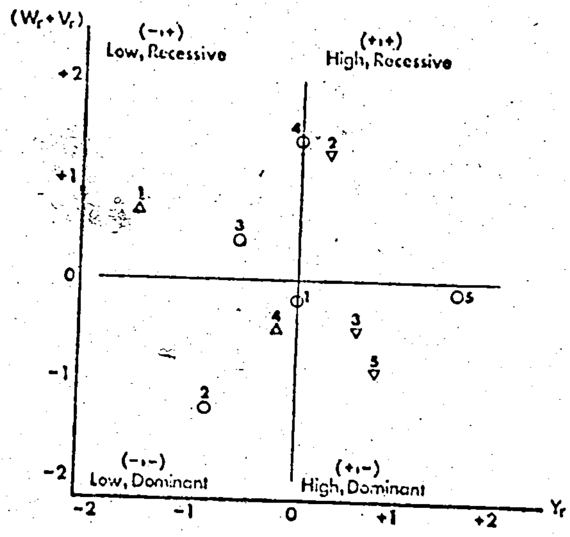

Figure 40. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for yield per plant from F_2 diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

were significant at Ellerslie while D, F and E at Parkland. Because of non-significance of other components of variation, the interpretation of estimates of genetic parameters given in Table 39 would be meaningless.

The W_r, V_r and standardized deviation graphs are interesting in their absurdity. The location effect on yield is sufficiently drastic so that the regression line, though cutting the limiting parabola above its origin (apparent partial dominance) shows a negative slope. The latter (at Ellerslie) implies that for every increase in variance of the rth array, there is a proportional decrease in parent-offspring covariance of that array. The regression line, in this case, cuts the limiting parabola in such a way that the recessive and dominant W_r, V_r array intercepts are difficult to define. However Figure 39 suggests that Ciano may be regarded as the highly recessive and Chinook the most dominant parent. At Parkland, the regression of W_r upon V_r reveals over-dominance. Chinook may be classified as the highly recessive and Inia the most dominant parents. The standardized deviation graph of Figure 40 reveals that, except for Inia, the ranking order for dominance of the parents seems to be altered between locations. Marquis, the recessive parent, with low yielding capacity at Parkland (-,+ quadrant) becomes dominant and comparatively high yielding at Ellerslie (+,- quadrant). Chinook, low yielding and dominant (-,- quadrant) at Ellerslie, becomes recessive and high yielding (+,+ quadrant) at Parkland. A similar situation exists with Ciano. The coefficient of correlation between the parental order of dominance and parental measurements is 0.19 at Ellerslie and -0.40 at Parkland. A positive but weak correlation at Ellerslie suggests however, that genes responsible for low yielding are mostly dominant, while the comparatively high negative correlation at Parkland indicates that the genes contributing toward increased yielding are mostly dominant. The estimates of heritability seem to be questionable because of the non-significance of relative components of genetic variation.

ANALYSIS OF BACKCROSS DATA

The expected mean of a pair of reciprocal backcrosses is the same as that of F_2 generation of the cross between the two parents provided the differential loci are independent in their action (Jinks, 1956). Therefore, assuming no non-allelic interaction, the expected statistics for the analysis of backcross family means in a diallel set are the same as those for F_2 family means.

In Appendix II there are eighty backcrosses including reciprocals. A complete diallel table for these backcrosses therefore requires an amalgamation of four backcrosses to compute the appropriate means for each of the off-diagonal cells in the diallel matrix. Using the same symbols as in Appendix II, and taking any two parents, the appropriate backcross combinations can be shown to be equivalent to the mean of the corresponding F_2 hybrid. Thus the mean of M(MxCH), (MxCH)M, CH(MxCH) and (MxCH)CH means is equivalent to the (MxCH)F_2 mean, while the mean of M(CHxM), (CHxM)M, CH(CHxM) and (CHxM)CH means is equivalent to the mean of its reciprocal, i.e., (CHxM)F_2 hybrid.

Denoting the parents Marquis, Chinook, Khush-hal, Ciano and Inia as 1, 2, 3, 4 and 5 the following two diallel tables (Tables 40, 41) may be constructed, the one by keeping the parents of rows as recurrent parents and the other by keeping the parents of columns as recurrent parents. The numbers in the brackets in Table 40 and Table 41 denote the F_1 hybrids while those outside the brackets denote the recurrent parents. From these two tables a complete diallel table can be constructed which will correspond statistically to the F_2 diallel table

TABLE 40

Arrangement of backcrosses and reciprocals
in which the parents of rows are kept as recurrent parents.

	1	2	3	4	5
1.	11	11(12) + (12)11	11(13) + (13)11	11(14) + (14)11	11(15) + (15)11
2.	22(21) + (21)22	22	22(23) + (23)22	22(24) + (24)22	22(25) + (25)22
3.	33(31) + (31)33	33(32) + (32)33	33	33(34) + (34)33	33(35) + (35)33
4.	44(41) + (41)44	44(42) + (42)44	44(43) + (43)44	44	44(45) + (45)44
5.	55(51) + (51)55	55(52) + (52)55	55(53) + (53)55	55(54) + (54)55	55

TABLE 41

Arrangement of backcrosses and reciprocals
in which the parents of columns are kept as the recurrent parents.

	1	2	3	4	5
1.	11	22(12) + (12)22	33(13) + (13)33	44(14) + (14)44	55(15) + (15)55
2.	11(21) + (21)11	22	33(23) + (23)33	44(24) + (24)44	55(25) + (25)55
3.	11(31) + (31)11	22(32) + (32)22	33	44(34) + (34)44	55(35) + (35)55
4.	11(41) + (41)11	22(42) + (42)22	33(43) + (43)33	44	55(45) + (45)55
5.	11(51) + (51)11	22(52) + (52)22	33(53) + (53)33	44(54) + (54)44	55

and may therefore be used for the analysis of genetic components of variation as described by Jinks (1956). Thus, for example, if the entry [11(12) + (12)11] above the main diagonal in Table 40 is denoted as x and the corresponding entry [22(12) + (12)22] in Table 41 as y, then the corresponding element of the F_2 diallel table would be $1/2[1/2x + 1/2y] = 1/4(x + y)$. The entries in the remaining cells of the F_2 diallel table are obtained in the same way. Such a table may be called a *synthetic F_2 diallel table.*

Simple coefficients of correlation between the characters on the basis of the *synthetic complete F_2 diallel table* are given in Table 42. Onset-of-heading was positively correlated with final heading plant height, number of tillers per plant, number of spikelets per spike at both locations. It was negatively correlated with weight of seeds per spike at Parkland and 1000-kernel weight at both locations. The correlations with heading-span and yield per plant at both locations and with weight of seeds per spike at Ellerslie were not significant. The correlations of final heading and heading-span with other characters may be interpreted in the same way.

Plant height was positively correlated with number of tillers per plant, number of spikelets per spike at both locations and with number of seeds per spike at Ellerslie. It was negatively correlated with weight of seeds per spike and 1000-kernel weight at both locations. No correlations were observed between plant height and yield per plant at either location or with number of seeds per spike at Parkland.

Number of tillers per plant was positively associated with

TABLE 42

Simple correlation coefficients between ten characters from backcross diallel set at two locations.

Character	2	3	4	5	6	7	8	9	10
1. Onset-of-heading	0.917** 0.830**	0.214 -0.025	0.727** 0.714**	0.332** 0.565**	0.592** 0.498**	0.327** 0.291**	-0.209 -0.289*	-0.607** -0.627**	-0.118 -.0111
2. Final heading	-	0.576** 0.532**	0.818** 0.720**	0.395** 0.671**	0.598** 0.550**	0.292** 0.254*	-0.305** -0.332**	-0.679** -0.631**	-0.179 0.096
3. Heading-span		-	0.507** 0.211	0.270* 0.341**	0.218 0.238*	-0.009 0.027	-0.362* -0.162	-0.431** -0.199	-0.233* 0.325**
4. Plant height			-	0.458** 0.538**	0.710** 0.650**	0.[illegible]2* 0.169	-0.303** -0.470**	-0.638** -0.708**	0.006 -0.106
5. Number of tillers per plant				-	0.305** 0.411**	-0.041 0.216	-0.132 -0.289*	-0.094 -0.531**	0.491** 0.173
6. Number of spikelets per spike					-	0.604** 0.651**	0.115 0.105	-0.405** -0.460**	0.149 0.212
7. Number of seeds per spike						-	0.621** 0.600**	-0.160 -0.212	0.116 0.236*
8. Weight of seeds per spike							-	0.638** 0.644**	0.365** 0.444**
9. 1000-kernel weight								-	0.400** 0.333**
10. Yield per plant									-

First reading under each column refers to Ellerslie and second to Parkland.
* Significant at 5% level
**Significant at 1% level

number of spikelets per spike at both locations and with yield per plant at Ellerslie. It was negatively correlated with weight of seeds per spike and 1000-kernel weight at Parkland. There was no correlation with number of seeds per spike at either location or with weight of seeds per spike and 1000-kernel weight at Ellerslie and yield per plant at Parkland. The correlations of number of spikelets per spike, number of seeds per spike, weight of seeds per spike and 1000-kernel weight respectively with other characters may be interpreted in the same way.

Yield per plant was positively correlated with 1000-kernel weight and weight of seeds per spike at both locations, with number of seeds per spike and heading-span at Parkland and with number of tillers per plant at Ellerslie. It was negatively correlated with heading-span at Ellerslie. Correlations with onset-of-heading, final heading and plant height at both locations were not significant.

The results of the factor analysis as the factor loadings of the varimax-rotated five factor matrix are given in Table 43. Approximately 93% of the total variability at both locations was explained by these factors.

The first principal factor was termed *lateness* because of its highest loadings for onset-of-heading and final heading at both locations. This factor negatively contributed towards weight of seeds per spike, 1000-kernel weight and yield per plant at both locations thus confirming the inverse relationship between time of maturity and yield as observed for F_1 and F_2 diallel data. Plant height at Ellerslie and number of tillers per plant contributed proportionately more towards

TABLE 43

Varimax rotated factor matrix for ten characters from backcross diallel set at two locations.

Character	Communality	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Onset-of-heading	0.986 0.913	0.958 0.721	0.154 0.561	0.023 0.061	0.210 -0.118	-0.005 -0.248
Final heading	0.982 0.885	0.869 0.709	0.135 0.532	0.026 0.024	0.252 -0.009	0.380 0.314
Heading-span	0.987 0.965	0.182 0.171	-0.040 0.109	-0.016 -0.038	0.180 0.139	0.959 0.951
Plant height	0.868 0.915	0.621 0.397	0.216 0.847	0.252 -0.086	0.501 -0.163	0.348 0.074
Number of tillers per plant	0.883 0.859	0.380 0.883	-0.139 0.152	0.812 0.054	0.009 0.027	0.243 0.227
Number of spikelets per spike	0.868 0.914	0.415 0.173	0.659 0.768	0.261 0.511	0.426 0.068	0.105 0.169
Number of seeds per spike	0.924 0.981	0.205 0.168	0.937 0.211	-0.048 0.952	-0.024 0.029	-0.004 0.012
Weight of seeds per spike	0.984 0.959	-0.188 -0.274	0.702 -0.266	0.103 0.732	-0.642 0.498	-0.184 -0.169
1000-kernel weight	0.911 0.892	-0.473 -0.489	-0.003 -0.502	0.232 -0.012	-0.768 0.601	-0.208 -0.199
Yield per plant	0.898 0.904	-0.182 0.092	0.193 0.021	0.860 0.167	-0.123 0.899	-0.196 0.244
Percent of total Variability explained	92.910 91.870	29.523 23.700	19.529 23.085	16.343 19.029	15.894 14.832	13.714 12.771

First reading under each column refers to Ellerslie and second to Parkland.

lateness than either the number of spikelets per spike or number of seeds per spike at both locations. *Lateness* explained 29% and 23% of the total variation present in the data for Ellerlie and Parkland respectively.

Number of spikelets per spike, number of seeds per spike and weight of seeds per spike could be grouped into the second factor *yielding ability* at Ellerslie, because of their higher contribution to this factor. At Parkland, this factor was termed *height* since it carried maximum loading for that character. Both the factors explained 19% and 23% variability in the data at respective locations. At Ellerslie, other yield components such as number of tillers per plant and 1000-kernel weight negatively contributed towards *yielding ability* confirming the results of Table 42. At Parkland, onset-of-heading, final heading and number of spikelets per spike had proportionately higher contributions towards *height* while weight of seeds per spike and 1000-kernel weight turned out to be the negative contributors to this factor.

Yield at Ellerslie and *seeds per spike* at Parkland were classified as the third principal factor which explained 16% and 19% of the total variability for respective locations. At Ellerslie, only number of tillers per plant contributed appreciably towards *yield*, otherwise the contributions of number of spikelets per spike, number of seeds per spike, weight of seeds per spike and 1000-kernel weight were comparatively low. The factor *lateness* also made a very poor contribution towards *yield*. At Parkland, number of spikelets per spike and weight of seeds per spike were the major contributors towards *seeds per spike*. Plant height and 1000-kernel weight were negatively affected by this factor.

The term *low yield* was selected for the fourth factor at Ellerslie because of the negative loadings for number of seeds per spike, weight of seeds per spike, 1000-kernel weight, yield per plant and the fact that the lowest positive value was found for number of tillers per plant. At Parkland the alternative fourth principal factor was chosen as *high yield* as it carried the highest loading for yield per plant and positive loadings for 1000-kernel weight, weight of seeds per spike, number of seeds per spike, number of spikelets per spike and number of tillers per plant. Onset-of-heading and final heading contributed positively toward *low yield* but negatively toward *high yield*. Plant height revealed an **inverse** relationship with respect to its contribution towards the yield factor at both locations.

The fifth principal factor, classified as *heading period*, explained 13% of the total variation at both locations. It carried maximum loadings for heading-span at both locations. The contribution of yield and its components, viz., number of spikelets per spike, number of seeds per spike, weight of seeds per spike and 1000-kernel weight towards *heading period* was either very low or negative at both locations, indicating an inverse relationship of yield with heading period. The negative contribution of initial heading towards this factor indicates that earlier heading entries take a longer period to complete

TABLE 44

Estimates of general combining ability of five parental lines used in backcross diallelset for ten characters at two locations.

Character	Marquis	Chinook	Khush-hal	Ciano	Inia
Onset-of-heading	1.8350	1.1600	-0.1316	-1.5753	-1.2899
	1.9650	1.4316	-0.0350	-2.4850	-0.8766
Final heading	2.3333	1.4667	-0.0166	-1.8500	-1.9333
	1.8967	2.1800	-0.3450	-2.2034	-1.5283
Heading-span	0.4667	0.4167	0.0917	-0.3083	-0.6667
	-0.0417	0.7750	-0.3500	0.2417	-0.6250
Plant height	14.2345	9.9832	-7.6700	-6.3678	-10.1798
	14.8495	10.2860	-8.0976	-7.7471	-9.2909
Number of tillers per plant	0.3025	0.6791	0.2759	-0.2361	-1.0213
	1.0841	0.4932	0.0704	-0.5536	-1.0940
Number of spikelets per spike	0.8035	0.2629	-0.4382	-0.5110	-0.1172
	0.6312	0.2373	-0.3260	-0.5021	-0.0404
Number of seeds per spike	3.5835	-1.8660	-1.1196	-2.1986	1.6006
	2.0422	-1.2955	0.5107	-2.4295	1.1722
Weight of seeds per spike	-0.0059	-0.1185	-0.0222	-0.0306	0.1771
	-0.0342	-0.0813	0.0577	-0.0309	0.0888
1000-kernel weight	-2.6314	-1.2960	0.3155	1.4580	2.1540
	-2.3445	-0.7879	0.9186	1.4448	0.7690
Yield per plant	0.0570	-0.7077	-0.6801	0.3461	0.9848
	-0.4831	0.2377	-0.0136	-0.0030	0.2419

First reading under each column refers to Ellorslie and second to Parkland.

their maturity. This kind of relationship was found to be in contradiction with the results obtained for F_1 and F_2 diallels.

Combining ability analysis

The general combining ability values of the parental lines used in the backcross diallel are given in Table 44. At both locations, Marquis ranked first in GCA for onset-of-heading and Ciano the lowest, and therefore these parents were regarded as being late and early maturing respectively. Similar interpretations may be given for final heading and heading-span. For plant height, Marquis and Inia at both locations ranked highest and lowest respectively, while for tiller number Chinook at Ellerslie and Marquis at Parkland scored highest. At both locations, Marquis and Ciano possessed the highest and the lowest GCA for number of spikelets per spike and number of seeds per spike respectively. Similar interpretations may be given for other yield components. As far as yield is concerned, at both locations Inia may be regarded as the best combiner, while Chinook at Ellerslie and Marquis at Parkland were the poorest.

The values of specific combining ability for heading data are given in Tables 45, 46 and 47. The results of Table 45 show that the cross (CxI) possessed the highest SCA and (MxI) the lowest at both locations. The best hybrid was associated with the parents with the lowest GCA's at both locations and the worst was from parents with the highest GCA's. The variances for GCA's were larger than those for SCA's. The reciprocal effects were not significant in all cases. Similar

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from backcross diallel set at two locations.

TABLE 45. Onset-of-heading

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	0.5067 -0.1399	-0.7017 0.0351	-0.9267 -0.5150	-1.4183 -1.3733	1.8350 1.9650	3.3042 3.7204	-0.1577 -0.3519
Chinook	Reciprocal effects	-0.2917 -0.5833	-	-0.5267 0.1100	-0.9600 -1.1483	-0.9100 -0.8816	1.1600 1.4316	1.2825 1.9089	-0.0721 -0.3453
Khush-hal		0.0417 -0.1250	-0.4583 -0.6667	-	0.3733 -0.2233	0.3817 0.0850	-0.1316 -0.0350	-0.0458 -0.1395	0.0989 -0.3474
Ciano		-0.2917 -0.7083	0.3333 -0.2083	0.0417 0.0	-	1.1566 0.1600	-1.5733 -2.4850	2.4122 6.0344	0.4822 0.1927
Inia		-0.1667 0.0417	-0.0833 0.0	0.0 0.1667	0.0 -0.0417	-	-1.2899 -0.8766	1.6009 0.6277	1.2834 0.5468

TABLE 46. Final heading

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	0.8584 -0.3133	-0.5333 -0.7883	-0.2417 -0.8883	-1.7000 -0.8967	2.3333 1.8967	5.3936 3.4204	-0.1267 -0.4424
Chinook	Reciprocal effects	-0.2093 -1.0000	-	-0.5416 -0.2383	-0.5000 -1.1716	-0.5000 -0.9330	1.4667 2.1800	2.1004 4.5753	0.1189 -0.4097
Khush-hal		0.2500 0.1667	-0.6250 -0.1667	-	-0.4333 0.6451	0.1917 0.3450	-0.0166 -0.3450	-0.0504 -0.0579	0.0658 0.2758
Ciano		-0.2083 -0.1250	0.0833 -0.3750	0.1667 0.6667	-	0.8584 0.4117	-1.6500 -2.2034	3.3718 4.6779	0.0387 0.4169
Inia		0.3333 0.2083	0.1667 0.3750	0.0417 0.2083	0.1250 -0.1667	-	-1.9333 -1.5283	3.6871 2.1588	1.1777 0.2101

First reading under each column refers to Ellerslie and the second to Parkland.

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from backcross diallel set at two locations.

TABLE 47. Heading-span

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	0.2500 -0.2000	0.2000 -0.7833	0.6833 -0.3333	-0.2500 0.4500	0.4667 0.0417	0.1601 -0.1984	-0.1442 -0.5003
Chinook	Reciprocal effects	0.0833 -0.4167	-	-0.1250 -1.3083	0.3583 0.0167	0.3000 -0.0750	0.4167 0.7750	0.1159 0.4005	-0.1234 -0.4870
Khush-hal		0.2083 0.2917	-0.1667 0.5000	-	-0.7750 0.6417	-0.1667 0.3000	0.0917 -0.3500	-0.0493 -0.0776	-0.1257 0.2748
Ciano		0.0417 0.5833	-0.2500 -0.1667	0.1250 0.3333	-	-0.2676 0.2917	-0.3083 0.2417	0.0374 -0.1417	0.2544 -0.3259
Inia		0.5000 0.1667	0.2500 0.3750	0.0417 0.0417	0.1250 -0.1250	-	-0.6667 -0.6250	0.3867 0.1905	-0.0604 -0.3726

TABLE 48. Plant height

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	1.2204 -1.5368	2.4292 6.4507	0.7733 3.8329	-5.9562 -4.4574	14.2345 14.8495	201.2519 218.5630	-3.4246 -4.8617
Chinook	Reciprocal effects	1.6708 -0.9280	-	0.2537 -0.4441	0.8719 0.9886	1.8012 -1.2487	9.9832 10.2860	98.2939 103.8567	-2.9272 -4.0744
Khush-hal		2.0138 1.1430	-1.9303 -2.0403	-	-2.2625 -1.2273	1.5805 -0.0541	-7.6700 -8.0976	57.4592 63.6259	-1.4352 9.0746
Ciano		-2.3949 -1.6303	-2.6567 -1.9159	0.6065 0.3160	-	0.5592 -0.9246	-6.3678 -7.7471	39.1798 58.0724	-1.2646 0.8631
Inia		4.3404* 4.2671*	2.5614 1.7700	0.8408 -0.0917	1.1077 0.1983	-	-10.1798 -9.2909	102.2588 84.3766	10.4201 2.5667

First reading under each column refers to Ellerslie and the second to Parkland.
*Significant at 5% level

interpretations for Tables 46 and 47 may be made.

Hybrids (MxK) and (MxI) showed the highest and the lowest SCA for plant height (Table 48) at both locations. The best hybrid at both locations was associated with the parent (Khush-hal) with the second lowest GCA, and the poorest hybrid was associated with one parent (Marquis) having the highest GCA and another (Inia) showing the lowest GCA at both locations. The variances for GCA were greater than those for SCA and the reciprocal effects at both locations were significant only for (IxM). This effect was attributed to the female parent because of the positive sign appended to it.

At both locations, hybrid (CxI) had the highest SCA while (KxI) at Ellerslie and (MxI) at Parkland ranked lowest and produced the lowest number of tillers per plant (Table 49). The best hybrid had a parent with the lowest GCA at both locations, while the poorest ranking hybrids had high GCA parents (Marquis and Khush-hal, respectively). The reciprocal effects were non-significant for all hybrids and GCA variances were usually higher than those for SCA, except for Marquis, Khush-hal and Ciano, all at Ellerslie. The larger SCA variances for the latter parents imply an importance of non-additive gene effects for number of tillers per plant, and reveal instability in the performance of their hybrids.

The results for the other components of yield, such as number of spikelets per spike (Table 50), number of seeds per spike (Table 51) weight of seeds per spike (Table 52) and 1000-kernel weight (Table 53) may be interpreted in a similar way.

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from backcross diallel set at two locations.

TABLE 49. Number of tillers per plant

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinock	Khush-hal	Ciano	Inia			
Marquis		-	0.0587	0.1659	-0.2478	-0.0077	0.3025	-0.0735	-0.4126
			-0.2333	-0.6416	-0.3376	-0.7573	1.0841	1.0034	-0.4296
Chincok	Reciprocal effects	-0.5267	-	0.2268	0.4683	-0.2315	0.6791	0.2961	-0.4114
		-0.2190		-0.3882	-0.2684	0.0716	0.4932	0.0714	-0.4114
Khush-hal		0.4750	0.0875	-	-0.2497	-0.6937	0.2759	-0.0889	-0.3863
		0.3750	0.2375		0.2336	-0.2010	0.0704	-0.1669	-0.2422
Ciano		-0.1367	-0.5357	0.1792	-	0.4877	-0.2361	-0.1093	-0.2982
		-0.2033	0.2167	-0.1958		0.3607	-0.5536	0.1346	-0.3494
Inia		0.2042	-0.0013	-0.2167	0.6943	-	-1.0213	0.8781	-0.1550
		0.2448	0.0412	-0.0958	0.1668		-1.0940	1.0251	-0.1799

TABLE 50. Number of spikelets per spike

♀ Parent		Marquis	Chinock	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	0.3819	0.2495	-0.0846	-0.3061	0.8035	0.6124	-0.0831
			0.1083	0.4159	0.0875	-0.0067	0.6312	0.3646	-0.0845
Chinook	Reciprocal effects	-0.0993	-	0.1926	-0.0259	-0.1115	0.2629	0.0359	-0.0345
		0.0133		-0.3419	0.2164	0.1788	0.2373	0.0215	-0.0805
Khush-hal		0.4042	-0.1623	-	0.1214	-0.0359	-0.4382	0.1588	-0.0500
		0.1975	-0.1708		0.0086	0.0971	-0.3260	0.0725	0.0122
Ciano		-0.2898	-0.1850	0.0875	-	0.0676	-0.5110	0.2279	-0.0756
		0.1233	0.2027	0.1573		-0.1626	-0.5021	0.2183	-0.0663
Inia		0.0335	0.0988	0.1557	0.1650	-	-0.1172	-0.0195	-0.0457
		0.3435	0.3020	0.0598	-0.0790		-0.0404	-0.0322	-0.0618

First reading under each column refers to Ellerslie and the second to Parkland.

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from backcross diallel set at two locations.

TABLE 51. Number of seeds per spike

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	0.1015 0.2519	0.0655 0.1132	0.4011 0.8717	-1.3428 0.3590	3.5835 2.0422	12.0552 3.7491	-1.9664 -1.0532
Chinook		0.1910 -0.0400	-	-0.3113 -1.5280	0.0544 0.2122	0.0701 1.3177	-1.8660 -1.2955	2.6953 1.2570	-1.9630 -1.0321
Khush-hal	Reciprocal effects	0.6403 0.7335	-0.7640 0.4013	-	-0.9921 -0.8981	0.2122 0.0125	-1.1196 0.5107	0.4670 -0.1605	-1.9327 -0.2707
Ciano		-1.1300 0.7405	-1.0005 0.4957	-0.5227 1.0112	-	1.8083 -0.2557	-2.1986 -2.4295	4.0471 5.4813	-1.5837 -0.5161
Inia		-0.4867 0.3572	0.0820 0.0558	-0.2068 0.3265	-1.2177 -0.5962	-	1.6006 1.1722	1.7754 0.9527	-0.2588 -0.4097

TABLE 52. Weight of seeds per spike

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	0.0490 0.0461	-0.0080 -0.0314	-0.0624 0.0606	-0.0289 0.0699	-0.0059 -0.0342	-0.0029 -0.0004	-0.0074 -0.0039
Chinook		0.0552 0.0048	-	-0.0406 -0.0746	-0.0150 0.0018	-0.0264 0.0180	-0.1155 -0.0813	0.0111 0.0050	-0.0066 -0.0032
Khush-hal	Reciprocal effects	0.0022 0.0150	-0.0190 0.0120	-	0.0007 -0.0103	0.0178 -0.0050	-0.0222 0.0577	-0.0025 0.0018	-0.0068 -0.0017
Ciano		-0.0810 0.0340	-0.0268 0.0335	-0.0028 0.0553	-	0.0589 -0.0137	-0.0306 -0.0309	-0.0020 -0.0036	-0.0068 -0.0027
Inia		-0.0638 -0.0573	0.0252 -0.0090	-0.0277 0.0240	-0.0853 -0.0190	-	0.1771 0.0888	0.0284 0.0063	-0.0056 -0.0021

First reading under each column refers to Ellerslie and the second to Parkland.

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from backcross diallel set set at two locations.

TABLE 53. 1000-kernel weight

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	0.6721 0.8088	-0.3252 -0.7960	-0.8322 0.4879	0.3192 1.4128	-2.6314 -2.3445	6.4507 5.0647	-1.1837 -1.0796
Chinook	Reciprocal effects	0.9477 0.4982	-	-0.5640 -0.5859	-0.4496 -0.1117	-0.4911 -0.5019	-1.2960 -0.7879	1.2062 0.1889	-1.0332 -0.8615
Khush-hal		-0.5490 -0.1602	0.3412 0.0255	-	0.5533 0.8728	0.3476 -0.0248	0.3155 0.9186	-0.3740 0.4120	-1.0425 -0.7540
Ciano		0.5182 0.4008	0.1213 0.3108	0.5002 -0.0305	-	-0.5193 -0.1230	1.4580 1.4448	1.6523 1.6556	-0.7835 -0.7422
Inia		-0.8622 -1.3710	0.5862 -0.2628	-0.1982 0.2245	-0.7360 -0.0462	-	2.1540 0.7690	4.1662 0.1496	-0.9392 -0.3250

TABLE 54. Yield per plant

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	0.5268 0.6335	0.1073 -0.0471	-0.2387 -0.3599	-0.6415 0.0177	0.0570 -0.4831	-0.3228 0.0377	-0.8150 -0.4891
Chinook	Reciprocal effects	0.7010 -0.4425	-	0.6673 -0.6144	-0.0782 -0.2531	-0.6920 0.0680	-0.7077 0.2577	0.1748 -0.1292	-0.7225 -0.3553
Khush-hal		0.3322 0.1092	-0.1002 0.6103	-	0.2599 0.5103	-1.2433 -0.7849	-0.6801 -0.0136	0.1365 -0.1995	-0.6627 -0.3625
Ciano		-0.3313 0.5293	-0.8415 0.0917	0.7498 0.6003	-	0.3511 0.0547	0.3461 -0.0030	-0.2062 -0.1956	-0.7715 -0.3378
Inia		-0.6825 -0.8422	0.2547 0.7200	-0.4963 0.0167	1.1603 0.1920	-	0.9848 0.2419	0.6438 -0.1371	0.0374 -0.2811

First reading under each column refers to Ellerslie and the second to Parkland.

TABLE 55

Analysis of variance of general and specific combining ability and reciprocal effects for ten characters from backcross diallel set at two locations.

Character	M.S. for GCA	M.S. for SCA	M.S. for reciprocal effects	Error M.S.
Onset-of-heading	22.1406** 32.1406**	2.5500** 2.3875**	0.1059 0.2753	0.2363 0.5273
Final heading	36.8594** 39.1250**	1.7687** 3.8375**	0.1462 0.3823	0.1901 0.6637
Heading-span	2.3482** 2.9344**	0.5423* 1.2388	0.0976 0.2347	0.2164 0.7498
Plant height	1263.1875** 1345.4687**	13.8687** 26.5062**	10.2239 6.8296	5.1350 7.2887
Number of tillers per plant	4.3223** 7.3193**	0.3368 0.9020	0.2838 0.0941	0.6138 0.6445
Number of spikelets per spike	2.9551** 2.0391**	0.1430 0.1289	0.0776 0.0736	0.1247 0.1266
Number of seeds per spike	62.4219** 33.4844**	1.6523 2.1719	1.1293 0.7036	2.9885 1.5811
Weight of seeds per spike	0.1172** 0.0499**	0.0032 0.0078	0.0047 0.0020	0.0110 0.0058
1000-kernel weight	38.6875** 24.1055**	0.8004 1.5766	0.7034 0.5068	.7762 1.6191
Yield per plant	5.1455** 0.9004	1.2141 0.5074	0.7258 0.5015	1.2218 0.7331

First reading under each column refers to Ellerslie and the second to Parkland.
* Significant at 5% level
**Significant at 1% level

In yield per plant (Table 54), cross (MxCH) had the highest SCA and consequently was the highest yielding at both locations, while cross (KxI) was the lowest yielding as it had the lowest SCA. The highest yielding hybrid had the parents (Marquis at Parkland and Chinook at Ellerslie) with the lowest GCA, while the poor yielding cross (KxI) had one parent (Khush-hal) with the lowest and one (Inia) with the highest GCA at both locations. The GCA variances were higher than those for SCA only for Marquis at Parkland and Chinook, Khush-hal and Inia at Ellerslie. The reciprocal effects were non-significant in all cases.

The analysis of variance for general and specific combining ability together with the reciprocal effects (Table 55) reveals important additive gene effects for all the characters at both locations, with the exception of yield per plant at Parkland. Thus the significance of mean squares for GCA's substantiates the differences among the parental lines. The significant mean squares for SCA's for onset-of-heading, final heading and plant height at both locations and heading-span at Ellerslie suggest a relatively greater importance of SCA over GCA. Thus for earliness and plant height, selection for SCA should be given priority in breeding programmes aimed at evolving desired lines.

Diallel cross analy s

Preceding the analysis, the validity of the assumption of no reciprocal differences was tested by means of Hayman's (1954a) analysis of variance. The results are given in Table 56. Heading-span at Ellerslie and plant height at Parkland showed a significant

TABLE 56

Mean squares from the analysis of variance of 5 x 5 backcross diallel set for ten characters at two locations.

Source of variation	D.F.	Onset-of-heading	Final heading	Heading-span	Plant height	Number of tillers per plant	Number of spikelets per spike	Number of seeds per spike	Weight of seeds per spike	1000 kernel weight	Yield per plant
a	4	66.5313** 96.3906**	110.6094** 117.4531**	7.0449** 8.8047*	3790.0000** 4037.0000**	12.9570* 21.9541**	8.6652** 6.1113*	187.3125** 100.3906**	0.2514* 0.1495*	115.9844** 72.2969**	15.4229** 2.6934
b	10	7.6625** 7.1937**	5.3062 11.5375**	1.6266 3.7156	41.5000* 79.3000*	1.0152 2.7094	0.4316 0.2918	5.0000 6.5812	0.0098 0.0234	2.4312 4.7312	3.6477 1.5289
b_1	1	27.4519 .4352	19.3802* 69.8419	0.1302 3.0000	4.8411 5.6988	0.0016 14.0152	0.5952 1.0854	0.0135 0.6248	0.0091 0.0113	4.9872 6.2116	2.8834 1.8030
b_2	4	4.5937* 3.8926	1.3437 7.8437	2.8215 6.3035	33.0156 120.1719	1.2312 2.6053	0.6533 0.2109	4.7842 12.2314	0.0036 0.0489	1.3271 5.3594	5.6904 1.1279
b_3	5	6.1500** 2.1875	5.6250** 2.8375	0.9711 1.7891*	55.6125 61.6000**	1.0469 0.5344	0.2281 0.4039*	6.2000 3.2625	0.0149 0.0055	2.8000 3.9750**	2.1734 1.7984
c	4	0.2365 1.1062	0.2542 0.7573	0.4969* 0.8417	46.9664 18.1423*	0.6718 0.4849	0.1605 0.3921	2.9725 3.6308	0.0112 0.0083	1.5768 1.0007	1.0532 1.4769
d	6	19 0.0192	0.5615 1.4066	0.1566 0.6125	19.8087 22.0532	0.9712 0.1470	0.2808 0.1070	3.6648 1.0973	0.0160 0.0045	2.4660 1.8668	2.9268 1.5227
Blocks x a	8	1.1953 1.5703	0.6484 2.2578	0.8697 2.5236	14.9219 38.5859	2.4395 2.3799	0.9517 0.8940	17.9219 8.5703	0.0558 0.0238	11.2734 4.4165	1.6191 3.7525
Blocks x b	20	0.9625 1.9560	0.8375 3.5156	0.8468 3.5536	19.8469 28.0469	2.4242 2.5652	0.2797 0.4021	8.5250 5.3062	0.0360 0.0257	6.3781 7.2645	5.4461 2.5219
Blocks x b_1	2	0.3767 9.2654	0.9554 25.2762	1.5654 5.1350	13.4177 217.9666	3.3930 25.4726	0.6469 0.0840	31.8310 0.5820	0.0879 0.0585	4.1877 17.8517	16.2239 0.1980
Blocks x b_2	8	0.9514 1.8023	0.8145 3.8279	1.0515 7.5864	26.3594 33.3281	4.8573 2.5774	0.2700 0.8656	9.7495 11.6685	0.0580 0.0530	13.1274 15.1216	7.6065 4.5069
Blocks x b_3	10	0.5062 1.4375	0.9625 1.8312	0.6352 0.5326	17.3562 7.5562	0.6220 0.5187	0.2527 0.9073	6.0667 1.2094	0.0167 0.0032	1.8535 0.6453	3.1770 1.4113
Blocks x c	8	0.2918 1.3125	0.2979 0.3069	0.1000 0.9120	13.7982 4.0368	0.9417 1.9616	0.1508 0.2277	5.0430 3.6050	0.0118 0.0098	1.5511 5.2596	3.5782 1.8341
Blocks x d	12	0.2427 1.1632	0.2771 0.3983	0.5253 0.7644	9.6492 12.6719	1.1389 0.5689	0.2946 0.1085	5.9260 2.0342	0.0276 0.0053	2.1627 0.9139	2.1360 0.8813
Error	48	0.7079 1.5338	0.5759 1.9922	0.6491 2.2514	15.4430 21.9569	1.8594 1.9246	0.3752 0.3817	8.8616 4.7487	0.0332 0.0176	5.3357 4.8681	3.6694 2.2023

* Significant at 5% level

**Significant at 1% level .

First reading under each column refers to Ellerslie and second to Parkland. Error D.F. comprises of block interaction with D.F. of (a+b+c+d)

Each component has been tested against its own block interaction.

TABLE 57

Analysis of variance of $W_r - V_r$ for ten characters from backcross diallel set at two locations.

Character	Block M.S.	Entry M.S.	Error M.S.
Onset-of-heading	4.9320 16.4215	1.5931* 1.6093*	0.3734 0.8179
Final heading	0.2722 38.3562	0.7335* 2.5496	0.1721 1.9131
Heading-span	0.5333 1.1121	0.0653 0.7220	0.2203 1.1663
Plant height	12060.9687 9119.5000	309.5469 303.1406*	229.9219 77.2656
Number of tillers per plant	6.5381 1.0551	0.4283 0.6512	0.7692 0.6967
Number of spikelets per spike	0.3822 0.0570	0.0215 0.0133	0.0378 0.0426
Number of seeds per spike	426.5668 54.6648	9.7215 3.2239	13.6523 4.9556
Weight of seeds per spike	0.0549 0.0021	0.0002 0.00	0.0052 0.00
1000-kernel weight	205.2457 36.0292	2.3595 1.3192	3.4363 4.8242
Yield per plant	6.7847 0.2112	1.9657 0.7162	2.6477 0.9051

First reading under each column refers to Ellerslie and second to Parkland.
*Significant at 5% level

TABLE 58

Estimates of second degree statistics for ten characters from backcross diallel set at two locations.

Character	V_{0L0}	W_{0L01}	V_{0L1}	V_{1L1}	$(M_{L1} - M_{L0})^2$
Onset-of-heading	15.0000 15.7002	5.7395 6.6334	2.2227 3.2148	3.4973 4.4137	1.4641 2.4233
Final heading	16.9668 27.1514	7.8656 10.1422	3.6934 3.9199	4.5766 5.8430	1.0336 3.7249
Heading-span	0.5869 3.6111	0.2610 0.8947	0.2349 0.2936	0.5060 0.9129	0.0069 0.1600
Plant height	486.7740 518.4434	246.3824 258.1760	126.3408 134.5703	133.2646 147.5088	0.2528 0.3040
Number of tillers per plant	1.4343 5.4749	0.7289 1.9703	0.4319 0.7317	0.6010 1.1834	0.0008 0.7475
Number of spikelets per spike	1.2283 0.5749	0.5699 0.3369	0.2957 0.2039	0.3676 0.2692	0.0317 0.0578
Number of seeds per spike	28.9980 12.2275	13.2521 5.7904	6.2422 3.3457	7.0721 4.4383	0.0007 0.0333
Weight of seeds per spike	0.0384 0.0360	0.0211 0.0116	0.0117 0.0050	0.0133 0.0089	0.0004 0.0006
1000-kernel weight	16.7744 13.1670	7.9937 5.4328	3.8662 2.4092	4.2670 3.1975	0.2660 0.3312
Yield per plant	5.4558 0.6875	1.5937 0.2552	0.5142 0.0899	1.1225 0.3447	0.1538 0.0961

First reading under each column refers to Ellerslie and second to Parkland.

c component, indicating significant reciprocal differences. Significance for *a* confirms the existence of parental differences for all characters at both locations, with the exception of yield per plant at Parkland. Significance of *b* shows that dominance is present for onset-of-heading, final heading and plant height at both locations while b_1 shows that dominance is directional for final heading at Ellerslie. Other assumptions underlying the diallel analysis were tested by analysis of variance of $W_r - V_r$ differences. The heterogeneity of $W_r - V_r$ over arrays for onset-of-heading and heading-span at Ellerslie and plant height at Parkland (Table 57) indicates non-validity of at least one of the assumptions: no multiple allelism, uncorrelated gene distribution and no non-allelic gene interaction. This situation is discussed later, during the graphical analysis of these characters.

The estimates of second degree statistics calculated from array variances and parent-offspring covariances are presented in Table 58. The genetic components of variation were computed according to Johnson and Aksel's (1959) procedure, where the effects of heterozygote is halved because the backcross entries were made equal to those of F_2's (Jinks, 1956). The estimates of genetic components of variation are given in Table 59. Significance was tested in a manner similar to that used for F_2's. Proportional estimates of genetic parameters, calculated from Table 59 are presented in Table 60. The interpretation of the results in Tables 59 and 60, together with, the graphical analysis of the data for all the characters under study is as follows:

Except *E* at Ellerslie and *F* at Parkland, all components

TABLE 59

Estimates of genetic components of variation from backcross diallel set for ten characters at two locations.

Character	D	F	H_1	H_2	h	E
Onset-of-heading	14.7635 ± 0.5161** 13.9224 ± 0.5422**	6.7593 ± 1.2692** 1.7335 ± 1.3543	5.4162 ± 1.3938** 4.1991 ± 1.4642**	4.6253 ± 1.2642** 3.7397 ± 1.3280**	5.7051 ± 0.8535** 9.3553 ± 0.8266**	0.2364 ± 0.2107 0.5278 ± 0.2213*
Final heading	16.7767 ± 0.4081** 25.6060 ± 0.1919**	2.2430 ± 1.2193 11.5783 ± 0.4993**	3.3163 ± 1.3182** 7.5494 ± 0.5393**	3.1526 ± 1.1956** 6.3649 ± 0.4996**	4.0130 ± 0.6022** 14.4746 ± 0.3305**	0.1901 ± 0.1993 0.6636 ± 0.0816**
Heading-span	0.3726 ± 0.2020* 2.9149 ± 0.4063**	-0.0458 ± 0.5645 2.6513 ± 1.2247*	1.0865 ± 0.5455* 1.7867 ± 1.3240	0.6157 ± 0.4947 0.9762 ± 1.2009	-0.1107 ± 0.3340 0.1597 ± 0.8106	0.2164 ± 0.0825** 0.7505 ± 0.2001**
Plant height	481.6389 ± 6.3170** 511.1506 ± 11.9086**	-18.1432 ± 15.7872 -4.5684 ± 29.7476	20.9514 ± 17.0677 58.0338 ± 32.1602	17.4245 ± 15.4806 38.3688 ± 29.1700	-2.2538 ± 10.4517 -3.4512 ± 19.6940	5.1354 ± 2.5801** 7.2925 ± 4.8716
Number of tillers per plant	0.8154 ± 0.0969** 4.8395 ± 0.1591**	-0.7879 ± 0.2422** 2.2954 ± 0.3750**	-0.0063 ± 0.2610** 0.6520 ± 0.4054	-0.5014 ± 0.2375* 0.5160 ± 0.3677	-0.3957 ± 0.1603** 2.5775 ± 0.2482	0.6189 ± 0.0396** 0.6444 ± 0.0613**
Number of spikelets per spike	1.1037 ± 0.0509** 0.4452 ± 0.0213**	0.0271 ± 0.1472 -0.3494 ± 0.0762**	0.0348 ± 0.1591 -0.0253 ± 0.0845	0.0382 ± 0.1443 0.0080 ± 0.0767	0.0472 ± 0.0975 0.1504 ± 0.0518**	0.1246 ± 0.0241** 0.1267 ± 0.0125**
Number of seeds per spike	26.0481 ± 0.7358** 10.6477 ± 0.6544**	1.4479 ± 1.6244 -0.6025 ± 1.6346	-3.3914 ± 1.9724 2.7113 ± 1.7672	-2.5798 ± 1.7890 -1.2106 ± 1.6028	-1.8849 ± 1.2078 -0.8779 ± 1.0622	2.9497 ± 0.2982** 1.5799 ± 0.2671**
Weight of seeds per spike	0.0278 ± 0.0067** 0.0302 ± 0.0017**	-0.0210 ± 0.0017** 0.0188 ± 0.0044**	-0.0215 ± 0.0019** 0.0101 ± 0.0047**	-0.0156 ± 0.0017** 0.0038 ± 0.0043	-0.0051 ± 0.0011** -0.0014 ± 0.0029	0.0111 ± 0.0003** 0.0059 ± 0.0007**
1000-kernel weight	14.9988 ± 0.1177** 11.5476 ± 0.3657**	-0.5569 ± 0.2940 2.6595 ± 0.9136**	-2.7452 ± 0.3178** 0.0153 ± 0.9877	-1.9401 ± 0.2882** -0.0656 ± 0.8958	-0.0724 ± 0.1946 0.2886 ± 0.6048	1.7756 ± 0.0480** 1.6194 ± 0.1493**
Yield per plant	4.2333 ± 0.3936** 0.1538 ± 0.1558	3.0700 ± 0.9832** -0.1264 ± 0.3892	0.3925 ± 1.0630 -0.6622 ± 0.4208	-0.0118 ± 0.9642 -0.4481 ± 0.3817	-0.1673 ± 0.6509 -0.0849 ± 0.2577	1.2225 ± 0.1607** 0.7336 ± 0.0631**

First reading under each column refers to Ellerslie and second to Parkland.

* Significant at 5% level

**Significant at 1% level

TABLE 60

Proportional estimates of genetic parameters from the backcross diallel set for ten characters at two locations.

Character	$[H_1/D]^{\frac{1}{2}}$	$[H_2/4H_1]$	$\{(4DH_1)^{\frac{1}{2}}+F\} \div \{(4DH_1)^{\frac{1}{2}}-F\}$	h^2/H_2	$r_{y_r/W_r + V_r}$	Heritability
Onset-of-heading	0.6057* 0.5492*	0.2135* 0.2227*	2.2149* 1.2557*	1.2334 2.5016	0.9758 0.9398	1.0275 0.7527
Final heading	0.4446* 0.5409*	0.2377* 0.2108*	1.3539* 2.4173*	1.2729 2.2741	0.9486 0.9672	0.9003 1.0562
Heading-span	1.7077* 0.7829	0.1500 0.1366	0.9305† 4.3292	-0.1699 0.1636	0.6344 0.4387	0.1571 0.6007
Plant height	0.2086 0.3369	0.2079 0.1653	0.8343 0.9738	-0.1293 -0.0899	0.3243 -0.6073	0.8898 0.8477
Number of tillers per plant	0.9174 0.3674	0.2045 0.1986	0.3090 4.6612	0.7049 4.9754	0.8415 0.9151	0.2403 0.8379
Number of spikelets per spike	0.2931 0.2375	0.1007 -0.0787	1.0880 -0.2433	1.2373 18.8908	-0.5694 -0.8324	0.9423 0.3502
Number of seeds per spike	0.3608 0.5046	0.1902 0.1116	1.1669 0.8938	0.7306 -0.7552	-0.5376 0.2682	0.7891 0.5250
Weight of seeds per spike	0.8864 0.5775*	0.1814 0.0946	0.3949 3.3493*	0.3291 -0.3582	-0.1965 0.3449	0.3834 0.6696
1000-kernel weight	0.4281 0.0364	0.1772 -1.4023	0.9169 -1.9226	0.0371 -3.3718	0.5993 -0.4941	0.7533 0.7507
Yield per plant	0.3045 2.0749	-0.0075 0.1692	-11.4843 0.6694	14.1870 0.1894	0.9215 -0.4361	0.6567 0.0602

First reading under each column refers to Ellerslie and second to Parkland.
*Genetic components of variation for the characters are significantly differenct from zero ($P \leq 0.05$)
†Components D and H_1 significant, F non-significant ($P > 0.05$)

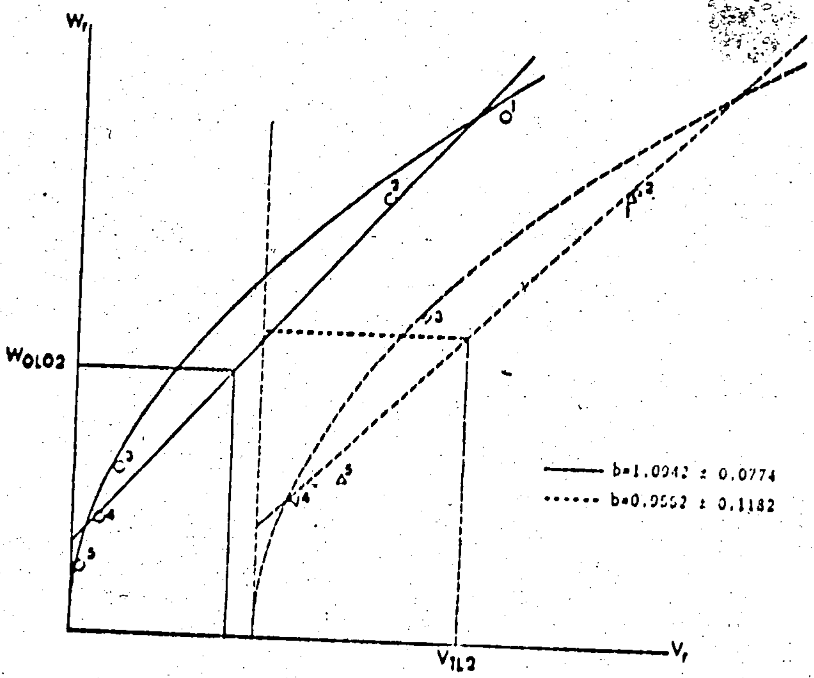

Figure 41. W_r, V_r graph for onset-of-heading from backcross diallel set.

— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

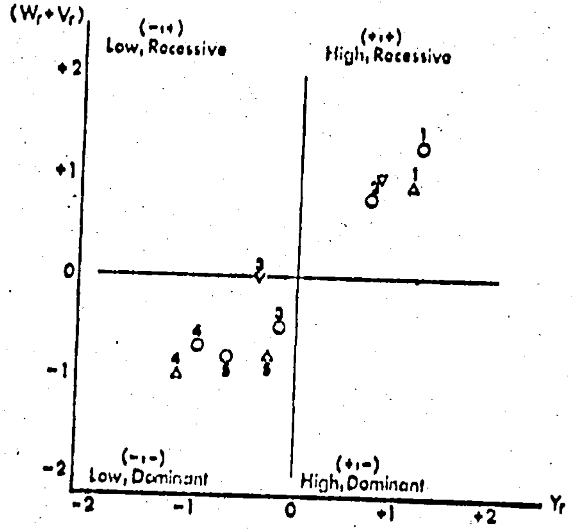

Figure 42. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for onset-of-heading from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

of variation were significant (Table 59) for onset-of-heading. The mean degree of dominance (Table 60) and the regression of W_r upon V_r (Figure 41) at both locations show that onset-of-heading is inherited as a partially dominant trait. The proportion of positive to negative alleles at loci exhibiting dominance in the parents is approximately 0.25 and consequently the parents may be assumed to have equal proportions of genes with positive and negative effects respectively. The estimates of $[(4DH_1)^{1/2} + F] \div [(4DH_1)^{1/2} - F] > 1$ for both locations suggest that dominant genes are in excess in the parents. Moreover, since h^2/H_2 is 1.2 for Ellerslie and 2.5 for Parkland, at least one and at least two groups of genes, respectively, are showing dominance in regard to the expression of the character. The correlation coefficient between Y_r and $(W_r + V_r)$ at both locations is 0.9, indicating that the genes for early heading are mostly dominant. The parents Marquis and Inia at Ellerslie and Chinook and Ciano at Parkland are the most highly recessive and highly dominant ones (Figure 41). The standardized deviation graph of Figure 42 categorized the late heading parents as recessives (Marquis and Chinook, in the +,+ quadrant) and the early parents as dominants (Khush-hal, Ciano and Inia, in the -,- quadrant) for both locations. Heritability estimates of 102.75% at Ellerslie and 75.27% at Parkland show that the character is highly heritable and fairly stable over the environmental fluctuations.

Only F and E for final heading were not significant at Ellerslie (Table 59). The character is partially dominant in its inheritance since $(H_1 \div D)^{1/2} < 1$ (see also Figure 43). Table 57 shows $W_r - V_r$

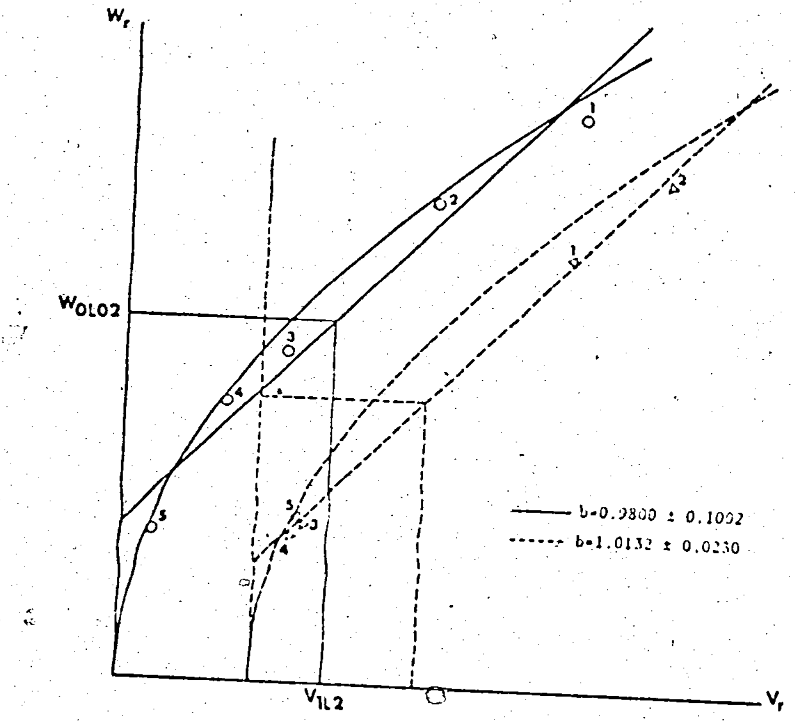

Figure 43. W_r, V_r graph for final heading from backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

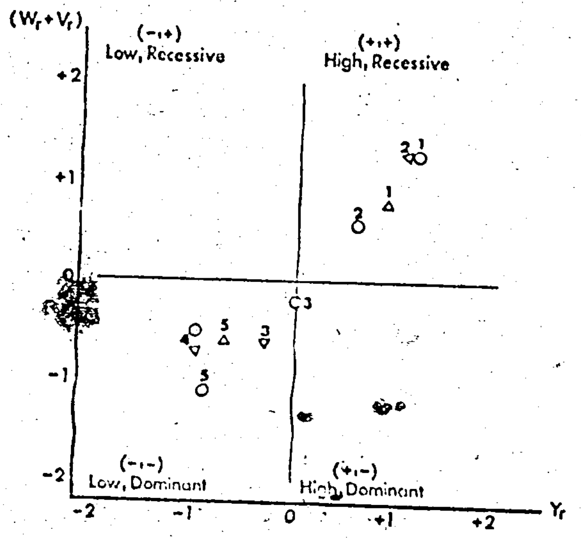

Figure 44. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for final heading from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

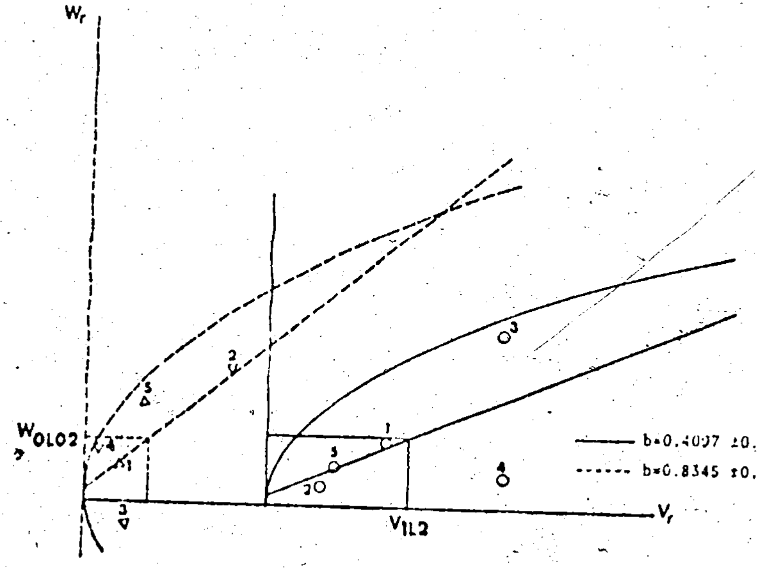

Figure 45. W_r, V_r graph for heading-span from backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

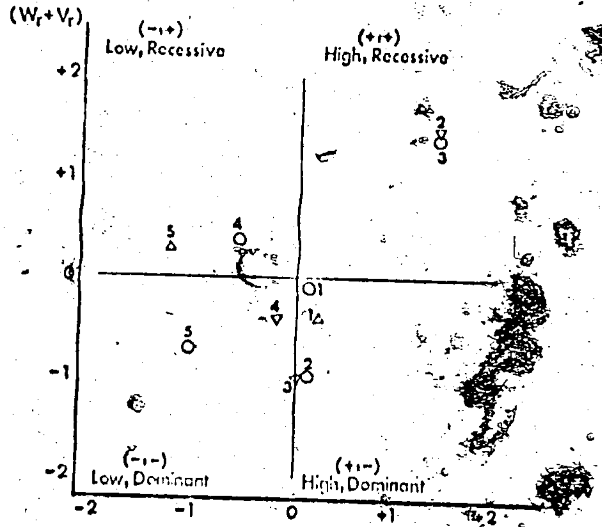

Figure 46. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for heading-span from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

heterogeneity which can be ascribed to either non-allelic interaction, multiple allelism or correlated gene distribution. It could be ascertained from Figure 41 (onset-of-heading) and Figure 43 (final heading) that the regression line does not deviate significantly from the expected unit slope and the W_r, V_r graph does not appear to be distorted. Therefore the question of non-validity of any of the above mentioned conditions has been ignored. The general conclusions of the diallel analysis for final heading (see Tables 59, 60; Figures 43, 44) and heading-span (see Figure 45, 46) are similar to that for onset-of-heading except for changes in the ranking order of parents for their dominance.

For plant height, all components of genetic variation except D were non-significant at both locations. The W_r - V_r heterogeneity at Parkland (Table 57) has been ignored, since the regression of W_r upon V_r is not significantly different from unity (Figure 47) and the W_r, V_r array-intercepts do not show distortion. Because of the non-significance of components of variation, interpretations of proportional estimates and genetic parameters are meaningless. However, the mean degree of dominance may be given as $(H_1 \div D)^{1/2} < 1$ indicating partial dominance (see also Figure 47). The correlation between the parental order of of dominance and parental measurements is 0.32 at Ellerslie and -0.607 at Parkland. The positive correlation at Ellerlie indicates that genes for shortness are mostly dominant; the negative correlation at Parkland that genes for tallness are mostly dominant. The most highly recessive parent (+,+ quadrant, Figure 48) contributing to tallness at Ellerslie is Marquis, while Khush-hal is the most highly reçessive parent at Parkland

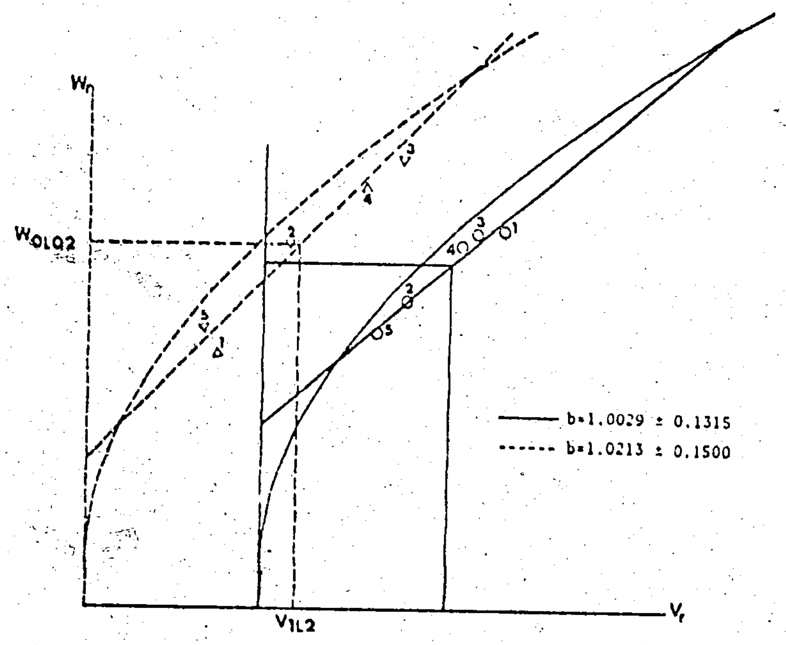

Figure 47. W_r, V_r graph for plant height from backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

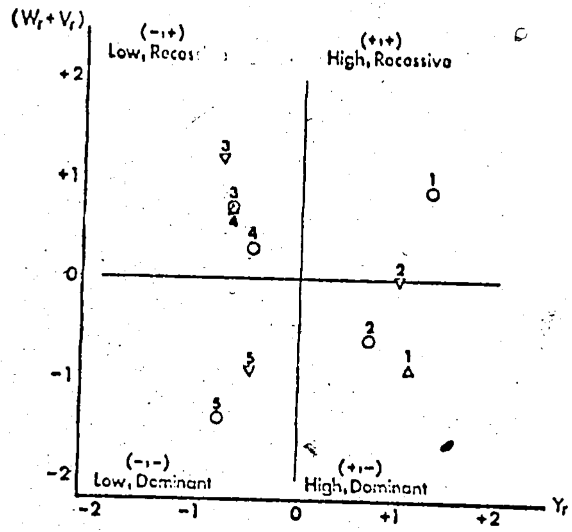

Figure 48. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for plant height from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

(−,+ quadrant) contributing to shortness. The most dominant parent, Inia, at both locations occupies the (−,−) quadrant and thus reflects its shortness. Marquis and Chinook show a discrepancy in dominance ranking order between locations. Chinook, highly dominant at Ellerslie had equal proportion of dominants and recessives at Parkland, while Marquis, highly recessive at Ellerslie is highly dominant at Parkland. The heritability estimates of 88.98% at Ellerslie and 84.77% at Parkland suggests that plant height, being highly heritable is quite stable with respect to environmental changes.

For number of tillers per plant, all components of variation except D and F are non-significant at Parkland. Consequently, proportional values discussed below may have a value only in showing trends and not definite conclusions. The same condition applies to the interpretation of graphs. At Ellerslie, $(H_1 \div D)^{1/2} \approx 1$, showing that dominance is nearly complete (see also Figure 49). The value of $(H_2/4H_1) = 0.204$ indicates a certain degree of asymmetry of positive and negative alleles at loci exhibiting dominance. the proportion of dominant to recessive genes in the parents (0.309), indicates a preponderance of recessive genes. Since $h^2/H_2 = 0.704$, probably at least one group of genes controls tillering capacity. The correlation between parental order of dominance and parental measurements at both locations is 0.9, suggesting that genes with low tillering capacity are mostly dominant. This situation is presented graphically in Figure 50, where almost all the parents at both locations occupy

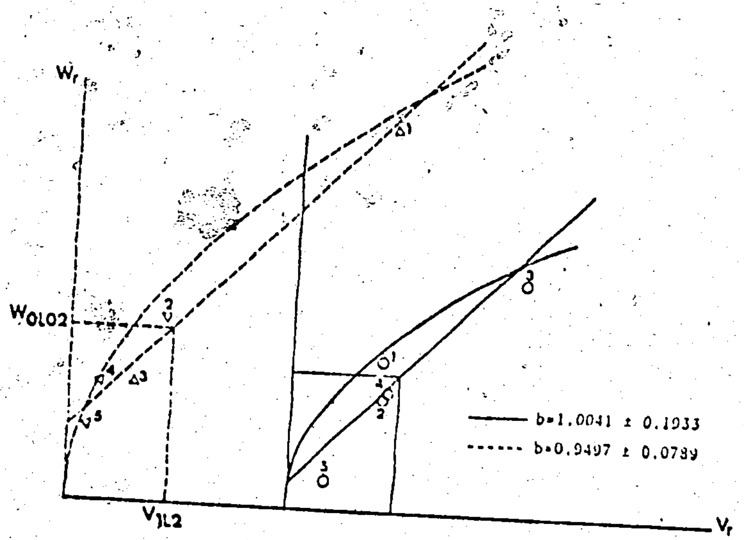

Figure 49. W_r, V_r graph for number of tillers per plant from backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

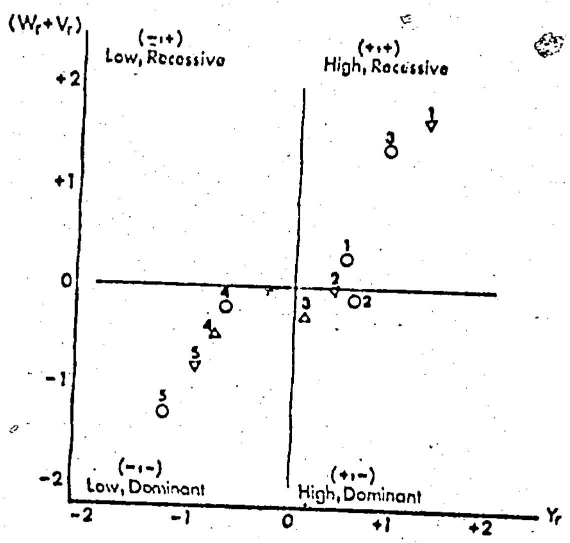

Figure 50. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of tillers per plant from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

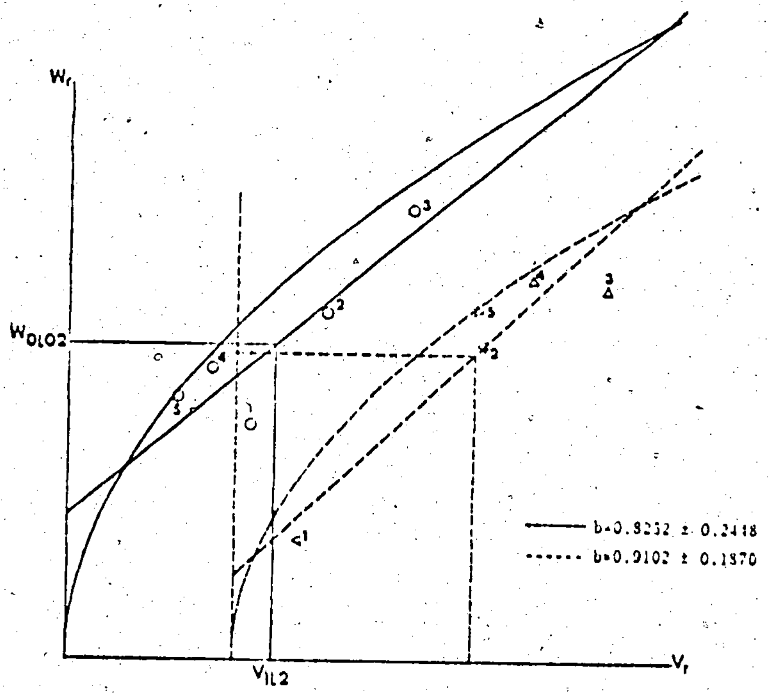

Figure 51. W_r, V_r graph for number of spikelets per spike from backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

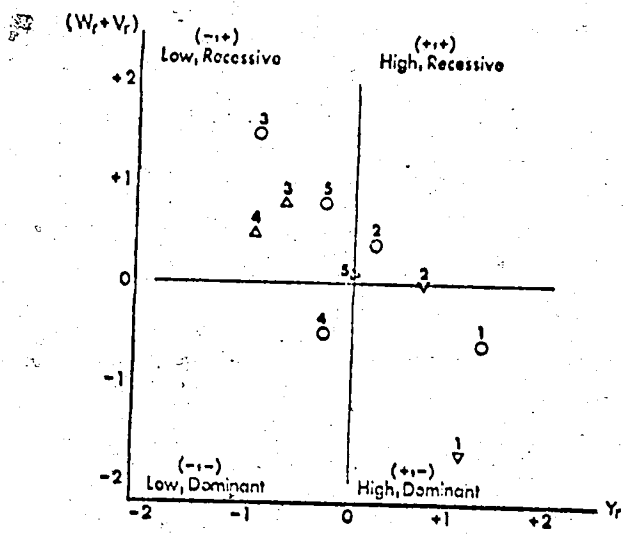

Figure 52. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of spikelets per spike from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

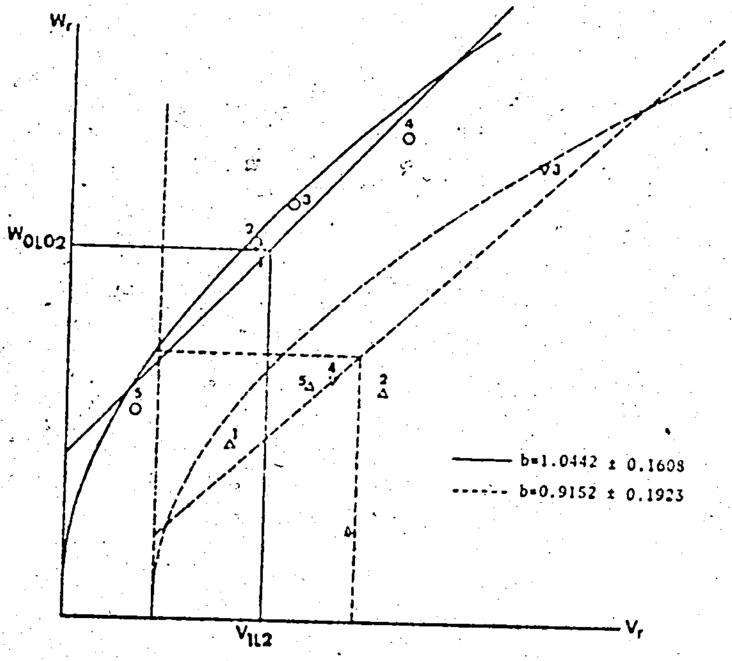

Figure 53. W_r, V_r graph for number of seeds seeds per spike from backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

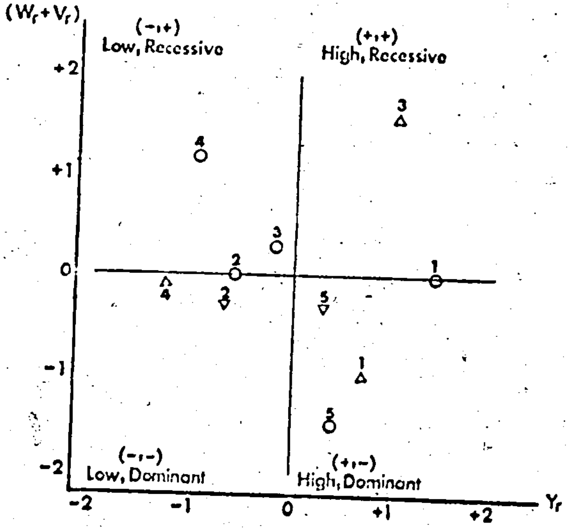

Figure 54. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of seeds per spike from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

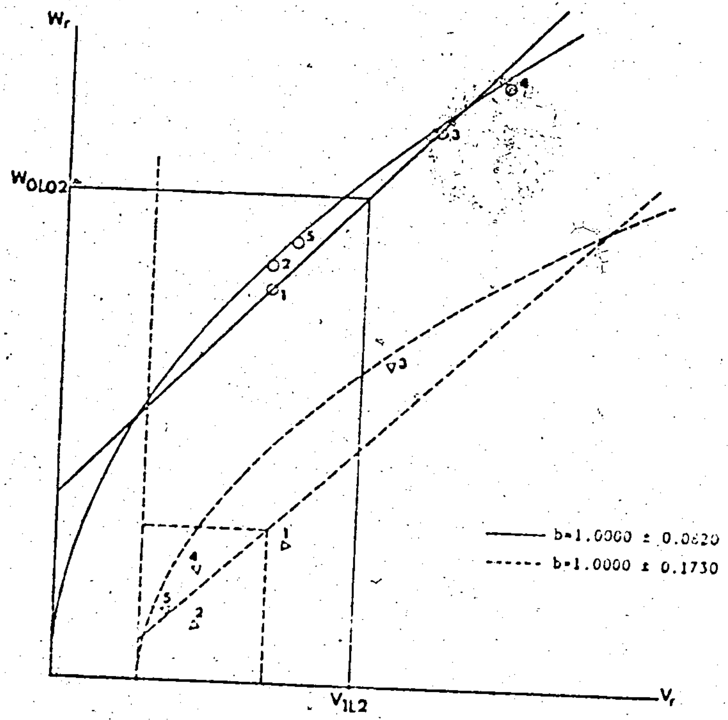

Figure 55. W_r, V_r graph for weight of seeds per spike from backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

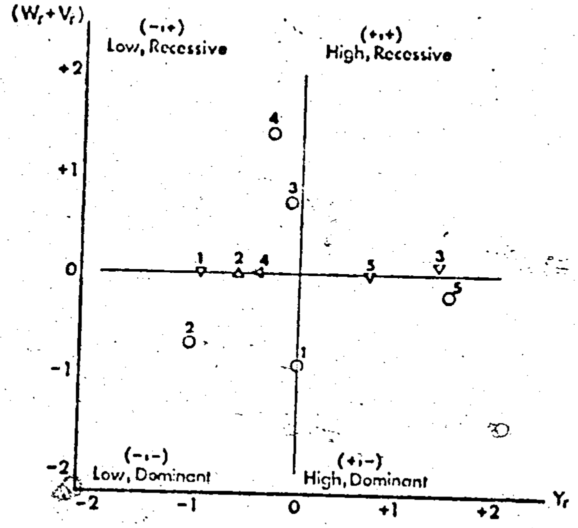

Figure 56. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for weight of seeds per spike from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

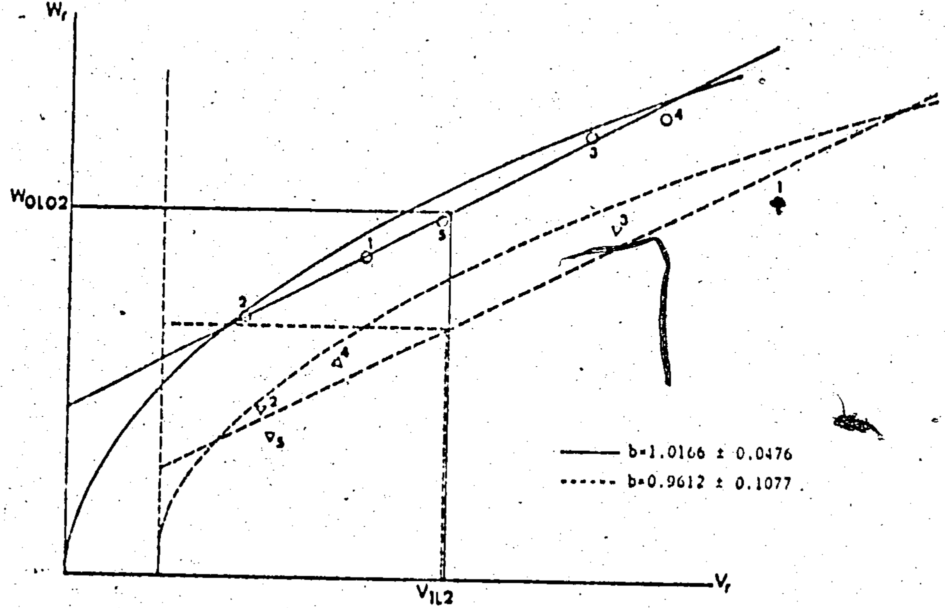

Figure 57. W_r, V_r graph for 1000-kernel weight from backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

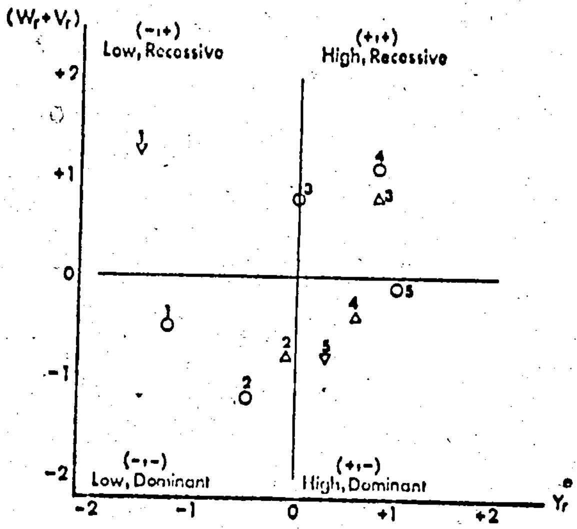

Figure 58. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for 1000-kernel weight from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

the (-,-) and (+,+) quadrants. Ciano and Inia, in the (-,-) quadrant, may be regarded as highly dominant for low tillering at both locations. Khush-hal at Ellerslie and Marquis at Parkland, in the (+,+) quadrant, may be said to be highly recessive for higher tillering. Chinook, with higher tillering capacity at both locations, shows more dominant than recessive genes at Ellerslie but equal proportions of dominants and recessives at Parkland. Only Khush-hal has changed its order of dominance between the two locations. Highly recessive at Ellerslie, it shows a preponderance of dominant genes at Parkland. Heritability values of 24.03% at Ellerslie and 83.79% at Parkland suggest that the heritability of tillering capacity is strongly influenced by environmental fluctuations.

The graphical interpretations of the results of Tables 59, 60 for other components of yield, are shown in Figures 51 - 58, (i.e. number of spikelets per spike, Figures 51, 52; number of seeds per spike, Figures 53, 54; weight of seeds per spike, Figures 55, 56; and 1000-kernel weight, Figures 57, 58). These may be explained in the same way as for number of tillers per plant.

For yield per plant, the components of variation in Table 59 were mostly non-significant. The overall picture of inheritance of yield seen from the W_p, V_p graph of Figure 59 is one of partial dominance at both locations. The correlations between parental order of dominance and parental measurements are 0.921 at Ellerslie and -0.436 at Parkland. These highly significant correlations indicate

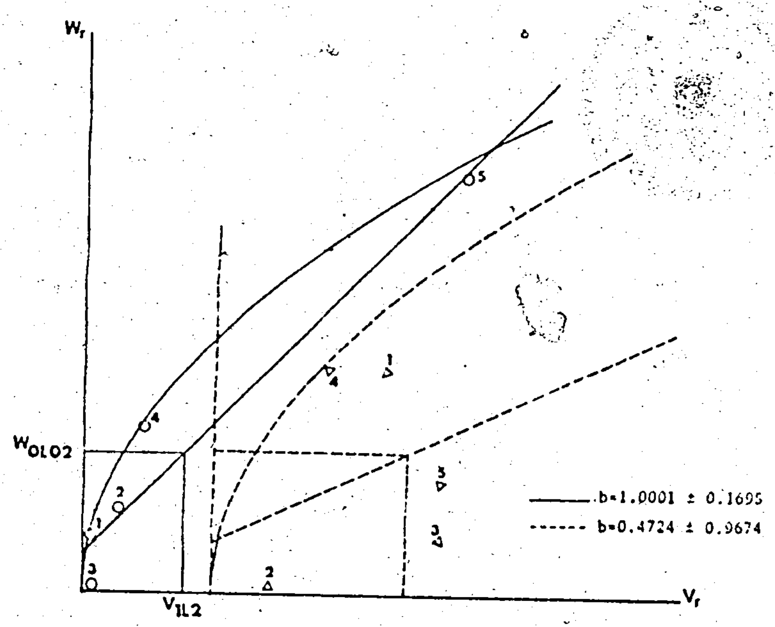

Figure 59. W_r, V_r graph for yield per plant from backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

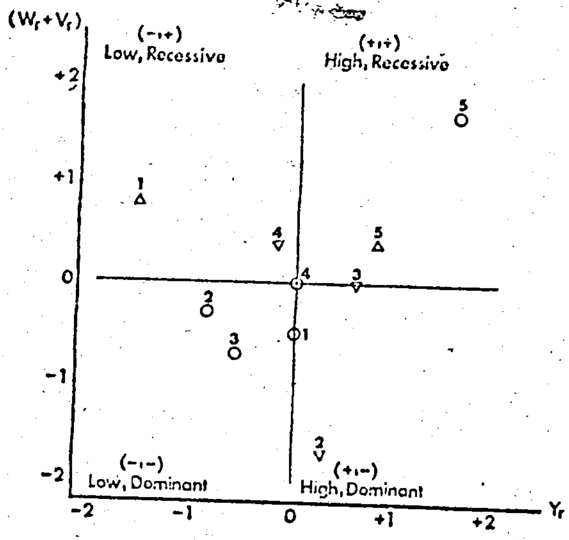

Figure 60. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for yield per plant from backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

that the genes for low yield at Ellerslie are mostly dominant while at Parkland high yielding is dominant over low. The dominance ranking order of parents seems to be significantly different for the two locations. Thus, from Figure 59, Inia and Marquis are the most recessive and Khush-hal and Chinook are the most dominant parents at Ellerslie and Parkland, respectively. Marquis, highly recessive at Parkland contains an excess of dominant genes at Ellerslie, while Khus-hal, with equal proportion of dominants and recessives at Parkland shows a preponderance of dominants at Ellerslie. Ciano, with equal proportions of dominant and recessive genes at Ellerslie possesses an excess of recessive genes at Parkland. The heritability values of 65.67% at Ellerslie and 6.02% at Parkland reflect this instability of yield inheritance between the two locations.

ANALYSIS OF SELFED BACKCROSSES

In the absence of non-allelic interaction the expected statistics for the analysis of family means of the first selfed backcross generation are the same as those of F_3 generation crosses. The diallel table of selfed backcross family means, i.e., 'synthetic F_3 diallel table' was subjected to simple correlation analysis and the results are presented in Table 61. The following conclusions may be made from Table 61:

Onset-of-heading was positively correlated with final heading, plant height, number of spikelets per spike, number of seeds per spike at both locations and with number of tillers per plant at Parkland only. It was negatively correlated with weight of seeds per spike at Parkland and 1000-kernel weight at both locations. The negative correlation with weight of seeds per spike and 1000-kernel weight indicates that early maturing varieties produce higher yields and higher seed weights than the late maturing ones. Similar results were also obtained for F_1, F_2 and backcross diallel data.

Plant height was positively correlated with number of tillers per plant and number of spikelets per spike at both locations and with number of seeds per spike at Ellerslie only. It was negatively correlated with weight of seeds per spike and 1000-kernel weight at both locations. Correlation with yield at both locations was not significant.

Number of tillers per plant was positively correlated with number of spikelets per spike and yield per plant at both locations

TABLE 61

Simple correlation coefficients between ten characters from a selfed backcross diallel set at two locations.

Character	2	3	4	5	6	7	8	9	10
1. Onset-of-heading	0.917** 0.842**	0.142 0.047	0.777** 0.818**	0.194 0.500**	0.534** 0.534**	0.346** 0.301**	-0.206 -0.288*	-0.643** -0.636**	-0.206 -0.162
2. Final heading	-	0.515** 0.578**	0.779** 0.771**	0.197 0.617**	0.445** 0.527**	0.316** 0.238*	-0.273* -0.347	-0.687** -0.656**	-0.307** -0.009
3. Heading-span		-	0.259* 0.191	0.055 0.390**	-0.081 0.169	-0.003 -0.011	-0.275* -0.204	-0.330** -0.254*	-0.349** 0.231*
4. Plant height			-	0.354** 0.511**	0.636** 0.588**	0.278* 0.155	-0.244* -0.465**	-0.606** -0.723**	0.016 -0.103
5. Number of tillers per plant				-	0.285* 0.428**	-0.056 0.239*	-0.034 -0.255	0.046 -0.536**	0.517** 0.253*
6. Number of spikelets per spike					-	0.619** 0.686**	0.212* 0.194	-0.412** -0.345**	0.252* 0.373**
7. Number of seeds per spike						-	0.695** 0.639**	-0.302** -0.061	0.126 0.409**
8. Weight of seeds per spike							-	0.526** 0.724**	0.442** 0.511**
9. 1000-kernel weight								-	0.418** 0.309**
10. Yield per plant									-

First reading under each column refers to Ellerslie and second to Parkland.

*Significant at 5% level

**Significant at 1% level

and with number of seeds per spike at Parkland. It was negatively correlated with 1000-kernel weight at Parkland. The correlation of tiller number with number of seeds per spike and 1000-kernel weight at Ellerslie and with weight of seeds per spike at both locations was not significant. A positive correlation with number of spikelets per spike, number of seeds per spike and yield per plant indicates a direct proportional relationship between tillering capacity and these characters, while negative correlation with 1000-kernel weight shows that plants with high tillering capacity tend to have a low kernel weight. The correlation coefficients for other components of yield, viz., number of spikelets per spike, number of seeds per spike and 1000-kernel weight among themselves and with heading dates have a similar interpretation.

Yield per plant was positively correlated with its components: 1000-kernel weight, weight of seeds per spike, number of seeds per spike, number of spikelets per spike and number of tillers per plant at both locations. The single exception was number of seeds per plant at Ellerslie. The positive correlation of yield with its components exhibits a direct proportional relationship of the former with the latter. Yield was negatively correlated with final heading and heading-span at both locations, indicating that the late heading entries are low yielding and vice versa. The negative correlation of yield with onset-of-heading was not significant at either location.

The results of the factor analysis are summarized in a varimax-rotated, five factor matrix in Table 62. 93% of the total

TABLE 62

Varimax rotated factor matrix for ten characters from a selfed backcross diallel set at two locations.

Character	Communality	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Onset-of-heading	0.982	0.977	0.057	-0.034	-0.025	0.147
	0.899	0.905	0.135	0.193	-0.005	-0.159
Final heading	0.985	0.908	0.036	-0.045	0.364	0.157
	0.956	0.766	0.078	0.241	0.520	-0.065
Heading-span	0.986	0.163	-0.078	-0.063	0.973	0.054
	0.991	0.086	-0.057	0.159	0.970	0.122
Plant height	0.850	0.787	0.010	0.266	0.166	0.383
	0.924	0.924	-0.079	0.348	0.053	0.017
Number of tillers per plant	0.877	0.246	-0.120	0.889	0.100	0.030
	0.898	0.344	0.079	0.817	0.227	0.234
Number of spikelets per spike	0.872	0.452	0.470	0.310	-0.158	0.572
	0.826	0.634	0.552	0.166	0.058	0.296
Number of seeds per spike	0.955	0.251	0.895	-0.060	0.030	0.293
	0.978	0.199	0.953	0.121	-0.011	0.122
Weight of seeds per spike	0.995	-0.206	0.899	0.138	-0.146	-0.332
	0.964	-0.325	0.749	-0.389	-0.112	0.366
1000-kernel weight	0.939	-0.534	0.126	0.261	-0.204	-0.727
	0.962	-0.581	0.115	-0.617	-0.139	0.388
Yield per plant	0.869	-0.232	0.281	0.817	-0.261	-0.018
	0.946	-0.066	0.298	0.085	0.140	0.908
Percent of total Variability explained	93.095	31.338	19.500	17.231	12.604	12.421
	92.841	33.077	19.144	14.301	13.203	13.115

First reading under each column refers to Ellerslie and second to Parkland.

variability present in the data for all the characters considered was explained by these factors at both locations.

The first factor was termed *lateness*. It carried highest loadings for onset-of-heading and final heading at both locations. Weight of seeds per spike, 1000-kernel weight and yield per plant were negative contributors to *lateness*. Of the remaining characters, the highest contributor to *lateness* was plant height at both locations. This confirms the results of the earlier F_1, F_2 and backcross diallel factor analyses. *Lateness* explained 31.33% and 33.07% of the total variability at Ellerslie and Parkland respectively.

The second principal factor was termed *yielding-ability* since it carried the highest loadings on number of seeds per spike, weight of seeds per spike and number of spikelets per spike. As expected, yield per plant appreciably contributed to this factor. The contributions of onset-of-heading and final heading, though positive, were the lowest. Heading-span and plant height showed a negative effect on *yielding-ability*. The factor explained 19% of the variability present in the data at both locations.

Tillering-capacity was chosen as the third principal factor as it carried the highest loadings for number of tillers per plant at both locations. Yield per plant showed the highest contribution to *tillering-capacity* at Ellerslie but its effect at Parkland was very low. Other components of yield, viz., number of seeds per spike, weight of seeds per spike and 1000-kernel weight, contributed negatively or very slightly to *tillering-capacity* at both locations. A negative effect

TABLE 63

Estimates of general combining ability for five parental lines used in selfed backcross diallel set for ten characters at two locations.

Character	Marquis	Chinook	Khush-hal	Ciano	Inia
Onset-of-heading	2.0733 2.3117	1.2483 1.5534	-0.5433 -0.6300	-1.6100 -2.3216	-0.0683 -0.9133
Final heading	2.8616 2.1917	1.4983 2.2334	-0.2433 -0.5500	-2.0183 -2.2250	-1.5183 -1.6500
Heading-span	0.1967 -0.1033	0.3717 0.6633	0.2550 0.0967	-0.4533 0.0967	-0.3700 -0.7533
Plant height	14.0397 12.5270	9.8603 12.5012	-8.6035 -8.7700	-6.1142 -7.7140	-9.1824 -8.5442
Number of tillers per plant	0.0554 0.7212	0.5642 0.7512	0.3819 0.3558	-0.0788 -0.7265	-0.9226 -1.1017
Number of spikelets per spike	0.7318 0.5099	0.1207 0.3313	-0.4789 -0.2941	-0.2321 -0.4894	-0.1415 -0.0577
Number of seeds per spike	3.7367 1.8352	-2.1908 -1.0805	-1.2477 0.4308	-1.6029 -1.8508	1.3047 0.6653
Weight of seeds per spike	0.0230 -0.0314	-0.1290 -0.0845	-0.0362 0.0607	-0.0017 -0.0282	0.1439 0.0834
1000-kernel weight	-2.3425 -2.0504	-1.1454 -1.0151	0.2468 0.9964	1.4072 0.9224	1.8379 1.1968
Yield per plant	-0.0471 0.5386	-0.8473 0.0681	-0.7653 0.3231	0.6451 -0.2341	1.0147 0.3815

First reading under each column refers to Ellerslie and second to Parkland.

was observed for onset-of-heading, final heading and heading-span at Ellerslie, but their effect at Parkland, though positive, was very low. *Tillering-capacity* explained 17.23% and 14.30% of the variability in the data at Ellerslie and Parkland.

The fourth principal component was chosen as *heading-span* because heading-span provided the highest contribution to this factor. It explained 12.6% and 13.2% of the variability at Ellerslie and Parkland. Yield per plant and its components had either a negative or a minimal effect on *heading-period*. This kind of response was also observed in the F_1, F_2 and backcross factor analyses.

The fifth principal factor was named *low seed weight* at Ellerslie and *high yield* at Parkland because of the inconsistency in factor loadings between the two locations; 1000-kernel weight carrying maximum negative loading at Ellerslie and yield per plant maximum positive loading at Parkland. *Low seed weight* explained 12.421% and *high yield* 13.115% of the variability in the data at the respective locations. The contribution of yield and its components towards *low seed weight* at Ellerslie was expectedly low except number of spikelets per spike. On the other hand the contribution of yield components towards *high yield* at Parkland was definitely positive. *Low seed weight* was associated with earliness, as reflected by the factor loadings for heading data at the two locations.

Combining ability analysis

The results of the general combining ability analysis are presented in Table 63. For onset-of-heading Marquis was the highest

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from selfed backcross diallel set at two locations.

TABLE 64. Onset-of-heading

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	0.4433 0.3217	-0.9317 -0.6616	-0.0733 0.6616	-1.1817 -0.9200	[illegible]	4.2302 5.2404	-0.1713 -0.2584
Chinook	Reciprocal effects	-0.4583 -0.1667	-	-0.8566 -0.3617	-0.8733 -0.9617	-0.1066 -0.1617	[illegible] [illegible]	1.4898 2.3096	-0.1058 -0.2239
Khush-hal		0.5417 0.3333	-0.2917 -0.5417	-	0.2933 0.4717	0.5183 0.0217	-0.5433 -0.6300	0.2267 0.2935	0.3626 -0.0689
Ciano		0.3333 0.5000	0.1250 0.2500	0.4167 -0.5000	-	0.5433 -0.3700	-1.6100 -2.3216	2.5235 5.2867	0.1134 0.2494
Inia		0.1667 -0.0417	-0.2500 -0.1250	0.0833 0.8750	-0.3750 0.1250	-	-1.1683 -0.9133	1.2965 0.7308	0.4859 0.0782

TABLE 65. Final heading

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	0.4517 0.9417	-0.6616 -1.4000	-0.2400 -0.5167	-0.8233 -0.9250	2.2816 2.1917	5.1591 4.6342	-0.1169 -0.4233
Chinook	Reciprocal effects	-1.0417** -0.5833	-	-0.9817 -1.4833	-0.4983 -1.3500	0.6350 -1.2583	1.4983 2.2334	2.1983 4.8185	-0.0489 -0.1277
Khush-hal		0.5000 0.1250	-0.3333 -0.0833	-	0.3683 1.0167	-0.0483 0.8167	-0.2433 -0.5500	0.0124 0.1332	0.3592 0.9634
Ciano		0.6667* 0.5000	0.7083* 0.2917	0.7500** -0.3750	-	0.1433 0.4500	-2.0183 -2.2250	4.0268 4.7811	0.0303 0.6177
Inia		1.0833** 0.2500	-0.4583 0.0417	-0.2500 0.2500	-0.2500 0.0417	-	-1.5183 -1.6500	2.2585 2.5532	0.3491 0.6795

First reading under each column refers to Ellerslie and the second to Parkland.
* Significant at 5% level
**Significant at 1% level

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from selfed backcross diallel set at two locations.

TABLE 66. Heading-span

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	-0.0800 0.6200	0.2867 -0.6883	-0.1300 -1.1467	0.3700 -0.0050	0.1967 -0.1033	-0.0175 -0.1874	-0.1405 -0.4982
Chinook		-0.6550 -0.4167	-	-0.2217 -1.1217	-0.2783 -0.3717	0.8200 -1.1467	0.3717 0.6633	0.0819 0.3419	-0.1304 -0.3700
Khush-hal	Reciprocal effects	-0.0417 -0.1250	-0.0417 0.4583	-	0.0200 0.5283	-0.5217 0.7950	0.2550 0.0967	0.0088 -0.1887	-0.0968 0.0821
Ciano		0.3333 0.0	0.5833 0.0417	0.2917 0.1250	-	-0.3550 0.8367	-0.4533 0.0967	0.1493 -0.1887	-0.1089 0.0822
Inia		0.9167** 0.2917	-0.2083 0.2500	-0.3333 -0.6250	0.1250 -0.0883	-	-0.3700 -0.7533	0.0807 0.3694	0.2620 0.3871

TABLE 67. Plant height

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	-0.9476 -0.2017	0.7593 2.1257	2.0884 2.3297	-3.1655 -4.4209	14.0397 12.5270	195.9310 155.3739	-2.9557 -3.8799
Chinook		-0.8675 1.6562	-	-1.0681 0.3258	0.9945 0.1680	5.5803 2.0856	9.8603 12.5012	96.0433 154.7285	-2.6564 3.8664
Khush-hal	Reciprocal effects	2.7257 2.7450	2.4108 1.6100	-	0.4511 2.1056	0.6493 -0.9884	-8.6035 -8.7700	72.8374 75.3602	-2.3832 -2.3383
Ciano		5.4176** 5.5917**	0.8667 3.7682	-0.8083 0.1045	-	-2.4269 -1.6792	-6.1142 -7.7160	36.2005 57.9532	-1.1045 -0.5836
Inia		4.6572** 3.6565*	4.0180** 3.6762*	2.4962 -0.8220	0.4758 -0.1612	-	-9.1824 -8.5442	83.1345 71.4512	12.8684 5.3504

First reading under each column refers to Ellerslie and the second to Parkland.
* Significant at 5% level
**Significant at 1% level

in GCA and Ciano was the lowest. Marquis at Ellerslie and Chinook at Parkland ranked first for final heading while Ciano at both locations ranked last. For heading-span, Chinook showed the highest GCA and Inia the lowest at both locations. Marquis was the best combiner for plant height at both locations, while Inia at Ellerslie and Khush-hal at Parkland were the poorest. Chinook showed the highest GCA for number of tillers per plant at both locations and Inia was the lowest. Interpretations of GCA's for number of spikelets per spike, number of seeds per spike, weight of seeds per spike and 1000-kernel weight may be made in the same way. For yield per plant, Inia at Ellerslie and Marquis at Parkland had the highest GCA while Chinook at Ellerslie and Ciano at Parkland were the poorest.

The estimates of specific combining abilities, reciprocal effects and variances for general and specific combining abilities for onset-of-heading, final heading and heading-span are presented in Tables 64, 65 and 66. For onset-of-heading, cross (CxI) at Ellerslie and (MxC) at Parkland had the highest SCA while cross (MxI) at Ellerslie and (CHxC) at Parkland scored lowest. The best hybrid (CxI) at Ellerslie had parents with the lowest GCA's at both locations while the worst (MxI) and (CHxC) had one parent Marquis and Chinook which showed the highest GCA's at both locations. The variances for GCA were greater than those for SCA in all cases and the reciprocal effects were not significant. Interpretations for final heading (Table 65) and heading-span (Table 66) may be made in the same way.

For plant height (Table 67), hybrid (CHxI) at both locations

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from slated backcross diallel set at two locations.

TABLE 68. Number of tillers per plant

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	-0.2510 -0.1161	-0.7515 -0.5486	0.5171 -0.6927	0.2983 -1.0161	0.0554 0.7212	-0.4926 0.3487	-0.4891 -0.4286
Chinook		-0.8792 0.1237	-	-0.0109 -0.7988	1.0864 0.2752	-0.1939 0.6594	0.5642 0.7512	0.1227 0.3928	-0.4681 -0.4241
Khush-hal	Reciprocal effects	-0.1787 -0.6792	-0.6125 -0.4780	-	0.1419 0.7439	0.6200 0.4993	0.3819 0.3598	-0.0498 -0.0448	-0.3008 -0.1156
Ciano		0.5208 1.3028*	-0.4260 0.7470	0.3883 0.2823	-	-0.6341 -0.3619	-0.0788 -0.7265	-0.1894 0.3563	0.0001 -0.0590
Inia		-0.1333 -0.0542	0.3333 0.5090	0.4685 -0.2125	-0.0167 0.0857	-	-0.9226 -1.1017	0.0556 1.0423	-0.1848 0.1873

TABLE 69. Number of spikelets per spike

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	0.0734 0.5629	0.0484 0.1757	0.2291 -0.0347	-0.1514 -0.0883	0.7318 0.5099	0.5031 0.2252	-0.0810 -0.0870
Chinook		-0.1043 0.2835	-	-0.0157 -0.0718	0.5060 -0.0863	-0.3085 0.1980	0.1207 0.3313	-0.0178 0.0750	-0.0792 0.0186
Khush-hal	Reciprocal effects	0.2930 0.2293	0.2042 0.0835	-	0.1958 0.3633	0.3165 0.0295	-0.4789 -0.2941	0.1969 0.0517	-0.0801 -0.0750
Ciano		0.5625* 0.4038	-0.0867 0.4050	0.0905 0.4162	-	-0.1921 0.1860	-0.2321 -0.4894	0.0215 0.2047	0.0346 -0.0402
Inia		-0.1140 0.1040	0.3238 0.0657	0.1035 0.0598	-0.4457 -0.2070	-	-0.1415 -0.0577	-0.0124 -0.0315	0.0041 -0.0595

First reading under each column refers to Ellerslie and the second to Parkland.
*Significant at 5% level

Estimates of specific combining ability, reciprocal [illegible] and variances of general and specific combining ability; ability from selfed back[illegible] diallel set at two locations.

TABLE 70. Number of seeds per spike

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	-0.7567 1.1823	0.5266 0.3948	1.6680 1.0759	-1.1312 -0.8422	3.7367 1.8352	13.2888 2.9362	-1.6858 -1.0793
Chinook	Reciprocal effects	-0.0193 0.3758	-	-1.5155 -0.9569	1.7828 0.2750	0.5295 1.0215	-2.1908 -1.0805	4.1253 0.7357	-1.4949 -0.6134
Khush-hal		2.2568* 0.4473	0.6565 1.2037	-	-0.6317 -0.6815	1.1138 -0.3786	-1.2477 0.4308	0.8823 -0.2461	-0.8277 -0.7157
Ciano		3.6503** 1.9765	1.2765 2.0132	0.1728 1.6060	-	0.4189 1.2470	-1.6029 -1.8508	1.8950 2.7759	-0.4341 -0.5141
Inia		-0.1647 0.1222	1.2072 -0.5362	-1.7647 -0.0292	-1.2285 -1.0437	-	1.3047 0.6653	1.0280 0.0109	-0.6937 -0.0279

TABLE 71. Weight of seeds per spike

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	0.0198 0.0547	0.0027 0.0141	0.0572 0.0700	-0.0088 0.0494	0.0230 -0.0314	-0.0013 -0.0005	-0.0045 -0.0039
Chinook	Reciprocal effects	0.0158 0.0358	-	-0.0387 -0.0251	0.0596 0.0611	-0.0314 -0.0083	-0.1290 -0.0845	0.0148 0.0056	-0.0044 -0.0030
Khush-hal		0.0616 0.0115	0.0010 0.0585	-	-0.0354 -0.0536	0.0368 0.0111	-0.0362 0.0607	-0.0005 0.0021	-0.0040 -0.0037
Ciano		0.0635 0.0322	0.0053 0.0606	-0.0500 0.0683	-	-0.0179 0.0659	-0.0017 -0.0262	-0.0018 -0.0008	-0.0018 -0.0013
Inia		-0.0382 -0.0605	0.0082 -0.0293	-0.0368 -0.0732	-0.0763 -0.0942	-	0.1439 0.0834	0.0189 0.0054	-0.0036 -0.0016

First reading under each column refers to Ellerslie and the second to Parkland.

* Significant at 5% level

**Significant at 1% level

Estimates of specific combining ability, reciprocal effects and variances of general and specific combining ability from selfed backcross diallel set at two locations.

TABLE 72. 1000-kernel weight

♀ Parent		Specific combining ability					GCA	Variance of GCA	Variance of SCA
		Marquis	Chinook	Khush-hal	Ciano	Inia			
Marquis		-	0.1205 0.3031	-0.4528 0.0634	-0.2338 0.5471	0.7582 1.7552	-2.3425 -2.0504	5.0186 3.8294	-1.1713 -0.9369
Chinook	Reciprocal effects	0.6497 6.4662	-	0.4032 0.04[illegible]	-0.1392 -0.2633	-1.1356 -0.8131	-1.1454 -1.0151	0.8434 0.6557	-1.1665 -0.9063
Khush-hal		-0.2560 -0.0027	-0.3190 0.5133	-	-0.3410 0.5745	0.0372 0.2047	0.2448 0.9564	-0.4096 0.6180	-1.0488 -0.9325
Ciano		-0.9073 -0.8827	-0.9833 -0.2765	-1.1687 0.1982	-	-0.8553 0.5392	1.4072 0.9224	1.5116 0.4760	-1.1070 -0.7040
Inia		-1.5043 -1.1452	-0.5807 -0.1232	0.6037 -1.6265	-0.5812 -1.[illegible]087	-	1.8379 1.1468	2.9294 0.9405	-0.3055 0.4212

TABLE 73. Yield per plant

♀ Parent		Marquis	Chinook	Khush-hal	Ciano	Inia	GCA	Variance of GCA	Variance of SCA
Marquis		-	-0.7261 0.5455	-0.3666 0.4427	-0.7549 0.1542	0.5342 0.1742	-0.0471 -0.5386	-0.2104 0.0529	-0.5317 -0.5930
Chinook	Reciprocal effects	-0.7872 0.9510	-	0.0690 -1.0145	2.2304 0.3140	-0.7179 0.4450	-0.8473 0.0681	0.5052 -0.2316	-0.3559 -0.4939
Khush-hal		0.4678 0.0278	-0.4883 0.3663	-	0.2590 0.4008	0.3710 0.7432	-0.7653 0.3231	0.3731 -0.1328	-0.4868 -0.1846
Ciano		-0.3572 0.7125	-0.6105 0.7263	0.1253 1.4295*	-	-1.7015 -0.5442	0.6451 -0.2341	0.2034 -0.1824	1.3389 -0.4987
Inia		-0.1232 0.2093	-0.2025 0.5000	-0.0010 -0.4568	0.0565 -0.1675	-	1.0147 0.3815	0.8169 -0.0917	0.7462 -0.2341

First reading under each column refers to Ellerslie and the second to Parkland.
*Significant at 5% level

ranked highest while (MxI) ranked lowest. One parent of (CHxI), Chinook, showed the second highest GCA and the other, Inia, the lowest GCA at both locations. Similarly one parent of (MxI), Marquis, showed the highest GCA and other parent, Inia, the lowest GCA at both locations. The variances for GCA were greater in all the cases than those for SCA and the reciprocal effects were non-significant, except for (CxM), (IxM) and [illegible] at both locations. These effects may be attributed to the female parents of the respective crosses, because of the positive sign appended to each effect.

For number of tillers per plant, (CHxC) at Ellerslie and (KxC) at Parkland scored highest for SCA while cross (MxK) at Ellerslie and (MxI) at Parkland scored lowest (Table 68). The highest scoring hybrids at both locations had one parent, Ciano, with the second lowest GCA, while the poorest hybrids had one parent, Marquis, scoring second highest for GCA at both locations. The variances for GCA were greater than those for SCA except for Khush-hal at both locations and for Marquis and Ciano at Ellerslie. The reciprocal effects were generally non-significant except for (CxM) at Parkland. The results of the specific combining ability analysis for number of spikelets per spike (Table 69), number of seeds per spike (Table 70), weight of seeds per spike (Table 71) and 1000-kernel weight (Table 72) may be interpreted in the same way. Respective changes in the relative positions of the parents and hybrids for their GCA's and SCA's may be pointed out accordingly.

For yield per plant (Table 73), (CHxC) at Ellerslie and (KxI) at Parkland ranked highest for SCA while cross (CxI) at Ellerslie

TABLE 74

Analysis of variance of general and specific combining ability and reciprocal effects from selfed backcross diallel set at two locations.

Character	M.S. for GCA	M.S. for SCA	M.S. for Reciprocal effects	Error M.S.
D.F.	4	10	10	48
Onset-of-heading	25.2656** 35.9375**	1.5062** 1.0437*	0.2253 0.3587	0.2568 0.3877
Final heading	34.6875** 44.3750**	0.0500** 3.8562**	0.8927 0.1934	0.1753 0.6340
Heading-span	1.4606** 2.5920**	0.4038 1.9051	0.3882 0.1924	0.2107 0.7428
Plant height	1225.0937** 1300.5469**	13.5937** 13.0375*	19.2865** 16.0161**	4.4336 5.8198
Number of tillers per plant	3.3135** 7.3857**	0.7684 1.3497*	0.4297 0.6839	0.7332 0.6427
Number of spikelets per spike	2.1357** 1.7500**	0.2266 0.2414	0.1581 0.1404	0.1166 0.1306
Number of seeds per spike	61.4688** 21.4844**	3.6574 2.8805	5.4534* 2.7848	2.5252 1.6190
Weight of seeds per spike	0.0980** 0.0489**	0.0033 0.0095	0.0059 0.0066	0.0068 0.0059
1000-kernel weight	30.5469** 21.3039**	1.0941 2.0250	1.4995 1.3617	1.7574 1.4052
Yield per plant	6.8789** 1.4990	2.5621** 0.7430	0.3304 0.9333	0.7980 0.8897

First reading under each column refers to Ellerslie and second to Parkland.
* Significant at 5% level
**Significant at 1% level

and (CHxK) at Parkland ranked lowest. The best hybrid at Ellerslie had one parent (Chinook) with the lowest GCA for that location while the best hybrid (KxI) at Parkland had one parent (Khush-hal) with the second lowest GCA for that location. On the other hand, the poorest ranking hybrid (CxI) at Ellerslie had one parent, Inia, with the highest GCA for that location while the lowest scoring hybrid at Parkland had one parent (Chinook) with the second highest GCA for that location. Variances for GCA were larger than those for SCA except for Marquis at Ellerslie, Chinook, Khush-hal and Inia at Parkland, and Ciano at both locations. Only cross (IxK) at Parkland showed significant reciprocal effect which may be ascribed to Inia.

Analysis of variance of general and specific combining ability (Table 74) yielded significant mean squares for GCA for all characters except for plant height, number of tillers per plant and yield per plant at Parkland. Significance for SCA mean squares for onset-of-heading, final heading and plant height at both locations, and for yield per plant at Ellerslie show a relatively greater importance of SCA over GCA for these characters in the selection procedures of the breeding programmes.

Diallel cross analysis

The assumption of no differences between reciprocal crosses is tested in Table 75. Significance of the c component for plant height, number of seeds per spike and 1000-kernel weight at both locations and heading-span and weight of seeds per spike at Parkland indicates reciprocal

TABLE 75

Mean squares from the analysis of variance of 5 x 5 selfed backcross diallel set for ten characters at two locations.

Source of variation	D.F.	Onset-of-heading	Final heading	Heading-span	Plant height	Number of tillers per plant	Number of spikelets per spike	Number of seeds per spike	Weight of seeds per spike	1000 kernel weight	Yield per plant
a	4	75.7813** 107.8125**	104.2781** 133.2812**	4.3618* 7.7773	3675.7500** 3910.7500**	9.9355 22.1445**	6.4014** 5.2451*	184.4062** 64.4669**	0.2940* 0.1460*	91.6406** 62.9531**	20.6309 4.5000
b	10	4.5612** 3.1750	3.1875** 11.5562**	1.2113 5.7149	40.6000* 40.9000	2.3000 4.0539	0.6820 0.7270	11.0250 8.6687	0.0099 0.0236	3.3000 6.0937	7.6695 2.2301
b_1	1	14.0519 12.1002	6.5269 41.2552	0.0513 8.6700	25.4775 10.2661	2.0285 5.5196	1.4763 4.5690*	12.0519 19.1336	0.0001 0.0721	10.1405 10.3402	1.2520 5.1668
b_2	4	2.5469 1.1406	2.3125 5.7969	1.2296 4.6944	22.5000 61.6034	1.4173 5.2702	0.8340 0.0742	10.5966 11.3848	0.0095 0.0482	2.4014 9.7090	[illegible] 0.3721
b_3	5	4.1375** 3.0000	3.1625** 10.2500**	1.3000** 5.9492**	58.2000* 30.6375*	3.0078* 2.7336**	0.4066 0.4367	11.1500 4.4373	0.0124 0.0044	2.6750 2.3750	10.0445 3.1320
c	4	0.6323 0.4510	2.4437 0.2665	0.0652 0.6625*	124.9277** 111.7065**	1.1638 2.3081	0.6293 0.9578	31.4601* 18.2904**	0.0241 0.0421**	6.2045** 6.9094*	0.5412 4.0602
d	6	0.7052 1.4927	2.8344 0.7934	1.4042 0.5201	13.1473 5.6094	1.3726 1.8806	0.3740 0.0632	6.2935 [illegible]	0.0834 [illegible]	2.8714 2.1623	1.2913 1.9465
Blocks x *a*	8	0.6354* 1.5469	0.5313 2.9687	0.6566 5.7076	35.1494 26.2500	4.2524 3.4037	0.6206 0.8687	[illegible]	0.0553 0.0357	12.6406 7.2256	3.5356 5.3936
Blocks x *b*	20	1.1750 1.5375	0.0219 2.7594	0.7957 2.6783	11.6469 27.2594	1.7526 2.4264	0.4207 0.4600	6.4000 5.3156	0.0207 0.0241	5.1812 5.0729	2.6195 2.7564
Blocks x b_1	2	7.9587 4.9004	1.1337 22.6079	3.9429 9.6837	35.1591 243.6152	0.6380 29.1593	0.9345 0.0720	28.6424 1.6645	0.0527 0.0962	1.9694 31.9250	2.5027 3.6281
Blocks x b_2	8	1.4365 [illegible]	0.7158 2.1784	1.3752 4.2428	11.5615 27.5938	3.1234 2.0336	0.5036 0.8176	6.4000 10.4900	0.0332 0.0393	9.0072 6.0999	5.2074 3.9131
Blocks x b_3	10	0.4367 1.0175	[illegible] 1.5125	0.0068 0.9535	10.7312 8.1167	0.6729 0.2539	0.3559 0.2363	4.7437 2.0675	0.0055 0.0065	2.2551 1.3659	0.7465 2.0207
Blocks x *c*	8	0.4682 0.7701	0.7219 0.5036	0.6130 0.1562	6.4531 5.2470	1.0612 0.9600	0.2022 0.1417	4.9007 1.2552	0.0101 0.0034	0.6012 1.3100	1.3497 1.6076
Blocks x *d*	12	3.1975 0.5823	0.2479 0.7042	0.1552 0.5399	6.2176 3.0175	2.4186 0.7633	0.2315 0.1323	2.2117 2.0705	0.0034 0.2046	3.5959 2.7544	1.9556 1.2623
Error	48	[illegible] 1.2632	0.5299 1.5045	0.0324 2.2223	11.3400 17.5610	2.2025 1.1313	0.3665 0.1935	7.6610 4.8671	0.0204 0.0178	5.2758 4.2249	2.3346 2.6701

* Significant at 5% level

** Significant at 1% level

First reading under each column refers to Ellerslie and second to Parkland. Error D.F. comprises of block interaction with D.F. of (a+b+c+d).

Each component has been tested against its own block interaction.

TABLE 76

Analysis of variance of [illegible] - V_r
from selfed backcross diallel set for ten characters at two locations.

Character	Block M.S.	Entry M.S.[1]	Error M.S.
Onset-of-heading	9.0481 3.0085	[illegible] [illegible]	[illegible] 0.2390
Final heading	[illegible] 34.1673	[illegible] 1.1202	0.1025 1.2703
Heading-span	[illegible] 4.9129	[illegible] [illegible]	[illegible] 1.1054
Plant height	[illegible] 6447.6375	[illegible] 166.1675	[illegible] 194.[illegible]
Number of tillers per plant	[illegible] 25.0647	0.2479 [illegible]	[illegible] [illegible]
Number of spikelets per spike	[illegible] [illegible]	[illegible] [illegible]	0.0445 [illegible]
Number of seeds per spike	230.2712 27.1[illegible]	[illegible] [illegible]	15.[illegible] [illegible]
Weight of seeds per spike	[illegible] [illegible]	[illegible] [illegible]	[illegible] [illegible]
1000-kernel weight	[illegible] 18.[illegible]	1.5702 5.[illegible]	2.7421 5.6779
Yield per plant	[illegible] [illegible]	[illegible] 0.1568	[illegible] [illegible]

First reading under each column refers to Ellerslie and second to Parkland.

TABLE 77

Estimates of second degree statistics from selfed
backcross diallel set for ten characters at two locations.

Character	[illegible]	[illegible]	[illegible]	[illegible]	$(M_{L1} - M_{L0})^2$
Onset-of-heading	15.6000 15.7002	0.1531 7.4024	2.5312 3.5077	3.2941 4.1244	0.7921 0.6434
Final heading	16.9006 27.1514	7.6016 10.9432	3.4756 4.4403	4.0049 6.3744	0.3941 -2.2001
Heading-span	0.5069 1.6111	0.2319 0.5279	0.1462 0.2593	0.3160 1.2118	0.0348 0.4624
Plant height	485.7744 516.4134	243.1320 257.2012	122.5254 130.6756	128.3212 137.4928	1.3533 0.5476
Number of tillers per plant	1.4343 5.4749	0.6190 1.6430	0.3113 0.7383	0.7159 1.4139	0.1081 0.2944
Number of spikelets per spike	1.2261 0.5749	0.4789 0.3149	-0.2136 0.1756	0.3275 0.2965	0.0787 0.2436
Number of seeds per spike	26.9183 12.2475	13.0658 4.0342	6.1455 2.1465	7.9799 3.5906	0.6427 1.0207
Weight of seeds per spike	0.0384 0.0360	0.0189 0.0115	0.0098 0.0049	0.0115 0.0097	0.0003 0.2238
1000-kernel weight	16.7744 13.1670	7.1279 4.9033	3.6537 2.0977	3.6014 3.1123	0.5408 0.5517
Yield per plant	5.4531 0.6675	1.7342 0.3533	0.0680 0.1502	1.9697 0.5220	0.0668 0.2755

First reading under each column refers to Ellerslie and second to Parkland.

differences for these characters. Significance of the a for all characters except heading-span at Ellerslie, number of tillers per plant at Parkland and yield per plant at both locations indicates substantial differences among the parents. Significance of b for final heading at both locations and onset-of-heading and plant height at Ellerslie shows that dominance is present while b_1 for number of spikelets per spike at Ellerslie shows that dominance is directional. Analysis of $W_r - V_r$ (Table 76) indicates that other assumptions, viz., no non-allelic interaction, no multiple allelism and uncorrelated gene distribution, are valid for all characters at both locations.

After Hayman's (1954a) procedure of replacement of reciprocal crosses by their common means, diallel analysis for genetic components of variation was carried out. Estimates of second degree statistics are given in Table 77 and the genetic components of variation obtained from them are presented in Table 78. Significance of components of variation was tested as in the previous diallel analyses of F_1, F_2 and backcross sets. The proportional values of the estimates of genetic parameters from Table 78 are given in Table 79.

The ratio $(H_1/D_1)^{1/2} < 1$ for onset-of-heading at both locations (Table 79) shows that dominance is partial (see also Figure 61). The estimate of $[H_2 \div 4H_1] = 0.21$ at Ellerslie and 0.24 at Parkland implies some asymmetry in numbers of positive and negative alleles at loci exhibiting dominance at Ellerslie and equal proportion of positive and negative effects at Parkland. The proportion of dominant to recessive genes in the parents is > 1 at both locations indicating thus

TABLE 78

Estimates of genetic components of variation from selfed backcross diallel set for ten characters at two locations.

Character	D	F	H_1	H_2	h^2	E
Onset-of-heading	14.7431 ± 0.2183** 15.3126 ± 0.1216**	5.0792 ± 0.5153** 1.0037 ± 0.3037**	2.8760 ± 0.5395** 1.3386 ± 0.3202**	2.5377 ± 0.5347** 1.3319 ± 0.2978**	3.0042 ± 0.3610** 2.3336 ± 0.2010**	0.2569 ± 0.0891** 0.3876 ± 0.0196**
Final heading	16.7914 ± 0.1355** 20.5164 ± 0.5172**	3.3863 ± 0.4394** 9.7661 ± 1.4663**	2.1242 ± 0.5200** 7.2254 ± 1.5958**	1.7665 ± 0.4789** 6.4425 ± 1.4383**	1.2804 ± 0.3233** 8.3949 ± 0.9711**	0.1753 ± 0.0795** 0.6350 ± 0.2397**
Heading-span	0.3701 ± 0.1709 2.8664 ± 0.3026**	-0.0027 ± 0.4460 2.6195 ± 0.9734**	0.5654 ± 0.4831 2.8156 ± 0.9766**	0.3859 ± 0.4381 2.3245 ± 0.6356**	0.0045 ± 0.2958 1.3742 ± 0.5981**	0.3108 ± 0.0750** 0.7428 ± 0.1476**
Plant height	482.[illegible] ± [illegible]** 512.[illegible] ± 4.6412**	-4.1311 ± 14.7593 1.7742 ± 12.6034	20.1[illegible] ± 15.9[illegible]24 24.4779 ± 13.0743	18.3212 ± 14.4962 15.6201 ± 11.6585	2.5931 ± 9.7870 -1.5344 ± 8.0062	4.4336 ± 2.4160** 5.8199 ± 1.9764**
Number of tillers per plant	0.7606 ± 0.1506** 4.6319 ± 0.2[illegible]**	-0.4021 ± 0.4[illegible] 2.6662 ± 0.5145**	-0.[illegible]52 ± 0.5256 2.0068 ± 0.5562**	0.0716 ± 0.4767 1.4165 ± 0.5045**	-0.0365 ± 0.3210 0.7661 ± 0.3406	0.7337 ± 0.0795** 0.6429 ± 0.0841**
Number of spikelets per spike	1.1564 ± 0.0[illegible]** 0.4344 ± 0.0434**	0.3353 ± 0.1531* -0.2666 ± 0.1[illegible]	0.3672 ± 0.1632 0.1616 ± 0.1172	0.2130 ± 0.1472 0.2248 ± 0.1063	0.2172 ± 0.0994** 0.8911 ± 0.0716**	0.1215 ± 0.0245** 0.1305 ± 0.0177**
Number of seeds per spike	26.4604 ± 0.7377** 26.7556 ± 0.7635**	3.4034 ± 1.5922** 3.9757 ± 1.9572**	2.8756 ± 2.1538 3.3441 ± 2.0619	2.2802 ± 1.9535 2.5367 ± 1.6702	0.9525 ± 1.3169 3.0465 ± 1.2620**	2.5286 ± 0.3250** 1.6169 ± 0.3117**
Weight of seeds per spike	0.0316 ± 0.0035** 0.0352 ± 0.0025**	-0.0017 ± 0.0023 0.0150 ± 0.0062**	-0.0092 ± 0.0025** 0.0133 ± 0.0067**	-0.0070 ± 0.0022** 0.0072 ± 0.0061	-0.0043 ± 0.0015** 0.0116 ± 0.0041**	0.0068 ± 0.0004** 0.0059 ± 0.0010**
1000-kernel weight	15.0175 ± 0.3656** 11.7016 ± 0.7513**	2.9138 ± 0.9958** 5.0319 ± 1.8779**	-1.8099 ± 0.9733 2.3466 ± 2.0302	-1.3233 ± 0.8833 1.2478 ± 1.8414	1.0390 ± 0.5964 1.3076 ± 1.2432	1.7569 ± 0.1472** 1.4054 ± 0.3069**
Yield per plant	4.6683 ± 1.1855** -5.0021 ± 3.2412	3.0160 ± 2.9624 -0.7056 ± 0.3527	4.3245 ± 3.2027 -0.7503 ± 0.3814	3.5319 ± 2.9049 -0.2018 ± 0.3459	-0.2431 ± 1.9612 0.5329 ± 0.2335	0.7975 ± 0.4841** 0.8896 ± 0.0476**

First reading under each column refers to Ellerslie and second to Parkland.
* Significant at 5% level
**Significant at 1% level

TABLE 79

Proportional values of the estimates of genetic parameters from selfed backcross diallel set for ten characters at two locations.

Character	$[H_1/D]^{1/2}$	$[H_2/4H_1]$	$\left[\frac{(4DH_1)^{1/2}+F}{(4DH_1)^{1/2}-F}\right]$	h^2/H_2	r_{Y_r, W_r+V_r}	Heritability
Onset-of-heading	0.4432* 0.2957*	0.2119* 0.2487*	2.2715* 1.2715*	1.1839* 1.7521*	0.9161 0.6870	1.0850 0.8945
Final heading	0.3557* 0.5220*	0.2079* 0.2229*	1.7680* 2.0905*	0.7248* 1.3030*	0.7816 0.9245	1.0301 1.0001
Heading-span	1.1562 0.9908*	0.1909 0.2064*	0.9939 2.7079*	0.0116 0.5912*	-0.0581 0.7279	0.2186 0.4752
Plant height	0.2043 0.2185	0.2176 0.1596	0.9584 1.0099	0.1418 -0.0982	-0.4065 -0.6697	0.9198 0.9165
Number of tillers per plant	0.3488 0.6572*	-0.2083 0.1697*	0.0013 2.5834*	-0.5189 0.5408	-0.7496 0.6240	0.1735 0.7228
Number of spikelets per spike	0.5268 0.6031	0.1733 0.3477	2.0258 0.3357	1.1137 3.9638	-0.8852 -0.0175	0.7355 0.3186
Number of seeds per spike	0.5298 0.6020	0.1979 0.1651	1.5011 1.9039	0.4177 1.2000	-0.6535 -0.5060	0.7359 0.6257
Weight of seeds per spike	0.5392 0.6640*	0.1904 0.1357	0.6546 2.8052*	0.6502 1.6045	0.9431 -0.2946	0.6159 0.6270
1000-kernel weight	0.3557 0.4467	0.1741 0.1329	1.7554 2.8281	-0.7852 1.0[illegible]	0.3482 -0.3856	0.8722 0.8002
Yield per plant	0.9635 18.0020	0.2042 0.0972	2.0130 -0.7970	-0.[illegible] -1.[illegible]	[illegible]2 0.5[illegible]5	0.5088 -0.0005

First reading under each column refers to Ellerslie and second to Parkland.
*Proportional values involving genetic components of variation significantly different from zero ($P \leq 0.05$)

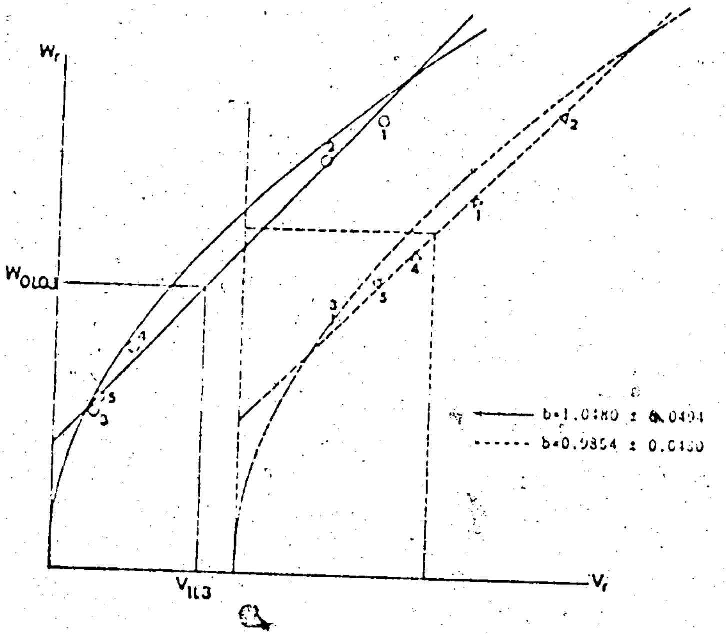

Figure 61. W_r, V_r graph for onset-of-heading from selfed backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

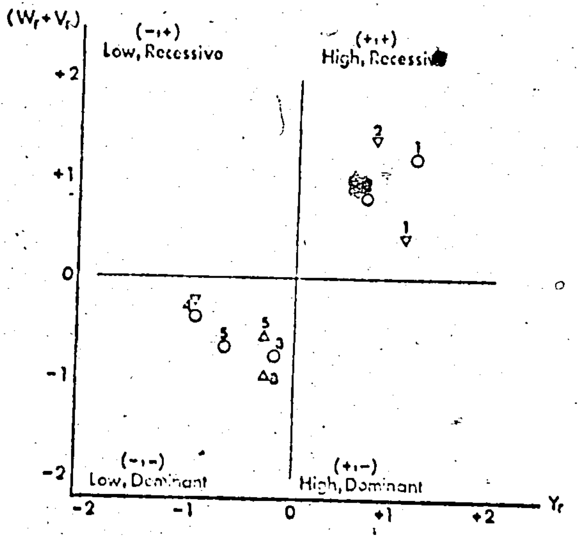

Figure 62. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for onset-of-heading from selfed backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

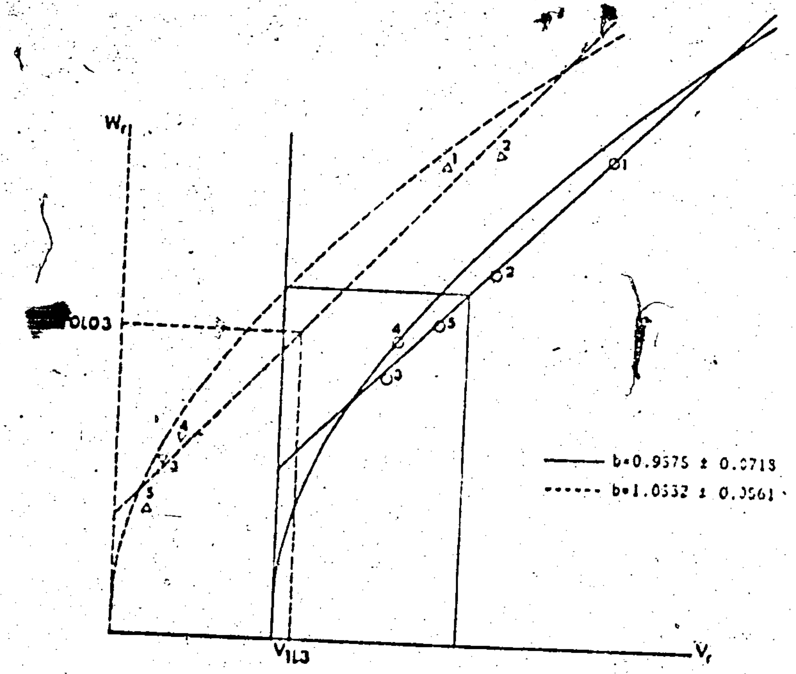

Figure 63. W_r, V_r graph for final heading from selfed backcross diallel set.

— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

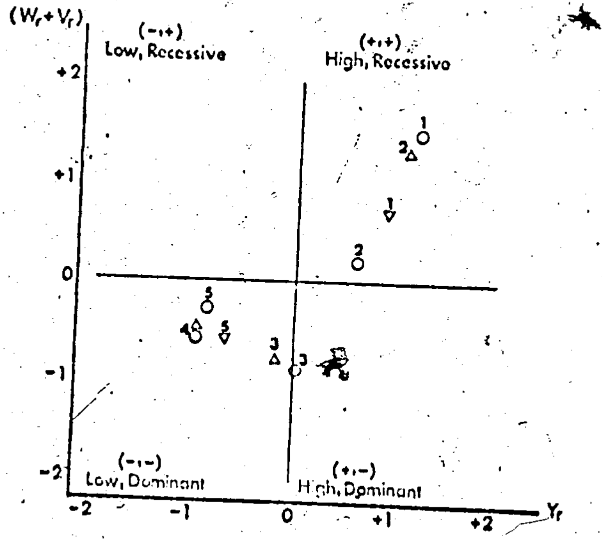

Figure 64. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for final heading from selfed backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

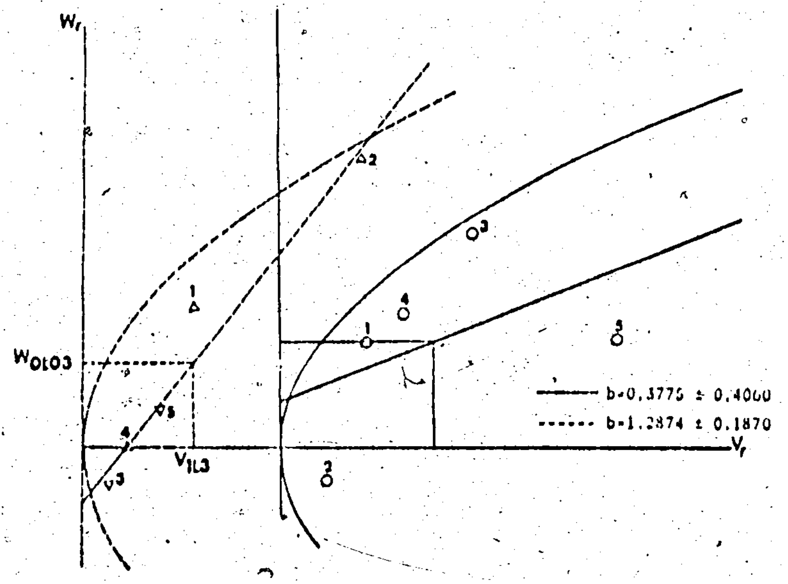

Figure 65. W_r, V_r graph for heading-span from selfed backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

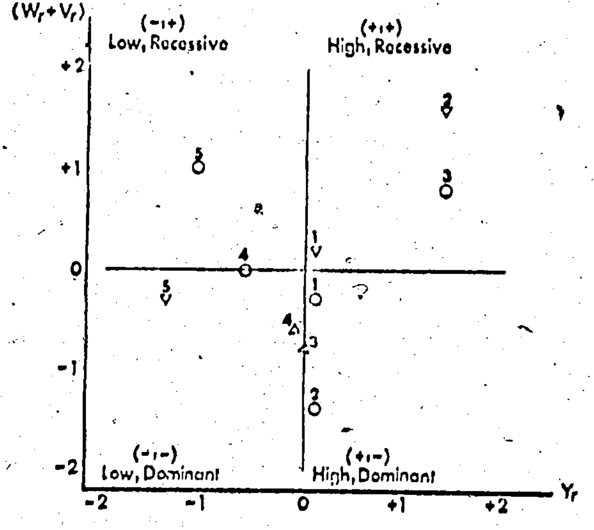

Figure 66. Standardized-deviation graph of $[Y_r]$ and $[W_r + V_r]$ for heading-span from selfed backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

a preponderance of dominant genes. $[h^2/H_2] > 1$ at both locations suggests that at least two groups of genes exhibiting dominance contribute to the control of onset-of-heading. The coefficients of correlation between parental order of dominance and parental measurements (0.916 at Ellerslie and 0.687 at Parkland) indicate that earliness is dominant over lateness. Figure 61 shows that Marquis at Ellerslie and Chinook at Parkland are the most recessive parents while Khush-hal at both locations is the most dominant. Figure 62 places Marquis and Chinook in the (+,+) quadrant, indicating that lateness of these parents is associated with recessive genes. Khush-hal, Ciano and Inia occupy the (-,-) quadrant at both locations, suggesting that these parents are early maturing dominants.

The interpretations from Tables 78 and 79 for final heading (Figures 63, 64) and for heading-span (Figures 65, 66) may be made in the similar fashion. The changes in the relative position of the parents with respect to their order of dominance at the two locations could be attributed to environmental effects.

In case of plant height, the ratio of $[H_1/D]^{1/2} < 1$ at both locations indicates that the character is inherited as a partially dominant trait. Since all other components of variation, except D and E are non-significant at both locations (Table 78), the interpretation of proportional values of genetic parameters is meaningless. Figure 67 classifies Ciano at Ellerslie and Khush-hal at Parkland as the most recessive parents and Chinook as the most dominant at both locations. Figure 68 indicates that the most dominant parent (Chinook) at both

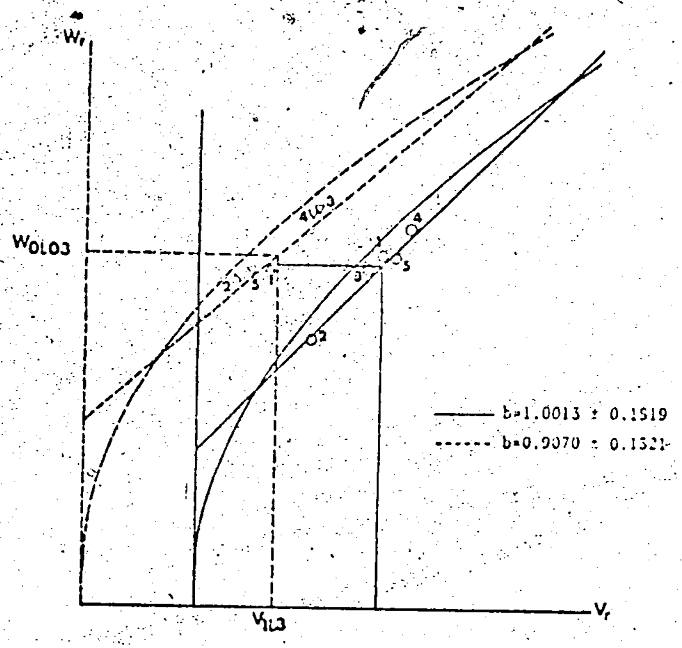

Figure 67. W_r, V_r graph for plant height from selfed backcross diallel set.

— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

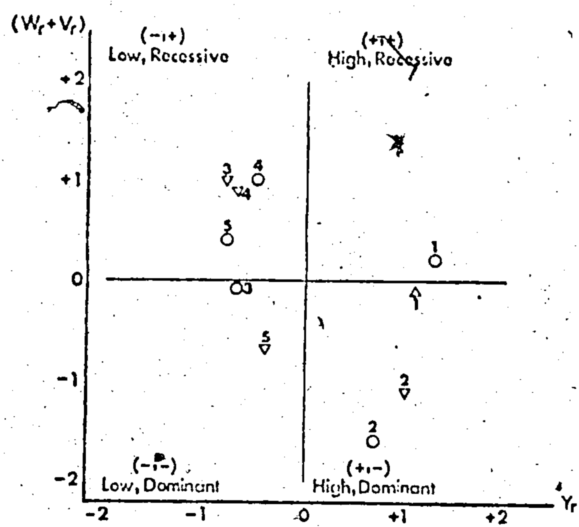

Figure 68. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for plant height from selfed backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

locations, contributes to tallness, while the most recessives (Ciano and Khush-hal) contribute to shortness; i.e. the order of dominance of the parents is negatively correlated with their measurements. However, as shown in Table 79, the respective coefficients of correlation do not reach the 5% level of significance. The order of dominance of parents seems to differ at the two locations (Figure 68). The most recessive parent at Parkland (Khush-hal; -,+ quadrant) possesses an excess of dominant genes (-,- quadrant) at Ellerslie, while India with an excess of recessive genes at Ellerslie (-,+ quadrant), appears to have a preponderance of dominants at Parkland (-,- quadrant). Marquis, recessive at Ellerslie becomes dominant at Parkland. The ranking order of Ciano and Chinook remained unchanged. The coefficient of heritability was very high (91%) at both locations.

For number of tillers per plant, only the D and E components of variation were significant at Ellerslie, while all components except h^2 were significant at Parkland. Consequently, the proportional values of the estimates of parameters for Ellerslie data are not discussed. However, the mean degree of dominance may be given, since $(H_1 \div D)^{1/2} < 1$ for both locations indicating that tillering capacity is inherited as partially dominant. The ratio $[H_2 \div 4H_1] = 0.169$ at Parkland suggests asymmetry of positive and negative alleles at loci exhibiting dominance. The proportion of dominant to recessive genes in the parents is 2.58 indicating a preponderance of dominants. Since $[h^2/H_2] = 0.54$, it may be assumed that at least one group of genes exhibit dominance and control the inheritance of tiller number. The correlation coefficient between

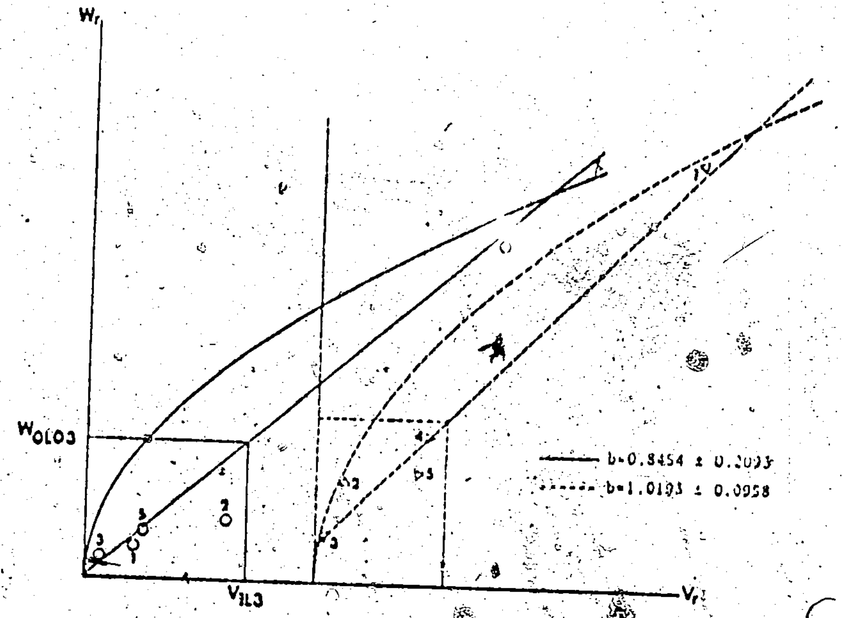

Figure 69. W_r, V_r graph for number of tillers per plant from selfed backcr diallel set.

—— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at P land

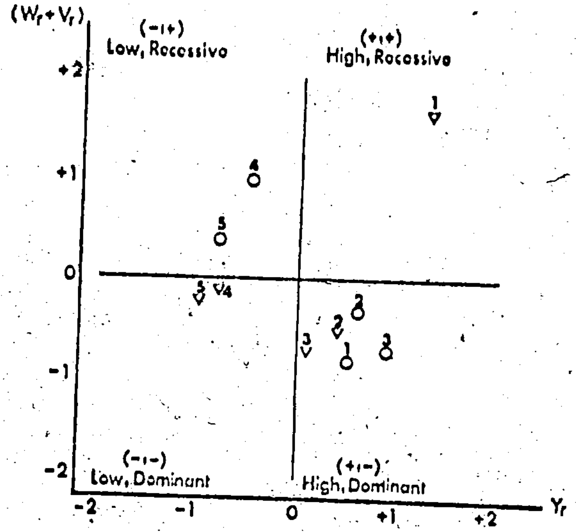

Figure 70. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of tillers per plant from selfed backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

parental order of dominance and parental mesurements is -0.748 at Ellerslie and 0.624 at Parkland. The significant negative correlation at Ellerslie indicates that the high tillering capacity is dominant over low tillering capacity while positive correlation at Parkland concludes that lower tiller number is dominant over higher. Figure 69 classifies Ciano and Khush-hal at Ellerslie as the most recessive and the most dominant parents, respectively. At Parkland, Marquis and Khush-hal are the most recessive and the most dominant parents, respectively. Figure 70 shows changes in the dominance ranking order of the parents between the two locations. Marquis, the most recessive parent at Parkland, (+,+ quadrant) appears to contain an excess of dominant genes at Ellerslie (+,- quadrant) while Ciano and Inia, recessive parents at Ellerslie (+,+ quadrant) appear as dominant at Parkland (-,- quadrant). Ranking order of Khush-hal and Chinook remain unchanged. The heritability estimates of 17.35% at Ellerslie and 72.28% at Parkland show that the character is highly unstable. This unstability may be due to non-significance of genetic components of variation at Ellerslie and significance of environmental components of variation at both locations.

The results of diallel cross analysis from Tables 78 and 79 for number of spikelets per spike (Figures 71, 72), number of seeds per spike (Figures 73, 74), weight of seeds per spike (Figures 75, 76) and 1000-kernel weight (Figures 77, 78) may be interpreted in the same way as number of tillers per plant. Respective changes in the ranking order of parents for order of dominance and significance or non-significance

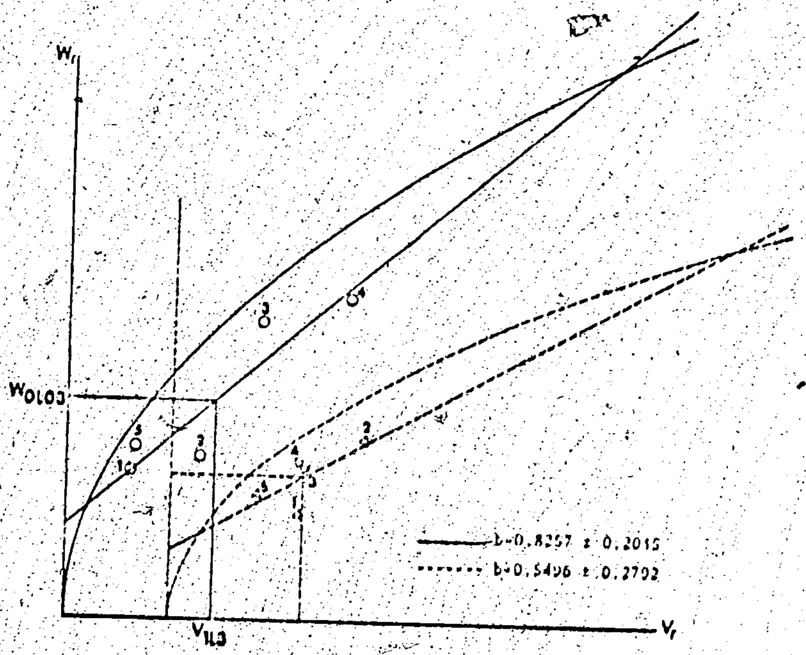

Figure 71. W_r, V_r graph for number of spikelets per spike from selfed backcross diallel set.

— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

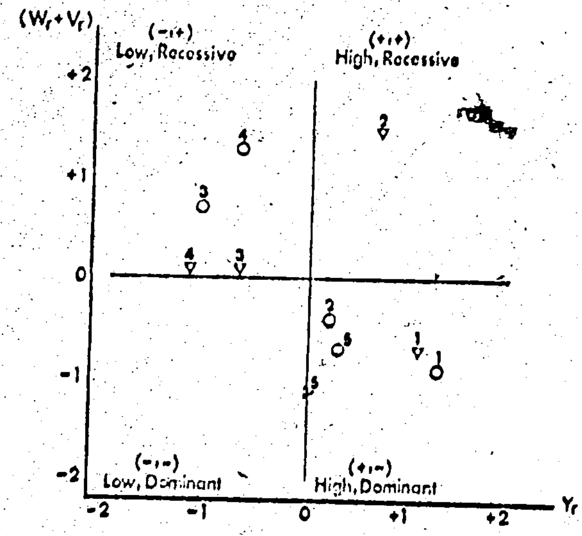

Figure 72. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of spikelets per spike from selfed backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

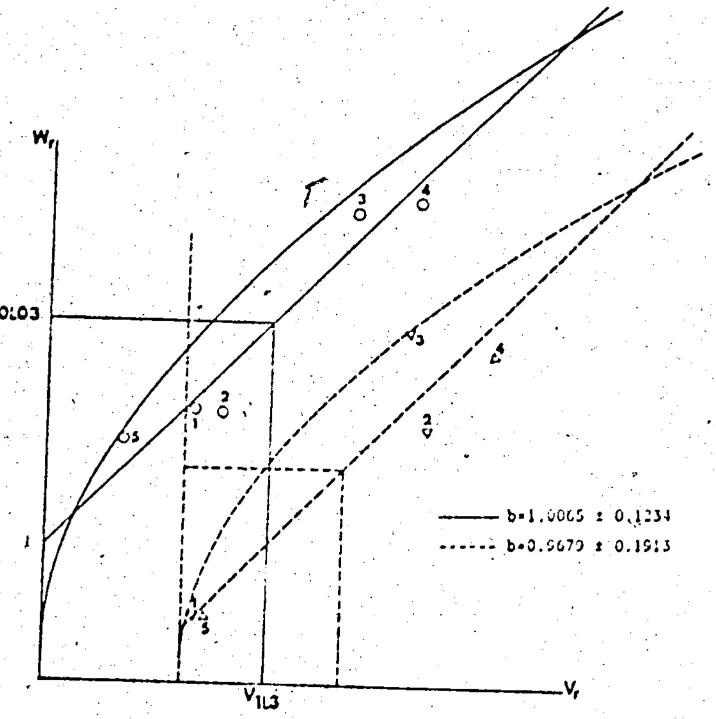

Figure 73. W_r, V_r graph for number of seeds per spike from selfed backcross diallel set.

—— o = W_r, V_r intercepts at Ellerslie

- - - Δ = W_r, V_r intercepts at Parkland

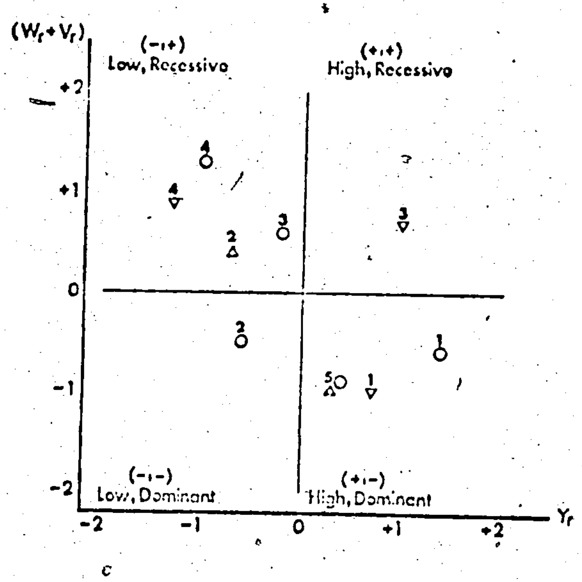

Figure 74. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for number of seeds per spike from selfed backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

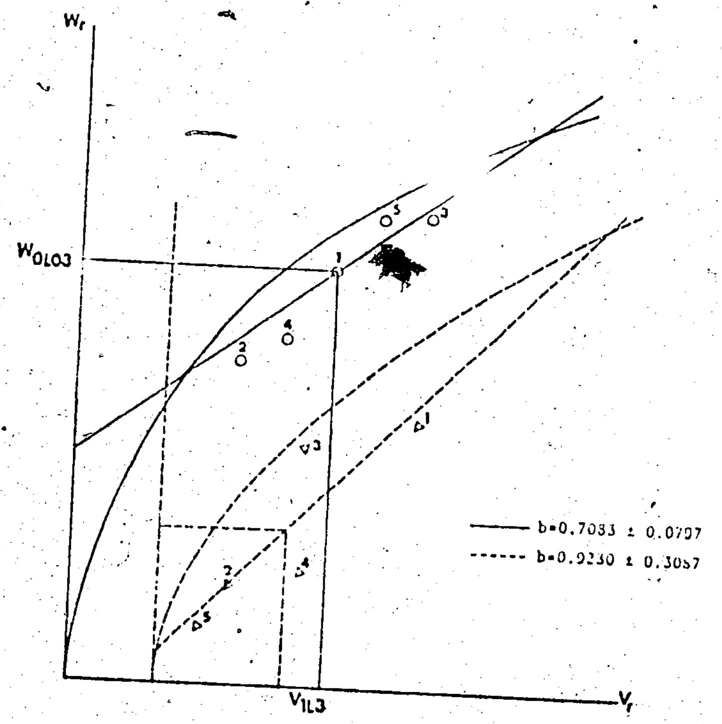

Figure 75. W_r, V_r graph for weight of seeds per spike from selfed backcross diallel set.

— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

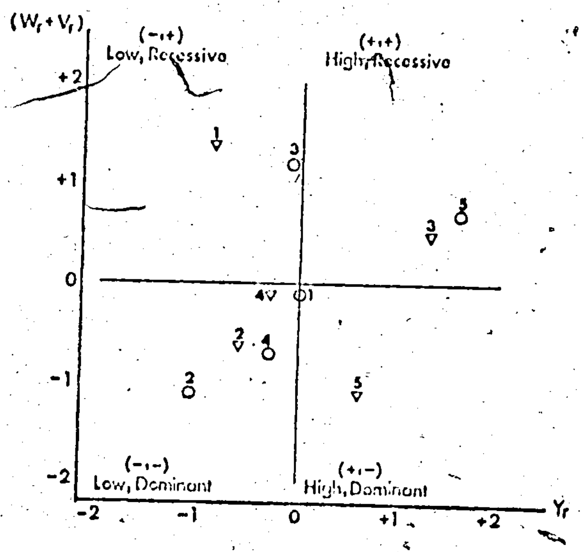

Figure 76. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for weight of seeds per spike from selfed backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

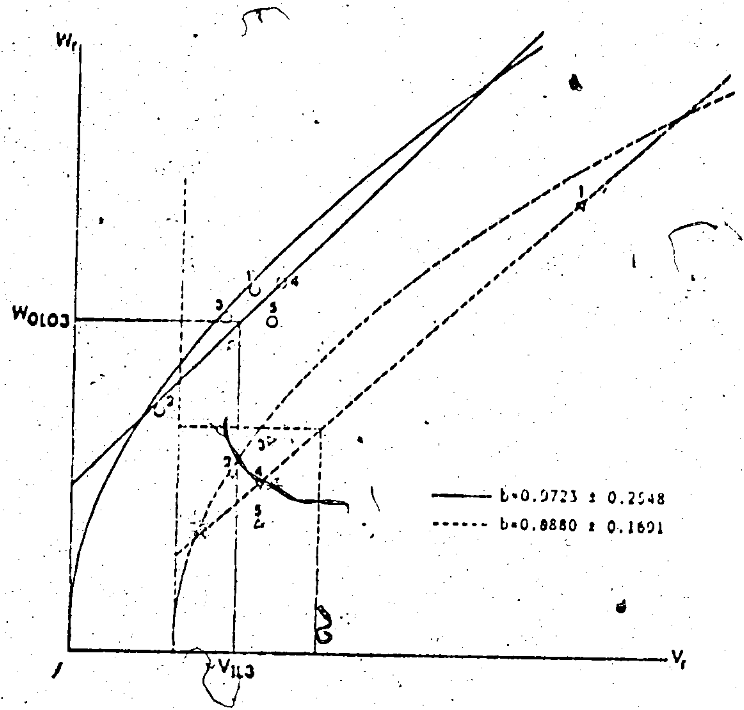

Figure 77. W_r, V_r graph for 1000-kernel weight from selfed backcross diallel set.

— o = W_r, V_r intercepts at Ellerslie

--- Δ = W_r, V_r intercepts at Parkland

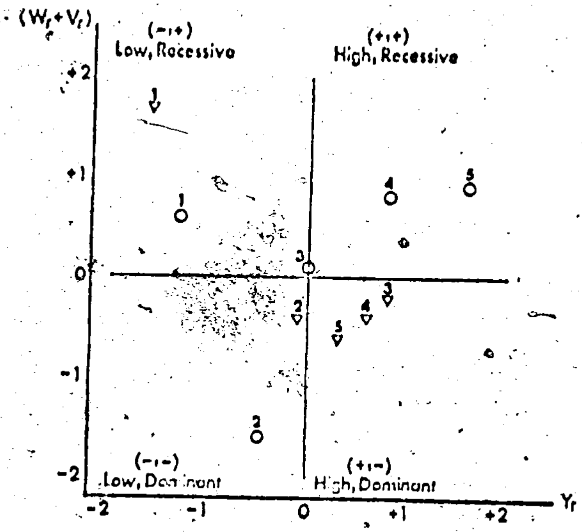

Figure 78. Standardized deviation graph of $[Y_r]$ and $[W_r + V_r]$ for 1000-kernel weight from selfed backcross diallel set.

o = Y_r, $[W_r + V_r]$ intercepts at Ellerslie

Δ = Y_r, $[W_r + V_r]$ intercepts at Parkland

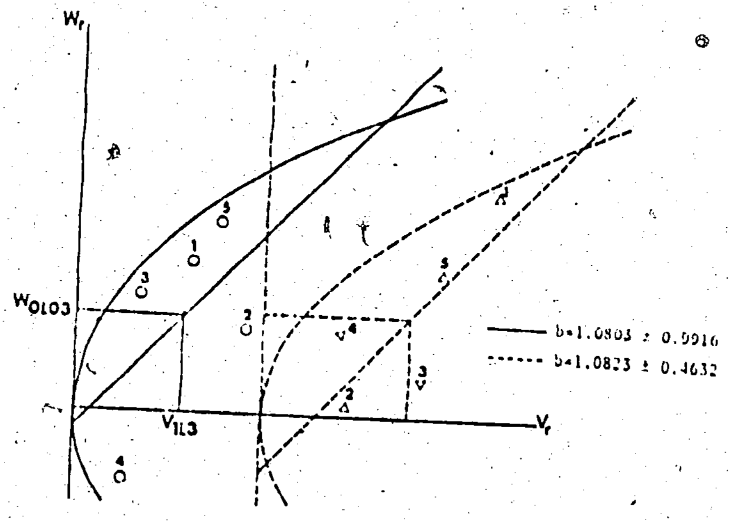

Figure 79. W_r, V_r graph for yield per plant from selfed backcross diallel set.

— o = W_r, V_r intercepts
at Ellerslie

--- Δ = W_r, V_r intercepts
at Parkland

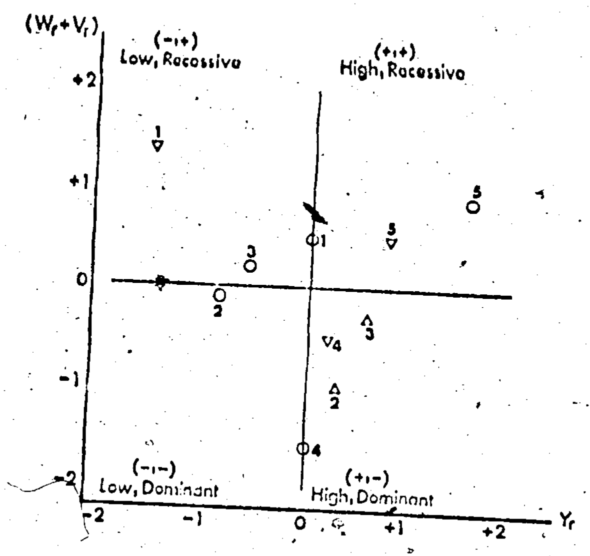

Figure 80. Standardized deviation graph of [Y_r] and [$W_r + V_r$] for yield per plant from selfed backcross diallel set.

o = Y_r, [$W_r + V_r$] intercepts
at Ellerslie

Δ = Y_r, [$W_r + V_r$] intercepts
at Parkland

of genetic components of variation over the two locations may be interpreted accordingly.

In case of yield per plant, all the components of variation except D and E at Ellerslie and E at Parkland were non-significant. The proportional values of the genetic parameters given in Table 79 therefore do not carry valid conclusions. The ratio $[H_1 \div D]^{1/2} > 1$ at Parkland and ≈ 1 at Ellerslie suggests over-dominance and nearly complete dominance. The W_r, V_r graph (Figure 79) shows over-dominance at both locations (the regression line intersects the limiting parabola below the origin). The correlation coefficient of 0.327 at Ellerslie and -0.594 at Parkland suggests that low yielding capacity is dominant over high yield at Ellerslie and vice versa at Parkland. Figure 79 categorizes Inia and Ciano as the most recessive and dominant parents, respectively, at Ellerslie, while Marquis and Chinook as the most recessive and dominant parents, respectively, at Parkland. Figure 80 suggests that the highly recessive parent at Ellerslie is high yielding (+,+ quadrant), while the highly recessive parent at Parkland is low yielding (−,+ quadrant). Figure 80 also reveals changes in the ranking of parents with respect to their order of dominance at both locations. Khush-hal, recessive low-yielding at Ellerslie, appears to be dominant high-yielding at Parkland. Marquis, the most recessive parent at Parkland, appears comparatively less recessive at Ellerslie. Inia, Chinook and Ciano remained unchanged. Heritability of 51% at Ellerslie and -0.0005 ≈ 0% at Parkland suggests, respectively, high and non-heritable nature of yield. This reflects the inter-location environmental effect on the inheritance of yield.

GENOTYPE-ENVIRONMENT INTERACTION

This section of the experimental results deals with the comparison of the estimates of factor loadings, general combining abilities and genetic components of variation obtained from the analyses of four diallel sets considered over two locations.

In order to assess the stability of five principal factors with respect to their loadings on different characters, the varimax rotated factor matrices of F_1, F_2, backcross and selfed backcross diallel sets were factorially analysed for two locations. The results of analysis of variance are given in Table 80. Significance of mean squares for principal factors (F) and Characters (C) (upper part of Table 80) suggests that the number of factors required to explain the variability in the data varies with the number and the degree of expression of the characters under study. This is also indicated by significant F x C interaction, which implies that the differences between the contributions of different characters to factor loadings vary with the number of principal components. Significant inter-location effects (L) indicate differences in scores on the characters related to different principal components at different locations. Significance of the second order interaction, L x F x C, may be considered as interaction [illegible] the L x F with C, L x C with F, or of F x C with L. Since L x C is not significant, indicating that characters do not vary with locations, the L x F x C interaction may be interpreted in the light of L x F and F x C interactions alone. In the first case, L x F x C indicates that after pooling the sum of squares

TABLE 80

Factorial analysis of variance of factor loadings of varimax rotated factor matrices of F_1, F_2, backcross and selfed backcross diallel sets over two locations.

Source of variation	D.F.	Sum of squares	Mean squares	F ratio
Locations (L)	1	0.23868	0.23868	5.15589*
Principal factors (F)	4	2.73528	0.68382	14.77165**
L x F	4	2.39790	0.59947	12.94968**
Generations (G)	3	0.07528	0.02509	0.54210
L x G	3	0.08975	0.02991	0.64629
F x G	12	0.54642	0.04503	0.97284
L x F x G	12	0.19273	0.01606	0.34695
Characters (C)	9	1.80613	0.20068	4.33507**
L x C	9	0.76141	0.08460	1.82754
F x C	36	22.47183	0.62421	13.48413**
G x C	27	0.54033	0.02001	0.43230
L x F x C	36	7.44184	0.20671	4.46545**
L x G x C	27	0.91759	0.03398	0.73413
F x G x C	108	12.82314	0.11837	2.56482**
Error (L x F x G x C)	108	4.99961	0.04629	-
Locations	1	0.23868	0.23868	1.76766
Principal factors	4	2.73528	0.68382	5.06437**
L x F	4	2.39790	0.59974	4.43972**
Error	390	52.66000	0.13502	-

* Significant at 5% level
**Significant at 1% level

for characters into error sum of squares, the values of factor loadings vary at each location, and in the second case, it shows that the score of factor loadings on each character varies with the number of principal factors, considered independently of locations. Similarly, significant F x G x C interaction may be interpreted considering the interactions of F x G with C, F x C with G and G x C with F. Since F x G and G x C are non-significant, the significance of F x G x C in the presence of a significant F x C means that different factor loadings are carried by characters when averaged over generations.

Generations do not seem to have any effect on the factor loadings nor do they show interaction with principal factors, locations and characters. When the sum of squares for generations are pooled into error (lower part of Table 80), the location effects are not significant but the principal components are, with significant L x F interactions. It follows, therefore, that though on the average there is no significant location effect, the L x F interaction is significant. Thus the contributions of different factor loadings on different characters at different locations are not the same.

The factorial analysis of variance on weighted values for general combining abilities over four generations and two locations is given in Table 81. Individual GCA's were standardized by dividing each value of a particular character by the GCA, averaged over four generations and two locations, for that character. The aim of such standardization preceding *factorial ANOVA* was to normalize the scales for different characters. For example, heading data were taken in number of days,

TABLE 81

Factorial analysis of variance of general combining ability over four generations and two locations.

Source of variation	D.F.	Sum of squares	Mean squares	F ratio
Locations (L)	1	1.71959	1.71959	1.15079
Parents (P)	4	2.54764	0.63691	0.42623
L x P	4	1.11852	0.27963	0.18713
Generations (G)	3	4.27284	1.42428	0.95316
L x G	3	1.78580	0.59526	0.39837
P x G	12	6.27137	0.52261	0.34975
L x P x G	12	3.89558	0.32463	0.21725
Error	360	537.93774	1.49427	-
Locations (L)	1	1.71959	1.71959	1.88320
Parents (P)	4	2.54764	0.63691	0.69752
L x P	4	1.11852	0.27963	0.30624
Generations (G)	3	4.27284	1.42428	1.55981
L x G	3	1.78580	0.59526	0.65191
P x G	12	6.27137	0.52261	0.57234
L x P x G	12	3.89558	0.32463	0.35552
Characters (C)	9	12.89835	1.43315	1.56952
L x C	9	8.39985	0.93331	1.02213
P x C	36	91.33239	2.53701	2.77842***
G x C	27	21.10522	0.78167	0.85606
L x P x C	36	192.26447	5.34067	5.84888***
L x G x C	27	21.24818	0.78696	0.86185
P x G x C	108	92.07365	0.85253	0.93366
Error (L x P x G x C)	108	98.61607	0.91311	-

***Significant at 0.1% level

plant height was measured in centimeters, yield per plant, weight of seeds per spike and 1000-kernel weight were expressed in grams, and number of tillers per plant, number of spikelets per spike and number of seeds per spike were scored as counts. Thus by dividing the GCA of each character by its mean over two locations, the scale differences were removed but the inter-location differences were preserved.

The first part of Table 81 shows a three-way layout analysis of general combining abilities where locations, parents and generations have been treated as main effects. None of the mean squares showed significance. This means that parental lines did not differ in their general combining abilities over the two locations in any generation of the diallel cross. When the characters were introduced as a fourth main effect by analyzing the normalized GCA's in a four-way factorial layout (second part of Table 81), the mean squares for P x C and L x P x C interaction were significant. This suggests that the combining ability values for different characters vary with the number of parents and locations.

It is interesting to note that after introducing characters as separate effects, the mean squares, either for generations or any of the interactions involving generations, were not significant. This indicates that generations do not affect GCA's for any characters in question. The significance of P x C and L x P x C interactions on the other hand provides the possibility for comparing which ~~of the~~ parental lines for their relative adaptability is more

TABLE 82

Analysis of variance of Parkland GCAs' regression upon Ellerslie GCAs' regression for each of the parental lines

Parent	Source of variation	D.F.	Sum of squares	Mean squares	Regression coefficient
Marquis	Due to regression	1	157.5731	157.5731***	
	Due to error	8	1.8675	0.2334	b = 0.9416
Chincok	Due to regression	1	138.6222	138.6222***	
	Due to error	8	1.3375	0.1671	b = 1.1118
Khush-hal	Due to regression	1	62.7426	62.7426***	
	Due to error	8	4.2024	0.5253	b = 1.0769
Ciano	Due to regression	1	60.1872	60.1872***	
	Due to error	8	1.0378	0.1297	b = 1.1163
Inia	Due to regression	1	75.7396	75.7396***	
	Due to error	8	0.4692	0.0586	b = 0.8821

***Significant at 0.1% level

adaptive. For this purpose the GCA's for all the characters (averaged over all generations) at Parkland were regressed for each of the parental lines upon those at Ellerslie. The regression coefficients and the sums of squares due to regression and error partitioned for each cultivar are given in Table 82. It may be pointed out that unweighted GCA's (original values) were used in regression analysis since the effect of change in the degree of expression of one character relative to the other can be studied regardless of the unit of scale used. Significance of mean squares due to regression (Table 82) indicates that for every unit of change in GCA's at Ellerslie there is a corresponding proportional change for the corresponding GCA's at Parkland.

The genetic components of variation (from unadjusted treatment means) D, F and H_1 were considered themselves as variables and factorially analysed over generations and locations in order to study their consistency over the two environments. Before performing the *factorial ANOVA*, the values of genetic components for each character were standardized at each location. Thus, each D value was divided by the V_{0L0} for the same character, generation and location. Similarly, F's were divided by their corresponding mean covariances (W_{0L01} in F_1 diallel, W_{0L02} in F_2 and backcross diallels and W_{0L03} in the selfed backcross diallel) and H_1's by their respective mean variances (V_{1L1} in F_1 diallel, V_{1L2} in F_2 and backcross diallels and V_{1L3} in the selfed backcross diallel). Thus, for example, the F for number of tillers per

TABLE 83

Factorial analysis of variance of genetic components of variation over generations and locations. The sum of squares are respectively partitioned for D, H_1 and F.

Component	Source of variation	D.F.	Sum of squares	Mean squares	F ratio
D	Locations	1	0.14331	0.14331	1.10820
	Generations	3	0.03167	0.01055	0.08164
	Location x Generation	3	0.07301	0.02433	0.18820
	Error	72	9.31106	0.12932	
H_1	Locations	1	10.38381	10.38381	7.77135***
	Generations	3	2.16681	0.72227	0.54056
	Location x Generation	3	1.10066	0.36688	0.27458
	Error	72	96.20391	1.33616	
F	Locations	1	15.78510	15.78150	7.34709***
	Generations	3	7.28304	2.42768	1.13021
	Location x Generation	3	0.43955	0.14651	0.06821
	Error	72	154.65565	2.14799	

***Significant at 0.1% level

plant at Ellerslie in the selfed backcross diallel set of Table 78 was divided by the corresponding V_{0L03} from Table 77 (at Ellerslie) as follows: $-0.4873 \div 0.6890 = -0.7072$.

The process of standardizing the scale is analogous to Allard's technique, where prior to *factorial ANOVA*, each variance and covariance was divided by V_{0L0} of the respective block for that character (Allard 1956; Crumpacker and Allard 1962). In the present study additive $[D]$, dominance $[H_1]$ and additive x dominance $[F]$ components are subsequently considered separately and analysed independently for their stability over generations and locations. The reciprocals of the variances of the parents of the array mean variances and of the array mean covariances were used as weights in standardizing the values of D's, H_1's and F's respectively. The use of these different multipliers in normalizing the scal. effects preserved the order of magnitude of respective parameters. The *factorial ANOVA* on the weighted values of D's, H's and F's is given in Table 83. The results show that additive effects of the genes (component D) are the same for two locations. Dominance gene effects (component H_1) and additive x dominance effects (component F) differ significantly at the two locations. On the whole, generations do not seem to affect the values of genetic components of variation. Significant mean squares for locations with respect to H_1 and F raises the question of the heterogeneity of location effects on the parameters in different generations. To answer this, the unweighted values of D's, H_1's and F's at Parkland were respectively regressed for each generation upon those of Ellerslie, and

TABLE 84

Analysis of variance of regression of genetic components of variation of Parkland upon those of Ellerslie for each generation.

Component	Generation	Source of variation	D.F.	Mean squares	F value	
Additive Component [*D*]	F_1 diallel	Due to regression	1	228657.5229	4578.6540***	r = 0.9990
		Due to error	8	49.9399		b = 1.0658
	F_2 diallel	Due to regression	1	227792.7663	3549.9323***	r = 0.9998
		Due to error	8	64.1682		b = 1.0603
	Backcross diallel	Due to regression	1	228207.7135	4597.8009***	r = 0.9990
		Due to error	8	49.6341		b = 1.0630
	[illegible]	Due to regression	1	229349.4236	4251.7073***	r = 0.9990
		Due to error	8	53.9429		b = 1.0642
Dominance Component [H_1]	F_1 diallel	Due to regression	1	1532.9815	81.7304***	r = 0.9534
		Due to error	8	18.7562		b = 0.8233
	F_2 diallel	Due to regression	1	2001.6299	391.1351***	r = 0.9398
		Due to error	8	5.1180		b = 1.3637
	Backcross diallel	Due to regression	1	2619.8806	74.1992***	r = 0.9500
		Due to error	8	35.3087		b = 2.4385
	Selfed back-cross diallel	Due to regression	1	412.1566	39.0566***	r = 0.9109
		Due to error	8	10.5528		b = 1.0623
Additive x dominance Component [*F*]	F_1 diallel	Due to regression	1	812.9743	80.8326***	r = 0.9538
		Due to error	8	10.0575		b = 0.4664
	F_2 diallel	Due to regression	1	1190.1414	31.2178***	r = -0.8921
		Due to error	8	38.1237		b = -1.4409
	Backcross diallel	Due to regression	1	40.3149	2.8143	r = 0.5100
		Due to error	8	14.3248		b = 0.3220
	Selfed back-cross	Due to regression	1	8.6977	0.8605	r = 0.3098
		Due to error	8	10.1077		b = 0.3603

***Significant at 0.01% level

the sum of squares of deviations were partitioned into variation due to regression and remainder (error). Extremely high variance ratios (Table 84) for the parameters D and H_1, and close agreements between the coefficients of correlation and regression, both in sign and magnitude, indicate stability of these parameters over the two locations. The case of parameter F is rather confusing. The diallels based on backcross and selfed backcross generations show a lack of correspondence between F values at the two locations (variance ratio for regression non-significant). This may be ascribed to a change of relationship between additive and dominance gene effects ($F = \Sigma dh$) caused by altered environmental conditions. A more drastic relational change is that between the F_1 and F_2 generations of the diallel sets ($r = 0.95$, $b = 0.47$ and $r = -0.89$, $b = -1.44$, respectively). It is rather difficult to think of a logical explanation for this reversed relationship.

Since, on the whole, generation did not significantly affect the genetic components of variation, their estimates were obtained by solving, least-square-wise, the following system of linear equations, where the known terms, i.e., the array variances and covariances for a given generation were obtained by using adjusted treatment means from analysis of variance as a partially balanced lattice design:

(Parents): $D + E - V_{0L0} = d_1$

F_1 diallel: $(1/2)D - (1/4)F + (1/5)E - W_{0L01} = d_2$

TABLE 65

Components of genetic variation obtained from statistics based on adjusted treatment means for ten characters over four generations at two locations.

Character	D	F	H_1	H_2	E
Onset-of-heading	6.3134 ± 0.7[illegible]** 8.6226 ± 2.7013**	9.2001 ± 1.7249** 11.7467 ± 6.2367	11.6477 ± 3.1676** 24.7571 ± 11.2393	10.6407 ± 2.7703** 21.4868 ± 10.0215	1.2718 ± 0.7546 2.7428 ± 2.7299
Final heading	9.9956 ± 1.4571** 7.0663 ± 3.7575	15.6060 ± 3.2459** 10.9821 ± 8.4867	16.0674 ± 5.0859** 20.9463 ± 15.2940	12.6612 ± 5.2157* 10.3467 ± 13.6368	3.6999 ± 1.4207 3.6404 ± 3.7147
Heading-span	0.1776 ± 0.1478* 0.5[illegible] ± 0.5762**	0.5467 ± 0.3111* 1.7013 ± 0.1767**	1.2007 ± 0.5612 4.6286 ± 0.3165**	0.9406 ± 0.5004 3.4230 ± 0.2660**	0.0144 ± 0.1163** 0.4756 ± 0.0773**
Plant height	49.1[illegible] ± 194.6[illegible] 15.[illegible]247 ± 324.[illegible]	-159.3[illegible] ± 439.5402 -334.9300 ± 733.1102	-134.[illegible] ± 792.1168 -274.4790 ± 321.1500	-26.7551 ± 706.2676 88.9776 ± 177.9948	329.6460 ± 192.3959 324.0350 ± 320.6911
Number of tillers per plant	0.4516 ± 0.5311* 1.4083 ± 0.1271**	1.3185 ± 1.2047 1.9869 ± 0.2671**	-1.0911 ± 2.1710 6.3148 ± 0.5175**	-1.5535 ± 1.9458 5.3106 ± 0.4614**	1.9733 ± 0.5273** 0.2227 ± 0.1257
Number of spikelets per spike	0.7624 ± 0.1548** 0.1911 ± 0.0[illegible]	1.1491 ± 0.3490* 0.2307 ± 0.2667	0.8665 ± 0.6287 1.3766 ± 0.1602**	0.5013 ± 0.5006 1.3117 ± 0.3033**	0.5284 ± 0.1527** 0.1053 ± 0.0826**
Number of seeds per spike	13.01[illegible] ± 3.2757* 9.[illegible] ± 1.6313	15.0023 ± 7.[illegible] 19.5576 ± 2.[illegible]**	26.[illegible] ± 13.[illegible]31 45.[illegible] ± 4.1577	17.6712 ± 11.[illegible] 30.6795 ± 3.7425**	13.0569 ± 3.2154** 0.2603 ± 1.0[illegible]
Weight of seeds per spike	0.0139 ± 0.0025** 0.0154 ± 0.0071**	0.0146 ± 0.0056** 0.0369 ± 0.0161**	-0.0113 ± 0.0105 0.0219 ± 0.0291	-0.0191 ± 0.0094** 0.0064 ± 0.0259	0.0259 ± 0.0025** 0.0170 ± 0.0070**
1000-kernel weight	5.0133 ± 1.2[illegible]** 9.243[illegible] ± 3.0167*	7.6471 ± 2.9262** 16.2749 ± 6.8130*	11.5453 ± 5.2724 19.2269 ± 12.2769	7.9798 ± 4.7020 11.4570 ± 10.9464	3.9345 ± 1.2608* 2.6962 ± 2.9424
Yield per plant	1.6962 ± 0.7181* -1.1075 ± 0.1945**	3.4032 ± 1.0130 -1.9412 ± 0.4460**	4.9964 ± 2.9068 -4.3292 ± 0.7930**	3.3320 ± 2.5918 -3.4484 ± 0.7071**	2.5752 ± 0.7060** 2.3649 ± 0.1926**

The first reading under each column refers to Ellerslie and the second to Parkland.

* Significant at 5% level

**Significant at 1% level

$$(1/4)D - (1/4)F + (1/4)H_1 + (3/5)E - V_{1L1} = d_3$$

$$(1/4)D - (1/4)F + (1/4)H_1 - (1/4)H_2 + (1/10)E - V_{0L1} = d_4$$

F_2 diallel:

$$(1/2)D - (1/8)F + (1/5)E - W_{0L02} = d_5$$

$$(1/4)D - (1/8)F + (1/16)H_1 + (3/5)E - V_{1L2} = d_6$$

$$(1/4)D - (1/8)F + (1/16)H_1 - (1/16)H_2 + (1/10)E - V_{0L2} = d_7$$

Backcross diallel:

$$(1/2)D - (1/8)F + (1/5)E - W_{0L02} = d_8$$

$$(1/4)D - (1/8)F + (1/16)H_1 + (2/5)E - V_{1L2} = d_9$$

$$(1/4)D - (1/8)F + (1/16)H_1 - (1/16)H_2 + (7/100)E - V_{0L2} = d_{10}$$

Selfed backcross diallel:

$$(1/2)D - (1/16)F + (1/5)E - W_{0L03} = d_{11}$$

$$(1/4)D - (1/16)F + (1/32)H_1 + (2/5)E - V_{1L3} = d_{12}$$

$$(1/4)D - (1/16)F + (1/32)H_1 - (1/32)H_2 + (7/100)E - V_{0L3} = d_{13}$$

In this system of equations $d_{k=1,2,\ldots,13}$ denotes the difference between the expected and observed values of the kth statistic. The environmental component of variation (E) was accounted for by using the multiplier (1/2) when F_1 and F_2 generations, and (1/4) when backcross and selfed backcross generation diallel sets were considered (Hayman 1958). The solutions of this system of equations for the various components of variation are shown in Table 85. Error terms were calculated in a manner usual to the **unweighted** least square solution, i.e. as $\pm (\Sigma d_k^2 c_{ii} \div DF)^{1/2}$, where c_{ii} is the appropriate term on the main diagonal of the variance-covariance matrix of the coefficients,

TABLE 86

Estimates of genetic parameters from diallel analysis of adjusted treatment means for ten characters over four generation at two locations.

Character	$[H_1 \div D^{1/2}]$	$[H_2 \div 4H_1]$	$\left[\dfrac{(4DH_1)^{1/2} + F}{(4DH_1)^{1/2} - F}\right]$	Heritability
Onset-of-heading	1.4763* 1.6751	0.1921* 0.2169	2.9621* 2.3189	0.3968 0.2689
Final heading	1.3455* 1.6356	0.1750* 0.2164	3.8012* 2.4948	0.3674 0.2420
Heading-span	1.8545 2.8931*	0.1827 0.1856*	3.9680 3.2920*	0.1145 0.1027
Plant height	2.1990 4.1866	0.0344 -0.0810	0.1188 -0.4922	0.0308 0.0109
Number of tillers per plant	1.5543 2.1175*	0.3559 0.2102*	46.3456 1.9999*	0.0764 0.2125
Number of spikelets per spike	1.0660 2.6639	0.1446 0.2362*	5.7672 1.6100	0.2935 0.0960
Number of seeds per spike	1.7276 2.3135	0.1642 0.1545	2.8599 2.7392	0.1366 0.2312
Weight of seeds per spike	0.9016 1.1099	0.4225 0.0669	3.7901 23.2285	0.1941 0.2679
1000-kernel weight	1.5144 1.4422	0.1727 0.1489	3.0116 4.1330	0.2020 0.4026
Yield per plant	1.6622 1.9770*	0.1667 0.1991	3.7498 0.3842	0.1327 -0.1855

First reading under each column refers to Ellerslie and the second to Parkland
*The parameters involved are significantly different from zero (Table 85)

and d.f. = 13 − 5 = 8 (thirteen equations, five fitted parameters). For one set of paradoxical results (significant negative values of D, H_1 and H_2 for yield per plant at Parkland), the source of error could not be determined.

The proportional estimates of genetic parameters obtained from Table 85 are given in Table 86. The data indicate that all characters are inherited as over-dominant traits at both locations, except for weight of seeds per spike at Ellerslie which showed nearly complete dominance, i.e. $(H_1 \div D)^{1/2} \approx 1$. Moreover $[(1/4DH_1)^{1/2} + F] \div [(1/4DH_1)^{1/2} - F] > 1$ in all cases, except for plant height at both locations and yield per plant at Parkland, suggests strongly a preponderance of dominant genes in the parents. When valid, $(H_2 \div 4H_1)$ was found to be less than 0.25, indicating thus a certain degree of numerical asymmetry of alleles with positive and with negative effects at loci showing dominance. Heritability values in all cases were low, the maximum being 40.26% (1000-kernel weight at Parkland).

The results of Table 86 when compared with those of Tables 20, 39, 60 and 79 show the effect of the adjustment factor characteristic of incomplete block designs. In the latter Tables, where genetic parameters have been estimated from analyses of F_1, F_2, backcross and selfed backcross diallel sets of unadjusted treament means (treated as randomized block design), the values of $(H_1 \div D)^{1/2}$, $(H_2 \div 4H_1)$ and $[(4DH_1)^{1/2} + F] \div [(4DH_1)^{1/2} - F]$ show a wide range of variation from partial dominance to overdominance, from a fully symmetrical distribution of alleles with positive and negative effects to strong

TABLE 87

Analysis of variance of regression of genetic components of variation at Parkland upon those at Ellerslie averaged over generations for all characters.

Component of variation	Source of variation	D.F.	Sum of squares	Mean squares	Coefficients of correlation & regression
Additive component [D]	Due to regression	1	228499.9514	228499.9514**	b = 1.0633
	Due to error	8	432.9894	54.1236	r = 0.9990
Dominance component [H_1]	Due to regression	1	1561.3878	1561.3878**	b = 1.3188
	Due to error	8	65.5032	8.1879	r = 0.9796
Additive x Dominance Component [F]	Due to regression	1	306.8222	306.8222**	b = 1.0430
	Due to error	8	100.9412	12.6176	r = 0.8674
Additive component [D]	Due to regression	1	197.6459	197.6459**	b = 0.3825
	Due to error	8	90.3328	11.2916	r = 0.7579
Dominance component [H_1]	Due to regression	1	76523.1655	75528.1655**	b = 1.4230
	Due to error	8	345.5664	43.1958	r = 0.9997
Additive x Dominance Component [F]	Due to regression	1	137604.3889	137604.3889**	b = 2.6663
	Due to error	8	963.3961	120.4245	r = 0.9964

The first part of the table refers to unadjusted treatment means (treated in randomized block design) and the second part refers to adjusted treatment means from partially balanced lattice design.

**Significant at 1% level

asymmetry, and from equal to unequal proportions of dominant to recessive alleles in the parents. Table 86 on the other hand shows that these ratios, especially those for valid parameters (* in Table 85), are more stable over characters since over-dominance in inheritance, asymmetry of alleles at loci exhibiting dominance, and inequality in the proportions of dominant and recessive alleles are constant features of the concerned characters.

The regression analysis of genetic components of variation D, H_1 and F for Ellerslie and Parkland, obtained first from unadjusted treatment means (randomized block design) averaged over generations, and then from adjusted treatment means of Table 85, is given in Table 87. The purpose of this analysis was to see whether there [illegible] concordance between the values of parameters evaluated from the data at the two locations separately. The results given in Table 87 show a good agreement in this respect between locations. Parameters D and F evaluated from array variances and covariances from unadjusted treatment means show the same rates of change from character to character at the two locations ($b = 1$). For H_1 this change is $b = 1.32$ at Parkland for unit change at Ellerslie. With adjustment of treatment means the situation is changed, so that for unit change at Ellerslie there is a change of $b = 0.38$ for D and $b = 2.67$ for F at Parkland. The corresponding change for H_1 is less pronounced ($b = 1.32$) without adjustment as compared to $b = 1.42$ with adjustment.

The relationships between the two locations in regard to changes in D, H_1 and F for the various characters are shown graphically

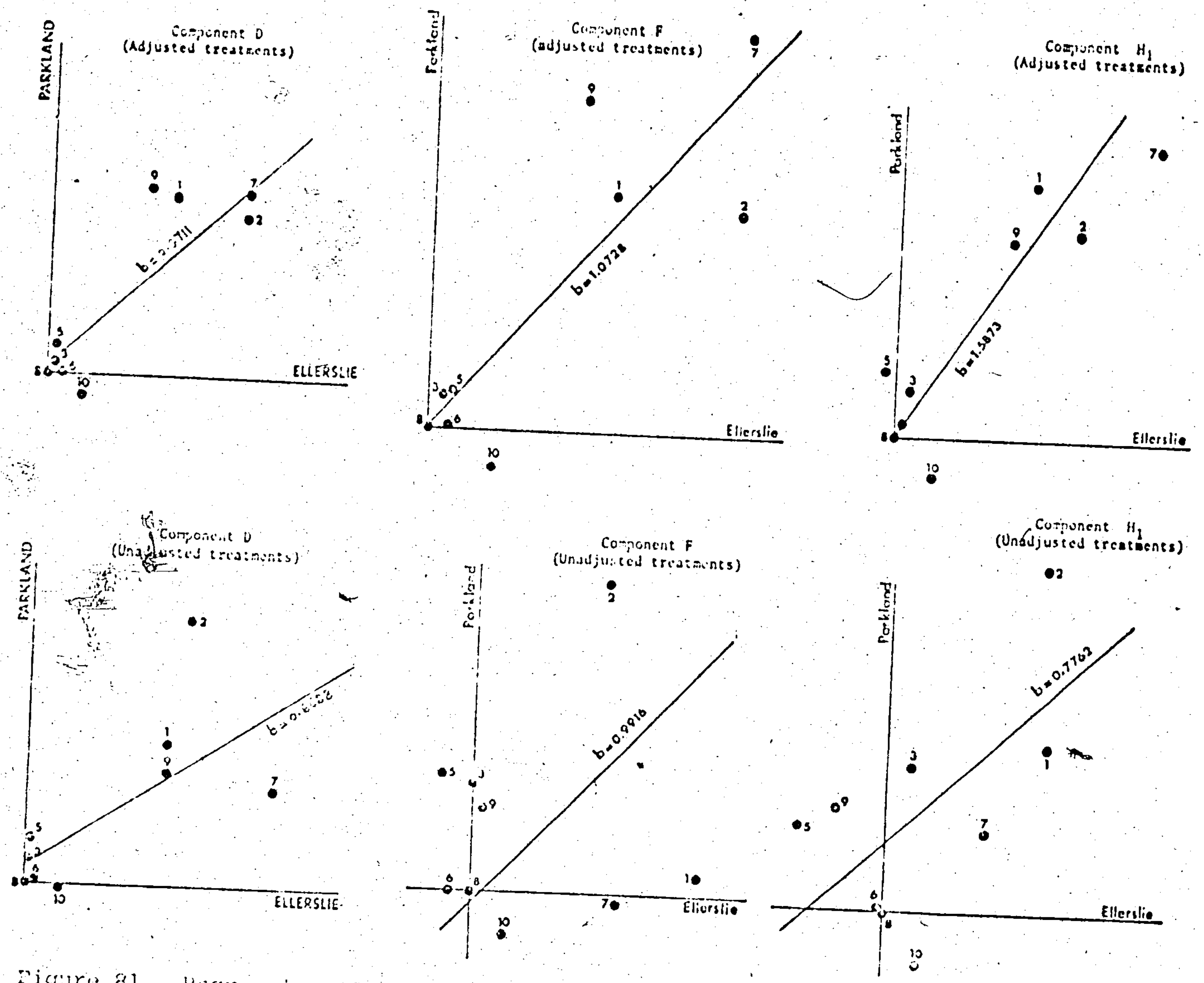

Figure 81. Regression of genetic components of variation at Parkland upon those at Ellerslie for all the characters except plant height. Solid circles refer to regression intercepts for different characters.

in Figure 81. The scatter of the intercept points around the regression lines shows that there are considerable discrepancies between the two locations. The points of intercepts for plant height are not shown in the graphs because of very high values of the components which far exceeded the boundaries of the graphs. Therefore the coefficients of regression were recalculated excluding plant height. It is rather difficult to determine either from the regression analysis of Table 87 or from the graphs whether and by how much the use of adjusted treatment means has improved the estimates of the parameters. Hence it is not possible to assess the parametric relationships within and between the characters and within and between the locations or environments. Nevertheless, looking at the graphs of the parameters derived begining with the adjusted traetment means, one would be rather strongly inclined to conclude that the adjustment of means has considerably improved the degree of concordance between the two locations with respect to parameters.

DISCUSSION

The F_1, F_2, backcross and selfed backcross generations of five parent diallel cross of common wheat (*Triticum aestivum* L.) were grown in 1972 at two locations and the data obtained was analysed with respect to correlation between the characters, principal factors, general and specific combining abilities, genetic components of variation and environmental effects. The experimental design used was a partially balanced triple lattice. However, most of the analyses were carried out both as a complete randomized block design and as a lattice design. The results obtained are discussed in sequel.

Correlation and factor analyses. Among the characters considered in this study, yield of grain per plant is agronomically the most important. Therefore the knowledge of its correlation with other characters is of importance from a theoretical and a practical point of view. The results of the correlation analyses of F_1, F_2, backcross and selfed backcross diallel sets are given in Tables 2, 21, 42, and 61. These results show that early maturing entries have produced high yields and the late maturing ones low yields of grain per plant. As expected, there was a positive correlation between yield per plant and most of its subcharacters or components. A strong positive association was found to exist between the subcharacters, number of tillers per plant, weight of seeds per spike and 1000-kernel weight with yield per plant. The components, number of spikelets per spike and number of seeds per spike were not correlated with yield at either location in F_1 (Table 2) but were positively correlated in the other generations of diallel cross either at both locations (Table 21) or at one of them (Tables 42 and 61). There was no correlation between yield and plant height.

The degree of expression of metrical characters (phenotypes) depends both on the genotypic constitution of the parents and the environmental conditions under which the experimental materials are grown. Therefore the comparison of results obtained by various researchers using different sets of parents and carried out under different environmental conditions lead only to non-related or loosely-related general information. For example, Lee and Kaltsikes (1973) working with durum wheat in Winnipeg have found that the characters days-to-maturity and yield per plant were positively correlated in both the F_1 and the F_2 generations of a 10 x 10 diallel cross, whereas in the present study of all the generations of diallel cross the correlation was negative. On the other hand, Hsu (1970) has found that in the F_1 generation of a five-parent diallel cross of common wheat there was no correlation between anthesis date (final heading) and yield per plant, a result similar to that found in the present case at Parkland. Although Hsu has conducted his study in Edmonton, the two experiments were spaced in time, and except for Inia, the parental lines used were different. The significant positive association of yield per plant with its components found in this study was also observed in the works of Johnson and Schmidt (1968), Smocek (1969), Lebsock and Amaya (1969), Hsu and Walton (1970), Kaltsikes and Lee (1971), Lee and Kaltsikes (1973) and Chebib *et al* (1973). The absence of correlation between plant height and yield per plant in the present study was also observed by Kaltsikes and Lee (1971) and Chebib *et al* (1973). These results are in disagreement with those of some other experiments [Lebsock and Amaya (1969), Kaltsikes and Larter (1970) and Lee and Kaltsikes (1973)].

The relationship between individual character is rather complicated. Therefore the data were subjected to factor analysis. This analysis provides information on contributions of independent variables relative to those of dependent ones. The results of the factor analysis of F_1, F_2, backcross and selfed backcross data obtained for two locations are shown in Tables 3, 22, 43 and 62, and the principal factors have been interpreted earlier. The first principal factor, *lateness*, has negative loading for yield per plant and the highest positive loading for onset-of-heading and final heading. This confirms the conclusion arrived at earlier, that the majority of late-heading entries have produced low grain yields per plant. The degree of expression of heading-span was found to be correlated with final heading but not with onset-of-heading. It was not correlated with yield in F_1 and F_2 but was positively associated with it in backcross and selfed backcross data. This inconsistency suggests that heading-span is not one of the characters affecting yield per plant. In fact the factor analyses based on the F_1, F_2 backcross and selfed backcross diallel sets have revealed positive factor loadings for heading-span and negative ones for yield. It follows therefore that positive correlations of heading-span with yield per plant at Parkland in the backcross and selfed backcross diallel sets does not necessarily imply a cause-and-effect relationship, and may in fact be attributed to strong environmental influence upon particular entries of the diallel table.

The second principal factor, termed differently in different generations, carried the highest loadings for number of spikelets per spike, number of seeds per spike and weight of seeds per spike except the backcross diallel at Parkland (Table 43), for which plant height had the highest loading. A similar situation was observed with respect to principal factors 3, 4 and 5 which had their highest loadings from different characters in different generations of the diallel cross. Thus it appears that different factors operate differently in different populations (generations) though they share the same gene pool.

<u>Combining ability analyses</u>. The results of the analyses of data for general and specific combining abilities with respect to the characters considered have shown that the parents with high GCA's do not necessarily produce hybrids with high SCA's. The comparisons of GCA's with SCA's for all the generations and characters are collected in Table 88. Of all the comparisons, eighty to be exact, 84% constitute cases in which high SCA's are associated with one or both parents having low GCA's, and *vice versa*. These observations are in agreement with those reported by Crumpacker and Urquhart (1962), Fonseca (1965), Brown *et al* (1966), Gyawalli *et al* (1968) and Singh *et al* (1969) in wheat. Analogous results have been observed by Larson (1941) in tomatoes, and

TABLE 68

Summary of the results of general and specific combining ability analyses showing that the hybrids with highest SCA's are associated with parents of low GCA's and vice versa.

		Onset-of-heading				Final heading				Heading-span				Plant height				Number of tillers per plant			
		F1	F2	B0	B1	F1	F2	B0	B1	F1	F2	B0	B1	F1	F2	B0	B1	F1	F2	B0	B1
	*Both parents with high GCA									+-				++	+-			+-			
Hybrid with highest SCA	One parent with low GCA				-+	++			+-	-+	++	++	++		-+	++	++		++		++
	Both parents with low GCA	++	++	++	+-		++	++	-+									-+		++	
	Both parents with high GCA				++									++	++			-+			
Hybrid with lowest SCA	One parent with high GCA	++	++	++		++	++	++	++	++	++	++	++			++	++	+-	++	++	++
	Both parents with low GCA																				

		Number of spikelets per spike				Number of seeds per spike				Weight of seeds per spike				1000-kernel weight				Yield per plant			
		F1	F2	B0	B1	F1	F2	B0	B1	F1	F2	B0	B1	F1	F2	B0	B1	F1	F2	B0	B1
	*Both parents with high GCA	-+	-+	+-	-+																
Hybrid with highest SCA	One parent with low GCA	+-	+-	-+	+-			+-		-+	++	++		++	++	++	++	++	++	-+	++
	Both parents with low GCA					++	++	-+	++	+-			++							+-	
	Both parents with high GCA					++								+-	+-			+-	-+		
Hybrid with lowest SCA	One parent with high GCA	++	++	++	++	++		++	++	+-	-+	-+	-+	-+	-+	++	++	-+	+-	++	++
	*Both parents with low GCA									-+	+-	+-	+-								

(+) and (-) signs indicate, respectively, affirmation and contradiction of the statements.
The first position of (+) or (-) refers to Ellerslie and the second to Parkland.
*(+) sign characteristic of the location shows disagreement of the proposition made in the text.
F1, F2 B0 and B1 refer to F_1, F_2, backcross and selfed backcross generations of diallel set.

by Walker (1963), Chang (1967), Soomro (1967), Baluch and Soomro (1969) and Soomro and Baluch (1969) in cotton. On the other hand Kime (1950) and Hawkins *et al* (1965) working with cotton have found that GCA and SCA were positively correlated so that the present results are in conradiction to their reports.

Significant variances of general and specific combining abilites for a particular character denote, respectively, the importance of additive and non-additive gene effects for that character. If the variance for specific combining ability for a particular character is significant and that for general combining ability is not, selection for the character will be on the basis of SCA. On the other hand, high SCA variances associated with a particular parent, even if it has high GCA, reflect an insonsistency in the performance of that parent with respect to the particular character (Griffing, 1956) and indicate that the hybrids involved with that parent would perform poorer than would be expected on the basis of their specific combining abilities. It follows therefore that in combining ability screening tests a pedigree selection procedure would be expected to screen out the strains with considerably larger SCA variances.

In the present studies variances of general combining ability were generally larger than those of specific combining ability for all characters, and diallel-set generations at both locations (Tables 5 to 14, 24 to 33, 45 to 54 and 64 to 73). There were a few cases where the estimates of SCA variances higher than those for GCA's, but the magnitudes of their differences were negligible. This would indicate a high consistency of performance of the parental lines an observation which may also be generally verified by their general combining ability values (Tables 4, 23, 44 and 63), and more specifically from the results of Table 82. The significance of variances for general and specific combining abilities were examined from Tables 15, 34, 55 and 74. In general, the mean squares for GCA were significant for all characters except heading-span and yield per plant at one or both the locations. Such significances of GCA mean squares are not uncommon in wheat (Brown *et al* 1966, Fonseca 1965, Paroda and Joshi 1970a, Parodi *et al* 1970 and Bitzer *et al* 1971). Mean squares for SCA were significant only for a few characters.

It may be pointed out that a high general combining ability for some characters as for example onset-of-heading and final heading may not be desirable under certain circumstances. High GCA for these characters implies lateness, so that when selecting for earliness, lines with the lowest GCA's must therefore be given priority. In the present study Ciano and Inia had the lowest GCA's for heading data, and consequently selection from their progenies is expected to result in early lines. Plant height is another character for which the selection of wheat cultivars with low GCA's may be desirable.

Diallel cross analysis. The analysis of variance of diallel tables according to Hayman (1954a) gave *a* component significances (for additive gene effects) in all generations of the diallel cross (Tables 16, 35, 56 and 75) for all the characters except heading-span and yield per plant

(Tables 16 and 35) and yield per plant (Tables 56 and 75). These results corresponded to those for general combining ability in *ANOVA*'s (Tables 15, 34, 55 and 74). Thus Hayman's a component and Griffing's GCA are analogous. Genetic components of variation for each generation of the diallel cross have shown values ranging from non-significance to high significance. The only paradoxical ones are the negative but significant D's and H_1's of Tables 19, 38, 59 and 78, which may be ascribed to high environmental variation. Such unexpected values are not uncommon (Mather 1949, Wright 1952, Newell 1970 and Holmes 1972) in biometrical genetics. The interpretation of genetic parameters in such cases becomes questionable.

Proportional values of the estimates of genetic parameters viz., $(H_1 \div D)^{1/2}$, $(H_2 \div 4H_1)$, $[(4DH_1)^{1/2} + F] \div [(4DH_1)^{1/2} - F]$ and $[h^2/H_2]$ for characters studied in different generations of the diallel cross ranged from partial dominance to over-dominance, from complete symmetry to strong asymmetry in distribution of genes with positive and negative effects in the parents, from equal proportions of dominant and recessive genes in the parents to a preponderance of dominants or recessives, and from high to low numbers of gene groups controlling a particular character. Heritability estimates also showed a wide range of values, from -0.1129 (yield per plant, Table 39) to +1.085 (onset-of-heading, Table 79), indicating in this example, a complete lack of heritability for yield and an extremely high heritability for earliness. Quite low heritability estimates of yield in wheat have been reported by a number of researchers (Wiebel 1956, McNeal 1960, Kronstad and Foot 1964, Johnson *et al* 1966, and Paroda and Joshi 1970, 1970a).

Genotype-environment interaction. The assessment of genetic and environmental components of variation with respect to a character depends upon the gene pool involved and the non-hereditary factors constituting the environment in which the experimental material is grown. The choice of statistical approach varies with the type of data available and the object of the study. In this study *factorial ANOVA* and regression analysis (Mather, 1951) were used to assess the degree of discordance between identical sets of materials grown at two locations with respect to factor loadings for the various characters, general combining abilities of the parents and the main genetic components of variation.

The factor loadings on various characters seemed to be different for the two locations (Table 80). The effect of generations on factor-loading scores for different characters was negligibly small. In fact none of the interactions involving generation were significant. This finding contradicts that of Lee and Kaltsikes (1973) who found discrepancies between their F_1 and F_2 diallel factor analyses with respect to the factor loading scores on various characters. They attributed these generation differences to a considerable difference in plot size for the two generations, and difference in planting techniques viz., space-planting for F_1 diallel and solid planting for F_2 diallel. In the present case, though plot size, planting techniques and experimental set up was the same, nevertheless, the environmental conditions at the two locations were quite different. Inspite of significant inter-location effects, different generations proved to be fairly homogeneous with regard to factor loadings.

In the *factorial ANOVA* for general combining abilites of the four generations of the diallel cross and the two locations (Table 81) it was found that the GCA values were more or less the same. However, when characters were treated separately in the analysis (*ANOVA* assumed single observation per cell), GCA's differed between locations. These results indicate that parents did not differ in GCA's over the two locations when their GCA's were averaged over all characters, but they certainly did when considered individually for each character. The response of each variety with respect to additive gene effects was studied after averaging the GCA's of a cultivar over four generations of the diallel cross and regressing the estimates obtained at one location upon those of the other. In the analysis of variance for regression (Table 82) the inter-location effects were found to be homogeneous for each variety. In other words, the GCA's for the two locations were concordant. The variances for general and specific combining ability also did not differ significantly at the two locations. Moreover, the conspicuous feature of the combining ability analysis was the high consistency with which the GCA variances were higher than the corresponding SCA variances at both locations. This in fact shows the stability of cultivars over locations according to Griffing's (1956) enunciation.

The stability of genetic components of variation, viz., D, H_1 and F was assessed over the two locations through *factorial ANOVA*. The results indicated (Table 83) that there was no significant difference between locations for any component. Moreover, the generations, on the whole, did not affect these parameters at either location. But when the estimates of one component for Parkland were regressed upon those of Ellerslie it was found that the selfed backcross generation of the diallel cross was affecting the component F. This constituted a significant change in the relationship between additive and dominance gene effects in the progeny of the backcrosses. Moreover the estimates of the [illegible] component for the two locations were correlated differently in the F_1 and F_2 generations ($+r$ and $-r$ respectively). It is rather difficult to think of a logical explanation for this change of relationship between additive and dominance gene effects [$\Sigma(d)$ x $\Sigma(h)$] in two generations of the same diallel set.

The occurrence of significant negative values for genetic components of variation was an unexpected feature of diallel cross analysis for which a satisfactory interpretation is lacking. Such values have been reported in a number of instances (Mather 1949, Wright 1952, Newell 1970 and Holmes 1972) but a logical explanation for their occurrence has not been given. The frequency of their occurrence appear to be too high to be attributed to chance.

BIBLIOGRAPHY

AALDERS, L.E. and D.L. CRAIG (1968). General and specific combining ability in seven inbred strawberry lines. Can. Jour. Genet. Cytol., 10: 1-6.

AKSEL, R. and L.P.V. JOHNSON (1961). Genetic studies on sowing-to-heading and heading-to-ripening periods in barley and their relation to yield and yield components. Can. Jour. Genet. Cytol., 3: 242-259.

AKSEL, R. and L.P.V. JOHNSON (1963). Analysis of a diallel cross: A worked example. Advancing Frontiers of Plant Science (India), 2: 37-53.

ALLARD, R.W. (1956). The analysis of genotype-environmental interactions by means of diallel crosses. Genetics, 41: 305-318.

ALLARD, R.W. (1961). Relationship between genetic diversity and consistency of performance in different environments. Crop Sci., 1: 127-133.

ALLARD, R.W. and P.L. WORKMAN (1963). Population studies in predominantly self pollinated species. IV. Seasonal fluctuations in estimated values of genetic parameters in lima bean populations. Evolution, 17: 470-480.

ANAND, I.J. and B.R. MURTY (1968). Performance of heterozygotes in presence of reciprocal and maternal effects in diallel crosses of linseed. Ind. Jour. Genet. Plant Breed., 28:

ANAND, I.J. and B.R. MURTY (1969). Serial analysis of combining ability in diallel and fractional diallel crosses in linseed. Theoret. Appl. Genetics, 39: 88-94.

ATHWAL, D.S. and G. SINGH (1966a). Variability in Kangni. I. Adaptation, genotypic and phenotypic variability in four environments. Ind. Jour. Genet. Plant Breed., 26: 142-152

ATHWAL, D.S. and G. SINGH (1966b). Variability in Kangni. II. Genotype x environment interaction, heritability and genetic advance. Ind. Jour. Genet. Plant Breed., 26: 153-161.

BAGNARA, D. (1967). A diallel analysis of quantitative characters in varieties and radio induced mutant lines of *Triticum durum*. Genetica Agraria, 21: 313-337.

BAKER, R.J. (1969). Genotype-environment interactions in yield of wheat. Can. Jour. Plant Sci., 49: 743-751.

BALUCH, M.A. and B.A. SOOMRO (1969). Combining ability for seed and lint-index in *Gossypium arboreum* L. Pakistan Cottons, 13: 116-128.

BAUMAN, L.F. (1959). Evidence of non-allelic gene interaction in determining yield, ear height and kernel row number in corn. Agron Jour., 51: 531-534.

BHATT, G.M. (1971). Heterotic performance and combining ability in a diallel cross among spring wheats *(Triticum aestivum L.)*. Aust. Jour. Agric. Res., 22: 359-368.

BITZER, M.J., F.L. PATTERSON and W.E. NYQUIST (1971). Hybrid vigour and gene action in a six parent diallel cross of soft winter wheat. Can. Jour. Genet. Cytol., 13: 131-137.

BREESE, E.L. (1969). The measurement and significance of genotype-environment interactions in grasses. Heredity, 21: 387-397.

BROWN, C.M., R.O. WIEBEL and R.[illegible]. SEIF (1966). Heterosis and combining ability in common winter wheat. Crop Sci., 6: 382-383.

BUCIO ALANIS, L. (1966). Environmental and genotype-environmental components of variability. I. Inbred lines. Heredity, 21: 387-397.

BUCIO ALANIS, L. (1966a). Environmental and genotype-environmental components of variability. II. Heterozygotes. Heredity, 21: 399-405.

CARNAHAN, H.L. (1947). Combining ability in flax. M.S. Thesis, University of Minnesota, St. Paul, Minn., U.S.A.

CATTEL, R.B. (1965). Factor Analysis: An introduction to essentials. I. The purpose and underlying models. Biometrics, 21: 190-215.

CHANG, M.A. (1967). Combining ability in *Gossypium hirsutum* L. Unpublished M.Sc. (Agriculture) Thesis, University of Sind, Hyderabad, Pakistan.

CHEBIB, F.S., S.B. HELGASON and P.J. KALTSIKES (1973). Effect of variation in plant spacing, seed size and genotype on plant-to-plant variability in wheat. Z. Pflanzenzuchtg, 69: 301-332.

CHENG, C.L. and T.Z. CHANG (1970). Diallel analysis of agronomic traits in rice (*Oriza sativa* L.). Bot. Bull. of Academia Sinica, (New Series), 11: 61-78.

CHIANG, M.S. (1969). Diallel analysis of the inheritance of quantitative characters in cabbage (*Brassica oleracea* L. *Var. capitata* L.). Can. Jour. Genet. Cytol., 11: 103-109.

CHIANG, M.S. and J.D. SMITH (1967a). Diallel analysis of inheritance of quantitative characters in grain sorghum. I. Heterosis and inbreeding depression. Can. Jour. Genet. Cytol., 9: 44-51.

CHIANG, M.S. and J.D. SMITH (1967b). Diallel analysis of inheritance of quantitative characters in grain sorghum. II. Gene action, the number of effective factors and heritability. Can. Jour. Genet. Cytol., 9: 823-830.

COCHRAN. W.G. and G.M. COX (1957). Experimental designs. Second edition. John Wiley and Sons, Inc., New York. xiv+611 pp.

CRUMPACKER, D.W. and R.W. ALLARD (1962). A diallel cross analysis of heading date in wheat. Hilgardia, 32: 275-318.

CRUMPACKER, D.W. and N.S. URQUHART (1962). Relationship of gene action and combining ability in set of wheat parents. Abstr., Annual meeting, Amer. Soci. Agron., Cornell Univ., Ithaca, page 65.

DUNN, G.M. and J.A. WRIGHT (1970). Performance of diallel crosses of *Bromus inermis* for forage yield. Crop Sci., 10: 56-58.

DURRANT, A. (1965). Analysis of reciprocal differences in diallel crosses. Heredity, 20: 573-607.

DURRANT, A. and H. TYSON (1964). A diallel cross of genotypes and genotrophs of *Linum*. Heredity, 19: 207-227.

EAGLES, C.F. (1967). The effect of temperature on vegetative growth in climatic races of *Dactylis glomerata* in controlled environments. Ann. Bot., 31: 31-39.

EBERHART, S.A. and W.A. RUSSELL (1966). Stability parameters for comparing varieties. Crop Sci., 6: 36-40.

EBERHART, S.A. and W.A. RUSSELL (1969). Yield and stability for a 10-line diallel of a single-cross and double-cross maize hybrids. Crop Sci., 9: 357-361.

EUNUS, A.M., L.P.V. JOHNSON and R. AKSEL (1962). Inheritance of winter hardiness in an eighteen parent diallel cross of barley. Can. Jour. Genet. Cytol., 4: 356-376.

FASCULAS, A.C. and R.W. ALLARD (1962). Non-allelic gene interactions in the inheritance of quantitative characters in barley. Genetics., 47: 899-907.

FINLAY, K.W. and G.N. WILKINSON (1963). The analysis of adaptation in the plant breeding programme. Austr. Jour. Agric. Res., 14: 742-754.

FONSECA, S.M. (1965). Heterosis, heterobeltiosis, diallel analysis and gene action in crosses of *Triticum aestivum*. Unpublished Ph.D. Thesis, Purdue University, U.S.A. Diss. Abstr., 26: 4153.

FONSECA, S.M. and F.L. PATTERSON (1968). Hybrid vigour in a seven parent diallel cross in common winter wheat (*Triticum aestivum* L.). Crop Sci., 8: 85-88.

FRYXELL, P.A., G. STATEN and J.H. PORTER (1958). Performance of some wide crosses in *Gossypium*. New Mex. Agric. Expt. Sta. Bult., 419: 1-15.

GRIFFING, B. (1956). Concept of general and specific combining ability in relation to diallel crossing systems. Austr. Jour. Biol. Sci., 9: 463-493.

GRISSOM, D.B. and R.R. KALTON (1956). Inheritance of combining ability for forage traits in bromegrass (*Bromus inermis* Leyss.). Agron. Jour., 48: 289-293.

GYAWALI, K.K., C.O. QUALSET and W.T. YAMAZAKI (1968). Estimates of heterosis and combining ability in winter wheat. Crop. Sci.; 8: 322-324.

HARMAN, H.H. (1960). Modern factor analysis. Second edition. The University of Chicago Press, Chicago, U.S.A.

HAWKINS, B.S., H.A. PEACOCK and W.W. BALLARD (1965). Heterosis and combining ability in upland cotton. Effect on yield. Crop Sci., 5: 543-546.

HAYMAN, B.I. (1954a). Analysis of variance of diallel tables. Biometrics, 10: 235-244.

HAYMAN, B.I. (1954b). Theory and analysis of diallel crosses. I. Genetics, 39: 789-809.

HAYMAN, B.I. (1958). Theory and analysis of diallel crosses. II. Genetics, 43: 63-85.

HAYMAN, B.I. (1960). Theory and analysis of diallel crosses. III. Genetics, 45: 155-172.

HILL, J. and J.M. PERKINS (1969). The environmental induction of heritable changes in *Nicotiana rustica*. Effects of genotype-environment interactions. Genetics, 61: 661 - 675.

HOLMES, T.M. (1972). A quantitative genetic analysis of avoidance behaviour in *Mus musculus*. M.Sc. Thesis, The University of Alberta, Edmonton, Canada.

HOTELLING, H. (1933). Analysis of a complex of statistical variables into principal components. Jour. Edu. Phychol., 24: 417-441 and 498-520.

HSU, PING-HWA (1970). Inter-relationships and inheritance of agronomic and morphological characters in spring wheat. M.Sc. Thesis, The University of Alberta, Edmonton, Canada.

HSU, P. and P.W. WALTON (1970). The inheritance of morphological and agronomical characters in spring wheat. Euphytica, 19: 54-60.

HULL, F.H. (1945). Regression analysis of yield of hybrid corn and inbred parental lines. Maize Genet. Newsletter, 19: 21-27.

JINKS, J.L. (1954). Analysis of continuous variation in a diallel cross of *Nicotiana rustica* varieties. Genetics, 39: 767-788.

JINKS, J.L. (1956). The F_2 and backcross generations from a set of diallel crosses. Heredity, 10: 1-30.

JINKS, J.L. and B.I. HAYMAN (1953). The analysis of diallel crosses. Maize Genet. Newsletter, 27: 48-54.

JINKS, J.L., J.M. PERKINS and S.R. GREGORY (1972). The analysis and interpretation of differences between reciprocal crosses of *Nicotiana rustica* varieties. Heredity, 28: 363-377.

JOHNSON, L.P.V. and R. AKSEL (1959). Inheritance of yielding capacity in a fifteen parent diallel cross of barley. Can. Jour. Genet. Cytol., 1: 208-265.

JOHNSON, L.P.V. and R. AKSEL (1964). The inheritance of malting quality and agronomic characters in a diallel cross of barley. Can. Jour. Genet. Cytol., 6: 178-200.

JOHNSON, V.A. and J.W. SCHMIDT (1968). Hybrid wheat. Adv. Agron., 20: 199-233.

JOHNSON, V.A., K.B. BIEVER, A. HAUNOLD and J.W. SCHMIDT (1966). Inheritance of plant height, yield of grain and other plant and seed characteristics in a cross of hard red winter wheat, *Triticum aestivum* L. Crop Sci., 6: 336-338.

JOHNSTON, T.D. (1968a). A biometrical approach to plant breeding. 5th. Congress of the European Assoc. for research on plant breeding, Milano, Italy, page 97-107.

JOHNSTON, T.D. (1968b). Studies on a diallel cross and double-cross hybrids among various *Brassica oleracea* types. Euphytica, 17: 63-73.

KALTSIKES, P.J. (1970). Genotype-environment interaction variances in yield trials of fall rye. Can. Jour. Plant Sci., 50: 77-80.

KALTSIKES, P.J. and N.E. LARTER (1970). The interaction of genotype and environment in *durum* wheat. Euphytica, 19: 236-242.

KALTSIKES, P.J. and J. LEE (1971). Quantitative inheritance in *durum* wheat. Can. Jour. Genet. Cytol., 13: 210-218.

KEHR, W.R. (1961). General and specific combining ability for four agronomic traits in a diallel series among six alfalfa clones. Crop Sci., 1: 53-55.

KEMPTHORNE, O. (1956). The theory of diallel cross. Genetics, 41: 451-459.

KIHARA, H. (1944). Die Entdeckung der DD-analysatoren bien weizen. Agric. Hort. (Tokyo), 19: 889-890.

KIHARA, H. and F.A. LILIENFELD (1949). A new synthesized 6x-wheat. Proc., Intern. Congress of Genetics, 8th., 307-319.

KIME, P.H. (1950). Hybrid vigour in upland cotton. Effect on yield and yield quality. Proc., Sec. Cotton Imp. Conf., Biloxi, Miss., U.S.A. (Mimeograph).

KINMAN, M.L. and G.F. SPRAGUE (1945). Relation between number of parental lines and theoretical performance of synthetic varieties of corn. Jour. Amer. Soci. Agron., 37: 341-351.

KNIGHT, R. (1965). The relation between the yield and the reproductive phase in cocksfoot (*Dactylis glomerata* L.) in a winter rainfall environment. Austr. Jour. Agric. Res., 16: 505-515.

KNIGHT, R. (1970). The measurement and interpretation of genotype-environment interactions. Euphytica, 19: 225-235.

KNOWLES, R.P. (1950). Studies in combining ability in bromegrass and crested wheat grass. Sci. Agric., 30: 275-302.

KRONSTAD, W.E. and W.H. FOOTE (1964). General and specific combining ability estimates in winter wheat (*Triticum aestivum L.*). Crop. Sci., 4: 616-619.

LARSON, R.E. (1941). The F_1 combining ability of certain tomato varieties. Proc., Amer. Soci. Hort. Sci., 39: 313-314.

LAWLEY, D.N. and A.E. MAXWELL (1963). Factor analysis as a statistical method. Butterworth, London. pp: 117.

LEBSOCK, K.C. and A. AMAYA (1969). Variation and covariation of agronomic traits in *durum* wheat. Crop Sci., 9: 312-315.

LEE, J. and P.J. KALTSIKES (1973). Multivariate statistical analysis of grain yield and agronomic characters in *durum* wheat. Theoret. Applied Genet., 43: 226-231.

LEGG, P.D., G.B. COLLINS and C.C. LITTON (1970). Heterosis and combining ability in diallel crosses of burley tobacco, *Nicotiana tabacum* L. Crop Sci., 10: 705-707.

LIANG, G.H. (1967). Diallel analysis of agronomic characters in grain sorghum, *Sorghum vulgare* Pers. Can. Jour. Genet. Cytol., 9: 269-276.

LINAG, G.H. and T.L. WALTER (1966). Genotype x environment interactions from yield tests and their applications to sorghum breeding programs. Can. Jour. Genet. Cytol., 8: 306-311.

LIANG, G.H., E.G. HEYNE, J.H. CHUNG and Y.O. KOH (1968). The analysis of heritable variation for three agronomic traits in a six-variety diallel of sorghum, *Sorghum vulgare* Pers. Can. Jour. Genet. Cytol., 10: 460-469.

LUPTON, F.G.H. (1961). Studies in the breeding of self pollinated cereals. III. Further studies in cross prediction. Euphytica, 10: 209-224.

LUPTON, F.G.H. (1965). Studies in the breeding of self pollinated cereals. V. Use of incomplete diallel in wheat breeding. Euphytica, 14: 331-352.

MARANI, A. (1963). Heterosis and combining ability for yield and components of yield in diallel crosses of two species of cotton. Crop Sci., 3: 252.

MARANI, A. and Y. SACHS (1966). Heterosis and combining ability in a diallel cross among nine varieties of oriental tobacco. Crop Sci., 6: 19-22.

MATHER, K. (1949). Biometrical genetics. Methuen and Co., London.

MATHER, K. (1951). Statistical analysis in biology. Fourth edition, Methuen and Co., London.

MATHER, K. and J.L. JINKS (1971). Biometrical genetics. Second edition. Chapman and Hall Ltd., London. pp. 382.

MATZINGER, D.F., G.F. SPRAGUE and C.C. COCKERHAM (1959). Diallel cross of maize in experiments repeated over locations and years. Agron. Jour., 51: 346-350.

MATZINGER, D.F., J.J. MANN and C.C. COCKERHAM (1962). Diallel crosses in *Nicotiana tabacum*. Crop. Sci., 2: 383-386.

McFADDEN, E.S. and E.R. SEARS (1944). The artificial synthesis of *T. spelta*. Rec. Genetics Soc. Amer., 13: 26-27.

McFADDEN, E.S. and E.R. SEARS (1946). The origin of *Triticum spelta* and its free-threshing hexaploid relatives. Jour. Hered., 37: 81-89 and 107-116.

McNEAL, F.H. (1960). Yield component in a Lemhi x Thatcher wheat cross. Agron. Jour., 52: 348-349.

MELBURNE, M.C. and W.P. THOMPSON (1927). The cytology of a tetraploid wheat hybrid *Triticum spelta* x *Triticum monococcum*. Amer. Jour. Botany, 14: 327-333.

MILLER, P.A. and A. MARANI (1963). Heterosis and combining ability in diallel crosses of upland cotton, *Gossypium hirsutum* L. Crop Sci., 3: 441-444.

MOHAMMAD, A.H. and A.S. HANNA (1965). Inheritance of quantitative characters in rice. Can. Jour. Genet. Cytol., 7: 406-417.

MORROW, E.B., R.E. COMSTOCK and T. KELLEHER (1958). Genetic variances in strawberries. Proc., Amer. Soci. Hort. Sci., 72: 170-185.

MURTY, B.R., V. ARUNACHALAM and I.J. ANAND (1967). Diallel and partial diallel analysis of some yield factors in *Linum usitatissimum*. Heredity, 22: 35-41.

NAKAMURA, N. (1950). Statistical studies on combining ability in maize. Hyago Noka Naigaku, Memor., Nyago Agric. Univ., 2: 53.

NEWELL, T.G. (1970). Three biometrical genetic analyses of activity in the mouse. Jour. Comp. Physiol. Psychol., 70: 37-47.

NIEHAUS, M.H. and R.C. PICKETT (1966). Heterosis and combining ability in *Sorghum vulgare* Pers. Crop Sci., 6: 33-36.

NIELSON, A.K. and R.R. KALTON (1959). Combining ability for seed characteristics in *Bromus inermis* Leyss. Agron. Jour., 51: 178-181.

NORINGTON-DAVIES, J. (1967). Application of diallel analysis to experiments in plant competition. Euphytica, 16: 391-406.

NORINGTON-DAVIES, J. (1968). Diallel analysis of competition between grass species. Jour. Agric. Sci., Camb., 71: 223-231.

PARODA, R.S. and J.D. HAYES (1971). An investigation of genotype-environment interactions for rate of ear emergence in spring barley. Heredity, 26: 157-175.

PARODA, R.S. and A.B. JOSHI (1970). Genetic architecture of yield and components of yield in wheat. Ind. Jour. Genet. Plant breed., 30: 298-314.

PARODA, R.S. and A.B. JOSHI (1970a). Combining ability in wheat. Ind. Jour. Genet. Plant breed., 30: 630-637.

PARODI, R.C., F.L. PATTERSON and W.E. NYQUIST (1970). A six-parent diallel cross analysis of coleoptile elongation in wheat (*Triticum aestivum* L.). Crop Sci., 578-580.

PARSONS, P.A. and R.W. ALLARD (1960). Seasonal variation in lima bean seed size: An example of genotype-environment interaction. Heredity, 14: 115-123.

PERKINS, J.M. (1970). Environmental and genotype-environmental component of variability. VI. Diallel sets of crosses. Heredity, 25: 29-40.

PERKINS, J.M. and J.L. JINKS (1970). Detection and estimation of genotype-environmental, linkage and epistatic components of variation for a metrical trait. Heredity, 25: 157-177.

PERKINS, J.M. and J.L. JINKS (1971a). Analysis of genotype-environment interaction in triple test cross data. Heredity, 26: 203-209.

PERKINS, J.M. and J.L. JINKS (1971b). Specificity of the interaction of genotypes with contrasting environments. Heredity, 26: 463-474.

PERSSON, G. (1969). Diallel analysis of ear internode length in barley. Hereditas, 63: 39-47.

PONELEIT, C.G. and L.F. BAUMAN (1970). Diallel analysis of fatty acid in corn (*Zea mays* L.) oil. Crop Sci., 10: 338-341.

PORCEDDU, D.E. (1968). Environmental component and gentotype x environmental interaction in plant breeding work. Publication of Institute of Agric. Ecology, The Univ. of Perugia, Italy, 13 pp.

POVILAITIS, B. (1966). Diallel cross analysis of quantitative characters in tobacco. Can. Jour. Genet. Cytol., 8: 336-346.

POVILAITIS, B. (1970). Diallel analysis of crosses between flue-cured and burley tobacco varieties. Can Jour. Genet. Cytol., 12: 484-489.

QUALSET, C.O. (1968): Genotype-environment interaction for awn development in isogenic lines of barley. Theoret. Appl. Genetics, 38: 355-360.

RIGGS, T.J. and A.M. HAYTER (1972). Diallel analysis of the time-to-heading in spring barley. Heredity, 29: 341-357.

RIGGS, T.J. and A.M. HAYTER (1973). Diallel analysis of number of grains per ear in spring barley. Heredity, 31: 95-105.

RILEY, R., G. KIMBER and V. CHAPMAN (1961). Origin of genetic control of diploid-like behaviour of polyploid wheat. Jour. Heredity, 52: 22-25.

RILEY, R., J. UNRAU and V. CHAPMAN (1958). Evidence on the origin of B genome of wheat. Jour. Hered., 49: 91-98.

SARKAR, P. and G.L. STEBBINS (1956). Morphological evidence concerning the origin of the B genome in wheat. Amer. Jour. Bot., 43: 297-304.

SCHEFFE, H. (1959). The analysis of variance. John Wiley and Sons, New York, 477 pp.

SCHMIDT, J. (1919). La valeur de l'individu a titre de generateur appreciees suivant le methode du croisement diallele. C.R. Lab., Clasberg, 14: 1-33.

SEARS, E.R. (1948). The cytology and genetics of the wheat and their relatives. Advances in Genet., 2: 239-270.

SEARS, E.R. and M. OKAMOTO (1958). Intergenomic chromosome relationships in hexaploid wheats. Proceedings, 10th. Intern. Congress of Genetics, 2: 258-259.

SINGH, K.B., D. SHARMA and P.D. MEHNDIRATTA (1969). Study of combining ability and genetic parameters for yield and its components in wheat. Japanese Jour. Genet., 44: 367-377.

SMOCEK, J. (1969). A contribution to the analysis between economic yield components and four morpho-physiological subcharacters in wheat. Biologia Pl., 11: 260-269.

SOOMRO, B.A. (1967). Combining ability in *Gossypium arboreum* L. M.Sc. Agriculture Thesis, University of Sind, Hyderabad, Pakistan.

SOOMRO, B.A. and M.A. BALUCH (1969). Combining ability in *Gossypium arboreum* L. Yield of seed cotton. Pakistan Cottons, 13: 78-91.

SPANGELO, L.P.S., R. WATKINS, C.S. HSU and S.O. FEJER (1971). Combining ability analysis in cultivated strawberry. Can. Jour. Pl. Sci., 51: 377-383.

SPRAGUE, G.F. (1964). Estimates of genetic variances in two open pollinated variaties of maize and their reciprocal F_1 hybrids. Crop Sci., 4: 332-333.

SPRAGUE, G.F. and W.T. FEDERER (1951). A comparison of variance components in corn yield trials. II. Error, year x variety, location x variety and variety components. Agron. Jour., 43: 535-541.

SPRAGUE, G.F. and L.A. TATUM (1942). General versus specific combining ability in single crosses of corn. Jour. Amer. Soci. Agron., 34: 923-972.

THEURER, J.C. and L.J. ELLING (1963a). Comparative performance of diallel crosses and related second generation synthetics of alfalfa. I. Bacterial wilt resistence. Crop Sci., 3: 50-53.

THEURER, J.C. and L.J. ELLING (1963b). Comparative performance of diallel crosses and related second generation synthetics of alfalfa. II. Winter hardiness and resistence. *Ibid.* 3: 245.

TROYER, A.F. and A.R. HALLAUER (1968). Analysis of a diallel set of early flint varieties of maize. Crop Sci., 8: 581-584.

TURNER, J.H. (1953). A study of heterosis in upland cottons. I. Yield of hybrids compared with varieties. Agron. Jour., 45: 484-486.

WALKER, J.T. (1963). Multiline concept and intervarietal heterosis. Empire Cotton Growing Review, 40(3): 190-215.

WALTON, P.D. (1969). Inheritance of morphological characters associated with yield in spring wheat. Can. Jour. Plant Sci., 49: 587-596.

WATKINS, R. and L.P.S. SPANGELO (1968). Components of genetic variance in cultivated strawberry. Genetics, 59: 93-103.

WESTERMAN, J.M. (1970). Genotype-environment interaction and developmental regulation in *Arabidopsis thaliana*. II. Inbred lines; analysis. Heredity, 26: 93-106.

WESTERMAN, J.M. (1971a). Genotype-environment interaction and developmental regulation in *Arabidopsis thaliana*. III. Inbred lines; analysis of response to photoperiod. Heredity, 26: 373-382.

WESTERMAN, J.M. (1971b). Genotype-environment interaction and developmental regulation in *Arabidopsis thaliana*. IV. Wild material; analysis. Heredity, 26: 383-395.

WHITE, T.G. and R.J. KOHEL (1964). A diallel analysis of agronomic characters in selected lines of cottons, *Gossypium hirsutum* L. Crop Sci., 4: 254-257.

WHITE, T.G. and T.R. RICHMOND (1963). Heterosis and combining ability in top and diallel crosses among primitive, foreign and cultivated American upland cottons. Crop Sci., 3: 58-63.

WHITEHOUSE, R.N.H., J.B. THOMPSON and M.A.M. DOVALLE PIENIRO (1958). Studies on the breeding ~~of~~ self pollinated cereals. II. The use of diallel cross analysis in yield prediction. Euphytica, 7: 147-169.

WIEBEL, D.E. (1956). Inheritance of quantitative characters in wheat. Iowa State College, Jour. Sci., 30: 450-451.

WILCOX, J.B. and C.P. WILSIE (1964). Estimated general and specific combining ability effects and reciprocal effects in crosses among nine clones of alfalfa, *Medicago sativa* L. Crop Sci., 4: 375-377.

WRIGHT, S. (1952). The genetics of quantitative variability. In Reeve, E.C.R. and C.H. WADDINGTON (Editors), Quantitative Inheritance. Her Majesty's Stationary Office, London, page 5-40.

WU, H.P [illegible]). Studies on quantitative inheritance of *Oryza sativa* L. I. A diallel analysis of heading time and plant height in F_1 progeny. Bot. Bull., Academia Sinnica, 9: 1-9.

WU, H.P. (1968b). Studies on quantitative inheritance of *Oryza sativa* L. II. A diallel analysis of panicle number, tiller number, panicle length, spikelet number and number of primary branches in F_1 progeny. Bot. Bull., Academia Sinnica, (New Series), 9: 124-138.

YAP, T.C and B.L. HARVEY (1971). Heterosis and combining ability of barley hybrids in densely and widely seeded conditions. Can. Jour. Plant Sci., 51: 115-122.

YATES, F. (1947). Analysis of data from all possible reciprocal crosses between a set of parental lines. Heredity, 1: 287-301.

ZOHARY, D. and M. FELDMAN (1962). Hybridization between amphidiploids and the evolution of polyploids in wheat (*Aegilops-Triticum*) group. Evolution, 16: 44-61.

APPENDIX I

Origin, parentage and varietal description of five cultivars of wheat used in diallel study

Variety: Marquis
Origin: Central Experimental Farm, Ottawa, Canada
Parents: Hard Red Calcutta x Red Fyfe
Growth habit: Spring
Plant height: 110 - 120 cms.
Spike: Mid-long, fusiform with apical awns; beaks short, acute
Kernel: Dark red, hard, ovate-truncate

Variety: Chinook
Origin: Central Experimental Farm, Ottawa, Canada
Parents: Thatcher x S-615-11
Growth habit: Spring
Plant height: 110 - 125 cms.
Spike: Fusiform, mid-long, short apical awns, white glumes with mid-wide beaks
Kernel: Red, hard, short to mid-long, oval

Variety: Khush-hal
Origin: Agricultural Research Institute, Peshawar, Pakistan
Parents: Local white x Standard Desi
Growth habit: Spring
Plant height: 80 - 90 cms.
Spike: White, flufy, awned, white pubescent glumes with mid-wide beaks
Kernel: Amber colored, soft, mid-long, oval

Variety: Ciano-67
Origin: National Institute of Agricultural Research, Mexico
Parents: Pitic 62-Chris 'Sib' x Sonora 64
Growth habit: Spring
Plant height: 85 - 95 cms.
Spike: White, bearded; fusiform
Kernel: Hard red, medium size

Variety: Inia-66
Origin: National Institute of Agricultural Research, Mexico
Parents: Lerma Rojo 64 x Sonora 64
Growth habit: Spring
Plant height: 100 - 110 cms.
Spike: White, bearded, fusiform
Kernel: Hard, red, medium-long

APPENDIX-II

NUMERICAL DESIGNATIONS OF THE PARENTS AND THEIR CROSSES USED IN THE DIALLEL ANALYSES

1. (KxCH)F22
2. (IxK)I1
3. I1(IxC)
4. (KxM)F22
5. (IxC)I1
6. (CxI)F22
7. CH1(MxCH)
8. (IxK)F2
9. M-PARENT
10. K1(KxCH)
11. (CxI)C1
12. (MxK)M0
13. K1(CHxK)
14. (CHxM)CH1
15. C1(CHxC)
16. K-PARENT
17. (IxK)K1
18. CH1(CHxK)
19. (KxCH)F2
20. CH1(CHxC)
21. (MxK)M1
22. I1(IxK)
23. C1(CxCH)
24. (KxC)F2
25. (MxK)F22
26. (IxM)F22
27. (CHxC)CH1
28. CH1(CHxI)
29. I1(KxI)
30. (IxCH)CH1
31. F1(KxC)
32. (CxI)I1
33. (CxM)F1
34. CH1(IxCH)
35. (CHxC)C0
36. K0(KxM)
37. (IxM)F2
38. (CHxK)K1
39. (IxK)K0
40. (KxM)K1
41. (CxI)F1
42. (KxM)F22
43. (CHxK)F2
44. (CHxC)CH0
45. (IxM)M0
46. (CHxI)I1
47. C-PARENT
48. (CxK)F22
49. (CHxI)CH0
50. (KxI)I1
51. (CHxI)F2
52. C1(IxC)
53. (KxM)K0
54. (KxM)M0
55. M0(MxC)
56. (MxI)F22
57. I0(IxC)
58. (MxC)C0
59. (CHxM)F2
60. CH1(CHxM)
61. (CHxC)F22
62. M0(CHxM)
63. (MxC)F2
64. M0(IxM)
65. (IxCH)CH0
66. (KxI)F22
67. (CxM)M0
68. (CxI)C0
69. (KxC)C1
70. (CxCH)CH0
71. M1(MxC)
72. K0(KxI)
73. (CHxI)CH1
74. (CxK)K1
75. (KxI)I0
76. (CHxM)M1
77. (CxCH)C1
78. (CHxM)F22
79. I0(MxI)
80. (MxCH)F2
81. M0(KxM)
82. (KxCH)K1
83. I0(CxI)
84. (MxK)F2
85. (CxCH)F1
86. (CHxM)M0
87. (IxCH)F22
88. CH0(IxCH)
89. (MxK)K1
90. (IxM)F22
91. I-PARENT
92. (CxK)C1
93. CH0(MxCH)
94. CH1(CxCH)
95. C1(CxM)
96. (IxM)I1
97. (MxCH)CH1
98. M1(CxM)
99. (CxCH)CH1
100. (CxCH)F2
101. C0(IxC)
102. K1(KxI)
103. (KxC)K0
104. (MxC)F22
105. (KxCH)CH0
106. C1(MxC)
107. CH-PARENT
108. C1(CxK)
109. (CHxK)CH1
110. (MxCH)M0
111. M1(MxCH)
112. (MxI)M1
113. (CxM)F2
114. (CHxM)CH0
115. (IxK)F1
116. (CHxK)K0
117. (CHxI)F22
118. (IxK)I0
119. I1(MxI)
120. M1(KxM)
121. (MxC)C1
122. (IxM)M1
123. CH0(CHxM)
124. (KxM)K1
125. (IxM)F1
126. M0(MxK)
127. (MxC)M1
128. I1(IxM)
129. (MxI)F2
130. K0(CHxK)
131. (IxCH)F2
132. (KxC)K1
133. C1(CxI)
134. (CxM)F22
135. C1(KxC)
136. K1(CxK)
137. (MxCH)M1
138. (CxI)F2
139. I0(KxI)
140. C0(MxC)
141. (CHxK)F1
142. (IxC)C1
143. M1(IxM)
144. C0(KxC)
145. (CHxC)F2
146. K0(IxK)
147. (CxM)C1
148. (MxCH)F22
149. K0(CxK)
150. (MxI)F1
151. (KxI)F2
152. CH1(KxCH)
153. C0(CxCH)
154. (MxI)M0
155. M1(CHxM)
156. K0(MxK)
157. (MxCH)CH0
158. (MxCH)F1
159. K1(IxK)
160. (IxC)C0
161. (CxM)M1
162. C0(CxM)
163. CH0(CHxK)
164. (KxI)K1
165. CH0(CHxI)
166. M1(MxI)
167. C0(CxK)
168. (CxM)F1
169. (KxM)F2
170. I0(IxCH)
171. K1(MxK)
172. (IxC)F2
173. (CxI)F1
174. M0(MxCH)
175. (CxCH)F22
176. (CHxM)F1
177. (MxI)I1
178. (KxCH)CH1
179. I1(CxI)
180. (MxK)K0
181. (CxK)F2
182. (IxC)F22
183. CH0(CHxC)
184. (IxCH)I1
185. (CHxC)C1
186. I0(IxM)
187. I0(CHxI)
188. (KxC)C0
189. (IxCH)F1
190. (KxI)I0
191. C0(CHxC)
192. (CxM)C0
193. (KxM)F1
194. (CHxK)CH0
195. (IxM)I0
196. (IxCH)I0
197. CH0(KxCH)
198. M1(MxK)
199. I0(IxK)
200. (MxC)M0
201. I1(CHxI)
202. (KxI)K0
203. (CxK)C0
204. (IxC)F1
205. (CHxC)F1
206. I1(IxCH)
207. K0(KxCH)
208. M0(CxM)
209. (IxC)I0
210. (CHxK)F22
211. (CHxI)I0
212. CH0(CxCH)
213. K1(KxM)
214. (CxK)K0
215. (KxI)F1
216. (MxC)F1
217. M0(MxI)
218. K0(KxC)
219. C0(CxI)
220. (MxK)F1
221. (CxCH)C0
222. (CxI)I0
223. (KxCH)F1
224. (KxCH)K0
225. (CHxI)F1

NOTE: M=Marquis, CH Chinook, K=Khush-hal, C=Ciano-67 and I=Inia-66.
Taking any two varieties, for example 'C' and 'K', above mentioned combinations could be explained as follows:

(CxK)F1 = F_1 hybrid.
(KxC)F1 = Reciprocal F_1 hybrid.
(CxK)F2 = F_2-generation hybrid.
(KxC)F2 = Reciprocal F_2 hybrid.
(CxK)F22 and its reciprocal are the F_2's repeated second time in each replication to complete the requirements of the 15x15 partially balanced lattice design.

(CxK)C0 = Back cross-1.
C0(CxK) = Reciprocal back cross.
(CxK)K0 = Back cross-2.
K0(CxK) = Reciprocal back cross-2.
(CxK)C1 = Selfed generation of (CxK)C0.
C1(CxK) = Reciprocal of (CxK)C1.
(CxK)K1 = Selfed generation of (CxK)K0.
K1(CxK) = Reciprocal of (CxK)K1.

APPENDICES III TO XXII

Unadjusted treatment means (original data) of all the entries with respect to ten quantitative characters at two locations.

The numbers in the first row of each block are the code numbers of entries and those in the second row are the mean values of the corresponding entries listed in Appendix II.

APPENDIX III Onset-of-heading at Ellerslie

ELLERSLIE REPLICATION-1.

(Block)															
1.	181 50.000	182 51.000	183 56.000	184 54.000	185 51.000	186 51.000	187 52.000	188 53.000	189 53.000	190 53.000	191 52.000	192 52.000	193 54.000	194 54.000	195 52.000
2.	16 52.000	17 52.000	18 52.000	19 52.000	20 53.000	21 54.000	22 53.000	23 53.000	24 52.000	25 52.000	26 52.000	27 55.000	28 54.000	29 53.000	30 55.000
3.	211 51.000	212 51.000	213 53.000	214 51.000	215 53.000	216 52.000	217 53.000	218 52.000	219 52.000	220 55.000	221 52.000	222 52.000	223 54.000	224 55.000	225 54.000
4.	46 53.000	47 49.000	48 51.000	49 53.000	50 52.000	51 53.000	52 49.000	53 53.000	54 54.000	55 52.000	56 52.000	57 51.000	58 52.000	59 52.000	60 57.000
5.	106 51.000	107 57.000	108 52.000	109 52.000	110 57.000	111 56.000	112 55.000	113 53.000	114 57.000	115 52.000	116 53.000	117 53.000	118 52.000	119 51.000	120 53.000
6.	121 55.000	122 54.000	123 54.000	124 52.000	125 51.000	126 55.000	127 57.000	128 53.000	129 54.000	130 53.000	131 51.000	132 51.000	133 52.000	134 51.000	135 52.000
7.	91 51.000	92 51.000	93 56.000	94 53.000	95 52.000	96 53.000	97 57.000	98 57.000	99 51.000	100 51.000	101 51.000	102 53.000	103 51.000	104 52.000	105 54.000
8.	61 53.000	62 56.000	63 51.000	64 53.000	65 52.000	66 52.000	67 52.000	68 53.000	69 51.000	70 51.000	71 56.000	72 52.000	73 54.000	74 50.000	75 52.000
9.	151 53.000	152 55.000	153 52.000	154 52.000	155 57.000	156 54.000	157 56.000	158 54.000	159 52.000	160 52.000	161 57.000	162 52.000	163 53.000	164 51.000	165 53.000
10.	1 54.000	2 52.000	3 52.000	4 51.000	5 51.000	6 51.000	7 55.000	8 51.000	9 53.000	10 52.000	11 53.000	12 54.000	13 52.000	14 53.000	15 52.000
11.	196 52.000	197 54.000	198 55.000	199 53.000	200 52.000	201 52.000	202 53.000	203 52.000	204 52.000	205 53.000	206 55.000	207 53.000	208 52.000	209 52.000	210 54.000
12.	31 53.000	32 51.000	33 51.000	34 56.000	35 52.000	36 54.000	37 53.000	38 53.000	39 54.000	40 57.000	41 53.000	42 50.000	43 53.000	44 52.000	45 55.000
13.	136 52.000	137 57.000	138 50.000	139 53.000	140 50.000	141 54.000	142 52.000	143 53.000	144 51.000	145 52.000	146 52.000	147 51.000	148 52.000	149 52.000	150 54.000
14.	76 53.000	77 51.000	78 57.000	79 51.000	80 57.000	81 55.000	82 55.000	83 51.000	84 52.000	85 54.000	86 53.000	87 52.000	88 51.000	89 52.000	90 53.000
15.	166 54.000	167 52.000	168 54.000	169 54.000	170 53.000	171 52.000	172 52.000	173 51.000	174 60.000	175 52.000	176 50.000	177 51.000	178 58.000	179 57.000	180 53.000

REPLICATION-2.

(Block)															
1.	14 53.000	29 54.000	44 53.000	59 57.000	74 52.000	89 53.000	104 54.000	119 52.000	134 53.000	149 52.000	164 52.000	179 52.000	194 56.000	209 52.000	224 56.000
2.	1 55.000	16 57.000	31 53.000	46 53.000	61 52.000	76 57.000	91 52.000	106 52.000	121 55.000	136 51.000	151 52.000	166 55.000	181 51.000	196 52.000	211 51.000
3.	9 63.000	24 52.000	39 53.000	54 56.000	69 50.000	84 54.000	99 54.000	114 57.000	129 53.000	144 52.000	159 52.000	174 57.000	189 54.000	204 54.000	219 51.000
4.	2 51.000	17 50.000	32 52.000	47 52.000	62 53.000	77 51.000	92 52.000	107 54.000	122 56.000	137 56.000	152 53.000	167 52.000	182 49.000	197 57.000	212 51.000
5.	6 53.000	21 57.000	36 55.000	51 55.000	66 53.000	81 54.000	96 53.000	111 54.000	126 55.000	141 54.000	156 54.000	171 54.000	186 53.000	201 53.000	216 53.000
6.	11 51.000	26 52.000	41 52.000	56 53.000	71 57.000	86 57.000	101 52.000	116 51.000	131 52.000	146 52.000	161 54.000	176 57.000	191 52.000	206 52.000	221 51.000
7.	10 50.000	25 53.000	40 56.000	55 53.000	70 57.000	85 53.000	100 52.000	115 51.000	130 53.000	145 53.000	160 52.000	175 52.000	190 52.000	205 54.000	220 55.000
8.	8 52.000	23 53.000	38 51.000	53 54.000	68 52.000	83 43.000	98 57.000	113 54.000	128 53.000	143 51.000	158 53.000	173 52.000	188 57.000	203 57.000	218 51.000
9.	3 53.000	18 54.000	33 52.000	48 52.000	63 53.000	78 57.000	93 57.000	108 52.000	123 59.000	138 51.000	153 52.000	168 52.000	183 52.000	198 53.000	213 54.000
10.	13 51.000	28 54.000	43 53.000	58 53.000	73 54.000	88 52.000	103 52.000	118 53.000	133 51.000	148 53.000	163 51.000	178 55.000	193 55.000	208 51.000	223 54.000
11.	12 56.000	27 53.000	42 52.000	57 52.000	72 52.000	87 53.000	102 53.000	117 53.000	132 52.000	147 53.000	162 54.000	177 53.000	192 53.000	207 51.000	222 52.000
12.	5 52.000	20 53.000	35 51.000	50 52.000	65 53.000	80 57.000	95 52.000	110 57.000	125 52.000	140 52.000	155 57.000	170 51.000	185 52.000	200 52.000	215 53.000
13.	4 55.000	19 55.000	34 43.000	49 53.000	64 54.000	79 52.000	94 53.000	109 54.000	124 52.000	139 52.000	154 52.000	169 53.000	184 53.000	199 52.000	214 53.000
14.	7 60.000	22 52.000	37 53.000	52 52.000	67 52.000	82 55.000	97 54.000	112 55.000	127 57.000	142 52.000	157 55.000	172 52.000	187 53.000	202 53.000	217 54.000
15.	15 52.000	30 55.000	45 53.000	60 59.000	75 53.000	90 53.000	105 58.000	120 53.000	135 52.000	150 54.000	165 54.000	180 53.000	195 53.000	210 53.000	225 54.000

REPLICATION-3.

(Block)															
1.	45 52.000	59 54.000	73 54.000	87 52.000	101 52.000	115 53.000	129 53.000	143 52.000	157 54.000	171 53.000	185 52.000	199 52.000	213 52.000	2 52.000	16 52.000
2.	150 53.000	164 54.000	178 51.000	192 52.000	206 52.000	220 54.000	9 59.000	23 52.000	37 53.000	51 53.000	65 52.000	79 52.000	93 57.000	107 53.000	121 54.000
3.	90 52.000	104 52.000	118 52.000	132 53.000	146 52.000	160 52.000	174 55.000	188 53.000	202 53.000	216 52.000	5 52.000	19 55.000	33 53.000	47 51.000	61 53.000
4.	195 53.000	209 57.000	223 55.000	12 54.000	26 52.000	40 57.000	54 55.000	68 53.000	82 53.000	96 53.000	110 57.000	124 53.000	138 52.000	152 55.000	166 56.000
5.	105 53.000	119 52.000	133 50.000	147 50.000	161 57.000	175 49.000	189 52.000	203 50.000	217 51.000	6 52.000	20 52.000	34 54.000	48 52.000	62 57.000	76 61.000
6.	180 54.000	194 54.000	208 54.000	222 52.000	11 50.000	25 54.000	39 52.000	53 53.000	67 57.000	81 57.000	95 52.000	109 52.000	123 54.000	137 52.000	151 53.000
7.	60 55.000	74 50.000	88 53.000	102 54.000	116 53.000	130 53.000	144 52.000	158 57.000	172 61.000	186 52.000	200 57.000	214 57.000	3 57.000	17 57.000	31 57.000
8.	15 50.000	29 52.000	43 53.000	57 51.000	71 51.000	85 52.000	99 53.000	113 52.000	127 57.000	141 52.000	155 56.000	169 53.000	183 52.000	197 54.000	211 52.000
9.	225 54.000	14 54.000	28 54.000	42 52.000	56 54.000	70 51.000	84 54.000	98 55.000	112 57.000	126 58.000	140 52.000	154 51.000	168 54.000	182 51.000	196 52.000
10.	135 52.000	149 51.000	163 53.000	177 53.000	191 53.000	205 52.000	219 53.000	8 52.000	22 51.000	36 51.000	50 50.000	64 52.000	78 54.000	92 52.000	106 54.000
11.	165 52.000	179 52.000	193 55.000	207 53.000	221 52.000	10 53.000	24 52.000	38 53.000	52 51.000	66 52.000	80 57.000	94 53.000	108 52.000	122 53.000	136 52.000
12.	120 54.000	134 52.000	148 55.000	162 52.000	176 54.000	190 52.000	204 52.000	218 52.000	7 57.000	21 57.000	35 52.000	49 51.000	63 54.000	77 52.000	91 52.000
13.	30 55.000	44 51.000	58 52.000	72 57.000	86 55.000	100 52.000	114 57.000	128 54.000	142 52.000	156 53.000	170 53.000	184 54.000	198 57.000	212 52.000	1 56.000
14.	75 52.000	89 53.000	103 53.000	117 55.000	131 52.000	145 55.000	159 54.000	173 52.000	187 53.000	201 52.000	215 54.000	4 56.000	18 56.000	32 52.000	46 55.000
15.	210 54.000	224 53.000	13 53.000	27 57.000	41 52.000	55 53.000	69 52.000	83 52.000	97 57.000	111 57.000	125 53.000	139 52.000	153 52.000	167 52.000	181 50.000

APPENDIX IV Final heading at Ellerslie

ELLERSLIE = REPLICATE 1.

(Block)															
1.	181 59.000	182 54.000	183 61.000	184 62.000	185 67.000	186 54.000	187 61.000	188 67.000	189 51.000	190 60.000	191 53.000	192 59.000	193 63.000	194 62.000	195 68.000
2.	16 62.000	17 63.000	18 64.000	19 62.000	20 62.000	21 64.000	22 63.000	23 53.000	24 59.000	25 61.000	26 57.000	27 62.000	28 52.000	29 [illegible]	30 65.000
3.	211 59.000	212 60.000	213 65.000	214 54.000	215 59.000	216 63.000	217 62.000	218 54.000	219 59.000	220 62.000	221 65.000	222 59.000	223 61.000	[illegible]	225 62.000
4.	46 63.000	47 57.000	48 [illegible]	49 61.000	50 58.000	51 64.000	52 54.000	53 61.000	54 62.000	55 59.000	56 60.000	57 54.000	58 63.000	59 65.000	60 67.000
5.	106 63.000	107 64.000	108 57.000	109 62.000	110 65.000	111 64.000	112 62.000	113 61.000	114 67.000	115 62.000	116 61.000	117 61.000	118 53.000	119 59.000	120 61.000
6.	121 62.000	122 63.000	123 65.000	124 61.000	125 63.000	126 63.000	127 55.000	128 53.000	129 62.000	130 61.000	131 61.000	132 53.000	133 59.000	134 63.000	135 60.000
7.	91 59.000	92 59.000	93 66.000	94 61.000	95 59.000	96 54.000	97 61.000	98 61.000	99 62.000	100 58.000	101 58.000	102 63.000	103 53.000	104 58.000	105 62.000
8.	61 58.000	62 65.000	63 59.000	64 63.000	65 58.000	66 54.000	67 62.000	68 58.000	69 54.000	70 59.000	71 64.000	72 63.000	73 63.000	74 53.000	75 53.000
9.	151 61.000	152 66.000	153 63.000	154 53.000	155 67.000	156 65.000	157 55.000	158 63.000	159 67.000	160 59.000	161 64.000	162 53.000	163 61.000	164 57.000	165 61.000
10.	1 60.000	2 59.000	3 58.000	4 62.000	5 54.000	6 54.000	7 64.000	8 54.000	9 67.000	10 53.000	11 56.000	12 64.000	13 53.000	14 65.000	15 63.000
11.	196 66.000	197 61.000	198 67.000	199 59.000	200 61.000	201 63.000	202 59.000	203 57.000	204 53.000	205 63.000	206 61.000	207 52.000	208 61.000	209 59.000	210 56.000
12.	31 66.000	32 57.000	33 57.000	34 67.000	35 53.000	36 61.000	37 67.000	38 63.000	39 63.000	40 54.000	41 59.000	42 63.000	43 62.000	44 65.000	45 64.000
13.	136 57.000	137 64.000	138 63.000	139 63.000	140 59.000	141 62.000	142 54.000	143 61.000	144 57.000	145 61.000	146 54.000	147 51.000	148 61.000	149 59.000	150 61.000
14.	76 64.000	77 59.000	78 65.000	79 57.000	80 64.000	81 64.000	82 54.000	83 59.000	84 63.000	85 57.000	86 66.000	87 63.000	88 63.000	89 63.000	90 60.000
15.	166 61.000	167 58.000	168 63.000	169 63.000	170 63.000	171 63.000	172 64.000	173 59.000	174 67.000	175 59.000	176 67.000	177 57.000	178 57.000	179 59.000	180 64.000

REPLICATE 2.

1.	14 57.000	29 62.000	44 63.000	59 67.000	74 59.000	89 63.000	104 63.000	119 57.000	134 53.000	149 58.000	164 59.000	179 64.000	194 61.000	209 59.000	224 64.000
2.	1 64.000	16 63.000	31 65.000	46 59.000	61 62.000	76 65.000	91 54.000	106 63.000	121 62.000	136 53.000	151 59.000	166 67.000	181 54.000	196 59.000	211 54.000
3.	9 64.000	24 58.000	39 63.000	54 64.000	69 54.000	84 51.000	99 62.000	114 65.000	129 63.000	144 57.000	159 54.000	174 54.000	189 62.000	204 53.000	219 57.000
4.	2 67.000	17 54.000	32 54.000	47 59.000	62 59.000	77 59.000	92 54.000	107 64.000	122 63.000	137 61.000	152 62.000	167 53.000	182 54.000	197 54.000	212 63.000
5.	6 62.000	21 57.000	36 62.000	51 53.000	66 54.000	81 53.000	96 53.000	111 55.000	126 62.000	141 63.000	156 62.000	171 61.000	186 57.000	201 63.000	216 54.000
6.	11 58.000	26 54.000	41 57.000	56 51.000	71 61.000	86 65.000	101 54.000	116 63.000	131 63.000	146 53.000	161 52.000	176 64.000	191 63.000	206 59.000	221 51.000
7.	10 61.000	25 59.000	40 67.000	55 62.000	70 67.000	85 63.000	100 [illegible]	115 58.000	130 62.000	145 60.000	160 57.000	175 53.000	190 53.000	205 61.000	220 64.000
8.	8 59.000	23 54.000	38 53.000	53 67.000	68 58.000	83 54.000	98 54.000	113 63.000	128 [illegible]	143 51.000	158 67.000	173 53.000	188 53.000	203 59.000	218 63.000
9.	3 59.000	18 57.000	33 58.000	48 65.000	63 62.000	78 64.000	93 65.000	108 54.000	123 64.000	138 59.000	153 62.000	168 59.000	183 62.000	198 57.000	213 53.000
10.	13 57.000	28 64.000	43 64.000	58 53.000	73 52.000	88 67.000	103 62.000	118 57.000	133 57.000	148 67.000	163 67.000	178 55.000	193 64.000	208 56.000	223 62.000
11.	12 65.000	27 65.000	42 59.000	57 57.000	72 53.000	87 61.000	102 61.000	117 67.000	132 61.000	147 57.000	162 62.000	177 62.000	192 62.000	207 62.000	222 54.000
12.	5 51.000	20 64.000	35 60.000	50 57.000	65 61.000	80 64.000	95 64.000	110 61.000	125 54.000	140 62.000	155 57.000	170 63.000	185 59.000	200 63.000	215 54.000
13.	4 64.000	19 64.000	34 64.000	49 64.000	64 52.000	79 53.000	94 54.000	109 64.000	124 64.000	139 53.000	154 61.000	169 61.000	184 51.000	199 54.000	214 54.000
14.	7 67.000	22 59.000	37 62.000	52 57.000	67 61.000	82 62.000	97 67.000	112 65.000	127 65.000	142 54.000	157 65.000	172 59.000	187 59.000	202 61.000	217 61.000
15.	15 59.000	30 65.000	45 60.000	60 [illegible]	75 59.000	90 58.000	105 54.000	120 63.000	135 59.000	150 62.000	165 59.000	180 62.000	195 59.000	210 53.000	225 60.000

REPLICATE 3.

1.	45 59.000	59 61.000	73 61.000	87 64.000	101 57.000	115 64.000	129 67.000	143 60.000	157 62.000	171 60.000	185 59.000	199 67.000	213 57.000	2 62.000	16 62.000
2.	153 64.000	168 63.000	170 63.000	187 62.000	204 56.000	220 62.000	8 67.000	23 59.000	37 61.000	54 62.000	65 67.000	73 53.000	91 65.000	107 54.000	121 63.000
3.	63 58.000	134 65.000	178 59.000	192 63.000	146 57.000	160 59.000	174 57.000	115 63.000	202 59.000	216 52.000	5 59.000	19 61.000	33 54.000	47 57.000	61 59.000
4.	115 59.000	229 58.000	223 62.000	12 63.000	26 59.000	40 61.000	54 62.000	68 62.000	82 59.000	95 58.000	109 64.000	123 51.000	138 54.000	152 60.000	164 62.000
5.	125 58.000	119 59.000	133 57.000	147 58.000	161 61.000	175 58.000	189 54.000	203 53.000	217 51.000	6 60.000	20 61.000	34 65.000	48 59.000	62 67.000	76 63.000
6.	190 67.000	196 60.000	208 62.000	222 64.000	11 57.000	24 61.000	39 67.000	51 67.000	62 64.000	41 64.000	65 59.000	137 53.000	121 64.000	117 65.000	151 62.000
7.	63 65.000	78 58.000	88 59.000	102 63.000	116 62.000	133 62.000	144 54.000	158 65.000	172 58.000	186 51.000	220 67.000	214 67.000	1 61.000	17 61.000	33 62.000
8.	15 59.000	29 58.000	43 62.000	57 57.000	71 62.000	85 59.000	99 62.000	113 59.000	127 64.000	141 63.000	155 61.000	169 57.000	183 60.000	197 53.000	211 60.000
9.	225 65.000	10 67.000	24 61.000	47 58.000	56 62.000	70 61.000	84 61.000	98 62.000	112 65.000	126 67.000	140 59.000	154 57.000	164 62.000	182 54.000	195 54.000
10.	135 59.000	149 59.000	163 61.000	177 63.000	191 59.000	205 62.000	219 59.000	8 58.000	22 56.000	36 60.000	43 53.000	64 53.000	79 65.000	92 54.000	106 59.000
11.	165 59.000	179 59.000	193 62.000	207 63.000	221 58.000	10 63.000	24 54.000	38 62.000	52 59.000	66 58.000	80 65.000	94 58.000	109 54.000	122 62.000	135 59.000
12.	128 62.000	130 62.000	140 64.000	162 61.000	176 66.000	193 59.000	206 57.000	218 54.000	7 64.000	21 65.000	35 59.000	49 62.000	63 60.000	77 59.000	91 58.000
13.	30 65.000	44 61.000	58 60.000	72 58.000	86 64.000	101 58.000	114 65.000	128 53.000	142 54.000	156 63.000	170 58.000	184 64.000	198 63.000	212 63.000	1 65.000
14.	75 58.000	89 61.000	103 59.000	117 64.000	131 60.000	145 63.000	159 59.000	173 58.000	187 59.000	201 60.000	215 59.000	4 62.000	18 53.000	32 58.000	46 65.000
15.	210 62.000	224 66.000	13 62.000	27 60.000	41 58.000	55 61.000	69 51.000	83 58.000	97 60.000	111 60.000	125 59.000	139 58.000	153 58.000	167 58.000	181 57.000

APPENDIX V Heading-span at Ellerslie

REPLICATION-1

(Block)															
1.	181 8.000	182 7.000	183 5.000	184 8.000	185 10.000	186 7.000	187 9.000	188 4.000	189 8.000	190 7.000	191 7.000	192 7.000	193 6.000	194 8.000	195 6.000
2.	16 10.000	17 8.000	18 7.000	19 10.000	20 7.000	21 10.000	22 7.000	23 6.000	24 4.000	25 9.000	26 7.000	27 7.000	28 8.000	29 6.000	30 10.000
3.	211 8.000	212 9.000	213 11.000	214 7.000	215 6.000	216 8.000	217 9.000	218 6.000	219 6.000	220 7.000	221 8.000	222 6.000	223 7.000	224 7.000	225 8.000
4.	46 8.000	47 8.000	48 7.000	49 6.000	50 6.000	51 7.000	52 9.000	53 8.000	54 9.000	55 7.000	56 8.000	57 7.000	58 8.000	59 8.000	60 10.000
5.	106 12.000	107 7.000	108 7.000	109 10.000	110 9.000	111 6.000	112 7.000	113 13.000	114 10.000	115 8.000	116 9.000	117 8.000	118 7.000	119 9.000	120 6.000
6.	121 8.000	122 9.000	123 11.000	124 9.000	125 7.000	126 8.000	127 8.000	128 6.000	129 4.000	130 8.000	131 4.000	132 8.000	133 7.000	134 7.000	135 8.000
7.	91 8.000	92 8.000	93 10.000	94 8.000	95 7.000	96 5.000	97 6.000	98 6.000	99 11.000	100 7.000	101 7.000	102 7.000	103 4.000	104 6.000	105 8.000
8.	61 5.000	62 9.000	63 8.000	64 7.000	65 7.000	66 6.000	67 10.000	68 4.000	69 8.000	70 6.000	71 9.000	72 9.000	73 9.000	74 13.000	75 7.000
9.	151 8.000	152 9.000	153 11.000	154 11.000	155 13.000	156 9.000	157 7.000	158 7.000	159 9.000	160 7.000	161 7.000	162 9.000	163 9.000	164 6.000	165 9.000
10.	1 10.000	2 7.000	3 6.000	4 9.000	5 7.000	6 7.000	7 9.000	8 7.000	9 7.000	10 7.000	11 6.000	12 13.000	13 8.000	14 7.000	15 6.000
11.	196 12.000	197 7.000	198 9.000	199 6.000	200 11.000	201 9.000	202 6.000	203 7.000	204 7.000	205 7.000	206 6.000	207 9.000	208 7.000	209 7.000	210 10.000
12.	31 9.000	32 6.000	33 6.000	34 11.000	35 7.000	36 9.000	37 9.000	38 7.000	39 9.000	40 7.000	41 5.000	42 10.000	43 9.000	44 13.000	45 9.000
13.	136 7.000	137 9.000	138 10.000	139 7.000	140 9.000	141 8.000	142 6.000	143 8.000	144 8.000	145 9.000	146 6.000	147 7.000	148 9.000	149 9.000	150 7.000
14.	76 8.000	77 8.000	78 8.000	79 6.000	80 7.000	81 9.000	82 9.000	83 9.000	84 9.000	85 7.000	86 7.000	87 8.000	88 7.000	89 8.000	90 6.000
15.	166 9.000	167 6.000	168 6.000	169 8.000	170 7.000	171 9.000	172 6.000	173 7.000	174 7.000	175 7.000	176 7.000	177 14.000	178 9.000	179 9.000	180 14.000

REPLICATION-2

1.	14 11.000	29 6.000	44 9.000	59 12.000	74 7.000	89 7.000	104 5.000	119 7.000	134 6.000	149 6.000	164 7.000	179 6.000	194 7.000	209 7.000	224 8.000
2.	1 9.000	16 6.000	31 12.000	46 13.000	61 13.000	76 6.000	91 5.000	106 9.000	121 6.000	136 7.000	151 7.000	166 12.000	181 7.000	196 7.000	211 8.000
3.	9 8.000	24 6.000	39 7.000	54 9.000	69 8.000	84 7.000	99 5.000	114 8.000	129 7.000	144 5.000	159 6.000	174 9.000	189 8.000	204 4.000	219 6.000
4.	2 12.000	17 9.000	32 6.000	47 7.000	62 4.000	77 9.000	92 7.000	107 9.000	122 7.000	137 7.000	152 8.000	167 5.000	182 9.000	197 7.000	212 7.000
5.	6 7.000	21 12.000	36 7.000	51 7.000	66 5.000	81 11.000	96 7.000	111 7.000	126 8.000	141 6.000	156 8.000	171 9.000	186 6.000	201 7.000	216 6.000
6.	11 7.000	26 6.000	41 5.000	56 4.000	71 8.000	86 8.000	101 6.000	116 7.000	131 7.000	146 7.000	161 8.000	176 7.000	191 9.000	206 7.000	221 7.000
7.	10 11.000	25 11.000	40 9.000	55 9.000	70 9.000	85 7.000	100 7.000	115 7.000	130 7.000	145 7.000	160 5.000	175 7.000	190 7.000	205 6.000	220 7.000
8.	8 6.000	23 6.000	38 6.000	53 9.000	68 4.000	83 6.000	98 7.000	113 4.000	128 6.000	143 8.000	158 9.000	173 6.000	188 4.000	203 6.000	218 7.000
9.	3 7.000	18 7.000	33 6.000	48 6.000	63 7.000	78 7.000	93 5.000	108 4.000	123 5.000	138 7.000	153 8.000	168 7.000	183 8.000	198 4.000	213 9.000
10.	13 9.000	28 12.000	43 9.000	58 9.000	73 5.000	88 8.000	103 4.000	118 6.000	133 7.000	148 9.000	163 13.000	178 10.000	193 9.000	208 11.000	223 8.000
11.	12 9.000	27 12.000	42 7.000	57 5.000	72 7.000	87 9.000	102 3.000	117 9.000	132 9.000	147 6.000	162 6.000	177 9.000	192 9.000	207 9.000	222 7.000
12.	5 7.000	20 11.000	35 7.000	50 8.000	65 3.000	80 9.000	95 7.000	110 4.000	125 7.000	140 10.000	155 13.000	170 7.000	185 7.000	200 9.000	215 5.000
13.	4 9.000	19 9.000	34 11.000	49 11.000	64 6.000	79 7.000	94 6.000	109 11.000	124 12.000	139 7.000	154 11.000	169 7.000	184 8.000	199 7.000	214 6.000
14.	7 7.000	22 7.000	37 7.000	52 5.000	67 9.000	82 7.000	97 9.000	112 12.000	127 8.000	142 5.000	157 10.000	172 7.000	187 7.000	202 9.000	217 7.000
15.	15 6.000	30 11.000	45 7.000	60 9.000	75 6.000	[illegible]	105 8.000	120 7.000	135 6.000	150 8.000	165 7.000	180 9.000	195 6.000	[illegible]	225 6.000

REPLICATION-3

1.	45 7.000	59 7.000	73 7.000	87 7.000	101 5.000	115 4.000	129 8.000	143 8.000	157 8.000	171 7.000	185 7.000	199 4.000	213 8.000	[illegible] 13.000	16 10.000
2.	150 7.000	164 6.000	178 7.000	192 9.000	206 7.000	220 4.000	9 8.000	23 7.000	37 5.000	51 7.000	65 9.000	79 8.000	93 8.000	107 8.000	121 6.000
3.	90 6.000	104 8.000	118 6.000	132 7.000	146 5.000	160 5.000	174 12.000	188 7.000	202 4.000	216 6.000	5 7.000	19 6.000	33 9.000	47 6.000	61 4.000
4.	195 6.000	209 6.000	223 7.000	12 9.000	26 7.000	40 6.000	54 9.000	68 7.000	82 6.000	96 6.000	110 11.000	124 8.000	138 5.000	152 5.000	166 8.000
5.	105 11.000	119 7.000	133 7.000	147 8.000	161 4.000	175 9.000	189 7.000	203 9.000	217 7.000	6 8.000	20 9.000	34 11.000	48 7.000	62 10.000	76 9.000
6.	180 6.000	194 6.000	208 6.000	222 6.000	11 7.000	25 7.000	39 9.000	53 7.000	67 7.000	81 7.000	95 7.000	109 8.000	123 13.000	137 8.000	151 7.000
7.	60 10.000	74 8.000	88 6.000	102 6.000	116 7.000	130 7.000	144 6.000	158 8.000	172 9.000	186 6.000	200 10.000	214 5.000	3 6.000	17 6.000	31 5.000
8.	15 9.000	29 7.000	43 7.000	57 6.000	71 7.000	85 7.000	99 7.000	113 7.000	127 7.000	141 8.000	155 7.000	169 7.000	183 8.000	197 6.000	211 8.000
9.	225 6.000	14 9.000	28 7.000	42 7.000	56 8.000	70 9.000	84 7.000	98 8.000	112 8.000	126 9.000	140 7.000	154 7.000	168 6.000	182 7.000	196 6.000
10.	135 7.000	149 8.000	163 6.000	177 7.000	191 7.000	205 3.000	219 6.000	8 6.000	22 5.000	36 7.000	50 6.000	64 7.000	78 8.000	92 7.000	106 5.000
11.	165 7.000	179 7.000	193 7.000	207 11.000	221 7.000	10 12.000	24 6.000	38 9.000	52 7.000	66 6.000	80 8.000	94 5.000	108 6.000	122 9.000	136 7.000
12.	120 8.000	134 10.000	148 9.000	162 9.000	176 8.000	190 7.000	204 5.000	218 6.000	7 8.000	21 8.000	35 7.000	49 6.000	63 8.000	77 7.000	91 6.000
13.	30 10.000	44 8.000	58 8.000	72 7.000	86 10.000	100 7.000	114 8.000	128 5.000	142 6.000	156 7.000	170 6.000	184 6.000	198 9.000	212 8.000	1 11.000
14.	75 7.000	89 8.000	103 6.000	117 9.000	131 8.000	145 5.000	159 5.000	173 6.000	187 6.000	201 8.000	215 5.000	4 6.000	18 7.000	32 6.000	46 10.000
15.	210 8.000	224 7.000	13 9.000	27 7.000	41 6.000	55 12.000	69 7.000	83 6.000	97 7.000	111 7.000	125 6.000	139 6.000	153 6.000	167 6.000	181 7.000

APPENDIX VI Plant height at Ellerslie

ELLERSLIE REPLICATION 1 PLANT HEIGHT

(Block)

1.	181 72.500	182 67.900	183 105.310	184 65.050	185 5.650	186 71.110	187 95.210	188 65.240	189 86.410	190 65.350	191 [illegible]	192 115.240	193 101.210	194 95.310	195 74.210
2.	16 74.850	17 76.270	18 110.130	19 91.230	20 101.450	21 111.370	22 69.920	23 67.610	24 74.670	25 101.390	26 75.450	27 112.340	28 121.400	29 75.710	30 106.320
3.	211 83.330	212 89.550	213 89.570	214 74.530	215 71.550	216 [illegible]	217 131.140	218 71.640	219 75.240	220 96.550	221 [illegible]	222 71.750	223 93.510	224 87.640	225 102.360
4.	46 96.430	47 81.890	48 79.170	49 116.920	50 83.460	51 126.270	52 [illegible]	53 116.530	54 122.640	55 91.230	56 [illegible]	57 75.222	58 124.620	59 125.310	60 120.450
5.	106 101.750	107 105.510	108 74.410	109 97.060	110 120.020	111 115.370	112 125.510	113 87.340	114 [illegible]	115 69.242	116 92.450	117 92.350	118 75.930	119 91.550	120 92.850
6.	121 95.030	122 96.260	123 106.700	124 81.310	125 86.160	126 74.270	127 113.610	128 75.940	129 87.650	130 86.650	131 [illegible]	132 77.350	133 77.470	134 65.310	135 74.760
7.	91 70.700	92 75.420	93 116.640	94 91.520	95 82.420	96 76.640	97 117.650	99 124.940	[illegible]	100 90.550	101 [illegible]	102 75.140	103 76.140	104 93.140	105 95.730
8.	61 83.200	62 115.210	63 86.940	64 91.620	65 79.720	66 72.500	67 126.230	68 74.270	[illegible]	70 [illegible]	71 [illegible]	72 74.270	73 131.520	74 71.350	75 64.650
9.	151 86.480	152 95.560	153 94.150	154 105.710	155 129.670	156 101.420	157 [illegible]	158 [illegible]	159 64.270	160 71.270	161 131.370	162 107.480	163 87.350	164 74.340	165 39.410
10.	1 90.030	2 70.320	3 68.010	4 91.470	5 71.320	6 73.570	7 126.270	8 116.370	9 117.340	10 91.550	11 [illegible]	12 [illegible]	13 83.360	14 112.730	15 64.620
11.	196 103.450	197 80.700	198 [illegible]	199 92.750	200 85.450	201 74.400	202 67.100	203 67.050	204 [illegible]	205 85.730	206 [illegible]	207 77.310	208 62.570	209 [illegible]	210 87.150
12.	31 69.200	32 56.970	33 66.900	34 37.400	35 [illegible]	36 92.100	37 72.420	38 82.210	39 [illegible]	40 121.550	41 73.270	42 71.220	43 [illegible]	44 [illegible]	45 87.420
13.	136 67.130	137 101.290	138 63.310	139 [illegible]	140 91.320	141 39.270	142 67.070	143 63.510	144 72.440	145 65.542	146 71.750	147 71.410	148 122.420	149 72.420	150 82.720
14.	76 104.030	77 78.310	78 101.770	79 77.750	80 105.410	81 93.500	82 75.610	83 75.370	84 62.442	85 96.300	86 [illegible]	87 66.770	88 75.320	89 [illegible]	90 74.125
15.	166 37.750	167 69.520	168 90.940	169 64.170	170 97.050	171 30.470	172 72.640	173 75.770	174 111.120	175 92.570	176 111.140	177 82.410	178 92.160	179 72.450	180 61.110

REPLICATION-2.

1.	14 104.160	29 71.220	44 100.150	59 112.410	[illegible]	89 81.340	104 96.460	119 94.110	134 [illegible]	149 72.160	164 82.110	179 73.440	194 83.420	209 71.410	224 91.310
2.	1 89.090	16 73.410	31 83.340	46 121.860	61 99.320	76 114.210	91 74.442	106 111.540	121 [illegible]	136 74.122	151 [illegible]	166 [illegible]	181 72.470	196 121.240	211 89.430
3.	9 120.420	24 83.070	39 77.290	54 101.740	69 73.420	84 101.730	99 127.750	114 123.290	129 [illegible]	144 79.760	159 [illegible]	174 121.180	189 [illegible]	204 [illegible]	219 70.500
4.	2 69.870	17 65.140	32 73.530	47 76.440	62 [illegible]	77 [illegible]	92 112.240	107 87.490	122 [illegible]	137 112.020	152 127.040	167 71.440	182 [illegible]	197 121.530	212 107.190
5.	6 73.520	21 112.240	36 90.230	51 124.770	66 86.440	81 95.370	96 87.570	111 121.500	126 [illegible]	141 [illegible]	156 [illegible]	171 131.240	186 89.220	201 [illegible]	216 95.920
6.	11 87.430	26 76.560	41 79.100	56 36.510	71 107.420	86 121.270	101 [illegible]	116 87.440	131 [illegible]	146 74.310	161 [illegible]	176 112.530	191 97.340	206 [illegible]	221 133.290
7.	10 75.030	25 95.720	40 104.810	55 92.111	70 94.440	85 91.310	100 94.110	115 [illegible]	130 [illegible]	145 42.532	160 [illegible]	175 [illegible]	190 72.522	205 [illegible]	220 91.720
8.	8 72.500	23 90.950	38 82.440	53 127.360	68 72.790	83 71.140	98 104.620	113 86.280	128 71.520	143 93.250	158 [illegible]	173 77.720	188 32.740	203 [illegible]	218 74.270
9.	3 71.150	18 124.450	33 76.510	48 78.142	63 102.240	78 92.730	93 122.540	108 74.750	123 [illegible]	138 76.510	153 121.710	168 137.240	183 95.570	198 [illegible]	213 67.920
10.	13 87.720	28 135.350	43 121.650	58 [illegible]	73 121.392	88 [illegible]	103 70.610	118 72.610	133 [illegible]	148 115.542	163 [illegible]	178 124.590	193 73.412	208 [illegible]	223 37.710
11.	12 103.320	27 101.710	42 72.750	57 71.550	72 63.150	87 93.422	102 72.310	117 63.910	132 [illegible]	147 74.462	162 [illegible]	177 [illegible]	192 95.242	207 [illegible]	222 72.770
12.	5 68.540	20 173.180	35 77.240	50 87.380	65 35.940	80 117.410	95 87.120	110 [illegible]	125 [illegible]	140 93.520	155 [illegible]	170 [illegible]	185 112.420	200 [illegible]	215 117.770
13.	4 72.040	19 96.310	34 104.040	49 137.372	64 83.120	79 74.180	94 93.310	109 96.430	124 [illegible]	139 79.172	154 115.770	169 91.510	184 74.550	199 71.420	214 72.550
14.	7 113.690	22 72.400	37 74.570	52 72.490	67 99.103	82 75.640	97 117.670	112 121.970	127 [illegible]	142 74.640	157 [illegible]	172 92.670	187 76.950	202 [illegible]	217 75.120
15.	15 81.070	30 102.660	45 79.440	60 115.920	75 86.910	90 75.150	105 96.640	120 81.650	135 77.910	150 95.420	165 [illegible]	180 97.640	195 87.590	210 [illegible]	225 89.180

REPLICATION-3.

1.	45 84.270	59 115.410	73 111.270	87 93.350	101 81.670	115 [illegible]	129 112.242	143 [illegible]	157 [illegible]	171 74.350	185 [illegible]	199 [illegible]	213 61.620	2 74.240	16 25.200
2.	153 165.300	168 80.240	174 131.460	[illegible]	206 94.910	220 110.140	9 128.250	23 87.180	37 64.570	44 126.550	58 121.240	[illegible]	86 124.322	[illegible] 118.540	[illegible] 121.510
3.	93 78.150	108 90.690	118 74.020	132 61.780	146 61.910	160 76.720	174 137.172	[illegible] 74.425	[illegible] 75.720	216 97.910	5 [illegible]	[illegible]	33 75.440	47 73.520	61 90.260
4.	195 87.120	209 75.460	223 101.310	12 105.410	26 73.720	40 115.570	54 127.250	68 [illegible]	82 74.422	96 83.250	110 125.330	124 31.970	138 85.670	152 107.470	166 114.920
5.	105 111.110	119 91.740	133 75.920	147 92.520	161 116.140	175 91.750	189 126.940	[illegible] 83.240	[illegible] 112.420	6 96.590	20 [illegible]	34 [illegible]	48 93.422	62 122.440	76 123.670
6.	140 110.340	154 107.010	[illegible] 117.040	222 91.810	11 74.440	25 137.720	39 78.170	53 87.910	67 115.140	81 82.120	95 96.730	109 [illegible]	123 125.070	137 127.670	151 75.650
7.	60 118.510	74 77.070	88 89.440	102 77.420	116 71.240	130 74.280	144 73.740	158 125.310	172 74.710	186 95.940	200 137.270	214 79.350	1 82.170	[illegible] 77.760	31 53.490
8.	15 82.910	29 77.040	43 126.010	57 76.240	71 118.340	85 105.160	99 124.110	113 124.460	127 117.250	141 [illegible]	155 126.720	169 125.442	183 127.510	197 [illegible]	211 [illegible]
9.	225 99.910	14 129.240	28 122.710	42 85.970	56 117.370	70 111.150	84 105.860	98 116.740	112 [illegible]	126 124.410	140 95.430	154 [illegible]	168 106.590	182 74.720	196 63.360
10.	135 79.610	149 76.810	163 120.160	177 99.560	191 91.260	205 106.550	219 86.260	8 78.150	22 78.310	36 126.210	52 [illegible]	66 [illegible]	78 [illegible]	92 [illegible]	106 111.040
11.	165 81.900	179 71.280	193 131.340	207 112.760	221 97.110	10 32.240	24 74.460	38 86.840	52 80.160	66 81.552	80 125.462	94 113.160	108 [illegible]	122 120.730	136 87.080
12.	120 97.890	134 100.690	148 126.290	162 95.170	176 125.160	190 75.190	204 69.240	218 79.260	7 121.210	21 113.180	35 [illegible]	49 116.270	63 102.420	77 [illegible]	91 75.310
13.	33 96.540	48 88.180	58 99.920	72 77.760	86 119.980	100 81.740	114 111.520	129 76.750	142 72.442	156 93.140	170 74.710	184 96.323	198 129.500	212 86.740	1 56.840
14.	75 83.520	89 91.750	103 77.120	117 101.020	131 92.520	145 97.690	159 71.500	173 76.750	187 [illegible]	201 93.210	215 76.660	4 [illegible]	18 135.910	32 76.120	46 130.880
15.	210 96.810	224 92.880	13 90.900	27 115.220	41 79.320	55 101.230	69 81.320	83 87.780	97 128.690	111 119.220	125 93.750	139 62.340	153 96.720	167 81.170	181 81.170

APPENDIX VII Number of tillers per plant at Ellerslie

ELLERSLIE REPLICATION-1. NUMBER OF TILLERS PER PLANT

(Block)															
1.	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195
	12.320	7.200	10.600	11.500	12.000	9.700	9.700	13.510	11.400	12.500	11.400	9.800	14.000	11.530	13.500
2.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	[illegible]	9.000	15.400	11.100	12.100	9.200	8.300	9.700	10.200	10.700	8.200	11.000	12.100	9.400	12.300
3.	211	212	213	214	215	216	[illegible]	218	219	220	221	222	223	224	225
	9.820	10.333	[illegible]	[illegible]	9.700	10.000	[illegible]	6.200	9.833	8.300	11.200	8.500	11.100	11.000	9.200
4.	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
	[illegible]	12.000	13.800	[illegible]	[illegible]	10.900	[illegible]	7.400	11.000	7.400	8.500	9.200	13.100	8.500	12.400
5.	106	107	108	109	[illegible]	[illegible]	112	113	114	115	[illegible]	117	118	119	120
	11.300	9.100	10.300	[illegible]	[illegible]	[illegible]	11.700	[illegible]	11.674	8.444	[illegible]	11.933	7.900	11.700	11.100
6.	121	122	123	124	125	[illegible]	127	128	129	130	131	132	133	134	135
	15.600	11.500	11.100	12.100	[illegible]	[illegible]	11.500	[illegible]	[illegible]	14.000	12.100	14.100	11.000	9.100	12.400
7.	91	92	93	94	95	96	97	[illegible]	[illegible]	100	101	102	103	104	105
	10.900	[illegible]	10.100	12.100	11.100	9.500	12.100	[illegible]	[illegible]	11.600	9.500	12.300	14.300	12.000	11.400
8.	61	62	63	64	65	66	67	[illegible]	69	70	71	72	73	74	75
	10.200	14.000	9.800	10.100	9.100	9.000	12.000	[illegible]	14.100	11.870	9.500	8.700	11.300	9.000	10.400
9.	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165
	10.200	11.400	11.100	10.200	9.400	10.100	8.200	12.100	12.600	8.000	10.400	9.500	13.000	12.200	13.100
10.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	12.500	9.000	9.000	10.500	9.400	9.251	8.800	9.000	9.600	9.700	12.500	11.400	12.000	13.000	10.400
11.	196	197	198	[illegible]	200	201	202	203	204	205	206	207	208	209	210
	9.900	9.400	8.700	7.400	9.000	7.300	6.600	9.370	7.320	7.000	7.570	5.100	7.370	5.700	13.000
12.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
	10.400	9.100	10.100	8.400	9.700	11.400	7.500	9.600	12.400	9.400	10.500	11.500	11.700	12.400	6.500
13.	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
	9.600	8.200	9.600	8.300	10.333	13.000	7.000	10.100	9.000	9.100	7.700	8.600	9.100	7.600	7.500
14.	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
	10.300	9.400	12.200	6.400	9.100	[illegible]	8.500	9.400	9.600	[illegible]	13.000	9.300	7.500	7.600	8.625
15.	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
	9.200	9.111	11.100	7.999	9.100	9.700	9.000	8.800	10.000	8.400	10.500	9.400	9.400	8.700	9.700

REPLICATION-2.

1.	14	29	44	59	74	83	124	119	134	149	158	179	194	209	224
	10.900	9.700	9.4006	11.900	10.000	9.700	12.000	8.500	12.200	11.600	12.200	11.373	12.000	9.925	12.700
2.	1	16	31	46	61	76	91	106	121	126	151	166	181	196	211
	11.600	12.300	15.222	9.600	11.600	[illegible]	9.700	9.900	11.333	3.842	12.100	13.410	13.111	12.400	[illegible]
3.	9	24	39	54	69	[illegible]	43	124	129	148	153	174	183	204	219
	15.100	12.600	12.702	11.000	11.920	[illegible]	[illegible]	13.220	11.700	12.133	13.100	14.500	11.222	12.900	17.233
4.	2	17	32	47	62	77	52	127	122	137	152	167	182	132	212
	13.200	9.556	8.500	[illegible]	[illegible]	10.300	13.200	[illegible]	9.100	11.800	14.500	9.400	11.400	15.200	14.400
5.	6	21	26	51	66	81	95	111	125	141	156	171	185	221	216
	13.600	14.111	13.200	14.300	10.400	12.400	12.000	12.300	15.900	12.311	15.370	11.500	11.222	13.200	16.200
6.	11	25	41	56	71	95	107	116	137	145	161	176	191	226	229
	11.600	10.600	13.400	12.700	14.700	14.900	12.500	13.500	13.100	[illegible]	14.200	17.300	10.200	9.900	17.400
7.	10	25	40	55	70	85	140	115	130	145	152	175	150	215	228
	10.900	[illegible]	11.700	11.775	15.400	15.200	13.900	11.000	8.200	12.200	12.600	8.200	9.000	12.722	11.222
8.	8	23	34	53	45	41	99	113	128	143	154	173	183	201	219
	14.100	16.600	13.200	14.300	11.700	11.200	12.700	11.200	14.400	12.222	15.300	12.100	11.200	11.500	11.400
9.	3	18	33	48	63	78	93	112	123	139	153	158	173	198	213
	9.700	13.300	12.000	12.700	12.200	14.700	12.200	12.400	14.700	12.400	11.400	11.300	14.100	11.100	14.120
10.	13	28	43	53	73	83	103	118	131	148	163	178	193	229	223
	12.900	12.600	15.200	9.100	11.400	12.400	10.100	8.700	11.400	[illegible]	17.922	14.400	13.422	14.300	13.933
11.	12	27	42	57	72	87	102	117	132	147	162	177	192	207	222
	13.300	9.300	13.300	9.400	3.500	11.400	11.500	12.700	11.100	9.200	9.000	8.100	14.700	15.700	13.400
12.	5	40	35	50	65	90	95	215	220	195	170	155	160	185	110
	9.700	15.900	9.400	11.000	11.600	13.700	[illegible]	15.000	12.400	14.774	10.100	13.120	11.100	13.400	13.000
13.	4	19	36	49	64	79	94	109	124	139	154	159	164	199	214
	11.700	12.200	14.100	11.700	11.100	8.400	15.500	12.700	7.400	11.400	11.900	9.400	9.700	8.500	11.000
14.	7	22	37	52	67	82	97	112	127	142	157	172	187	202	217
	14.300	11.200	10.400	12.700	12.333	11.900	[illegible]	11.120	15.600	11.300	[illegible]	13.200	14.500	11.700	13.120
15.	15	33	45	60	75	90	105	120	135	150	165	180	195	210	225
	15.700	10.100	11.100	13.400	12.200	10.700	12.000	10.200	11.100	9.100	10.800	11.300	9.800	14.800	8.100

REPLICATION-3.

1.	45	59	73	87	101	115	124	143	157	171	185	199	213	2	16
	8.700	11.400	12.500	12.900	11.500	11.500	13.100	12.500	14.300	8.100	11.100	12.522	17.000	11.400	14.100
2.	153	168	138	162	205	223	5	21	17	51	65	36	81	127	121
	12.333	14.500	15.300	12.400	11.300	13.700	11.400	14.100	12.400	14.600	11.360	11.270	11.300	11.200	11.400
3.	90	134	114	112	146	160	174	191	202	215	5	19	31	47	63
	12.200	11.600	10.100	15.700	11.400	8.300	12.100	11.000	8.900	10.400	11.325	[illegible]	11.100	11.000	9.600
4.	195	203	223	12	26	40	54	69	82	96	113	128	144	152	166
	15.000	12.400	13.700	11.000	11.176	11.700	15.200	[illegible]	12.770	15.700	12.792	17.700	14.400	10.900	14.500
5.	105	119	133	147	161	175	189	203	217	6	20	34	49	62	76
	15.000	12.500	12.000	13.100	12.700	12.070	13.700	15.700	11.200	14.500	13.900	14.000	12.400	14.900	15.500
6.	180	194	208	222	11	25	39	53	67	81	95	109	121	137	151
	16.000	11.700	14.300	11.300	[illegible]	13.600	12.300	[illegible]	11.400	12.000	10.900	12.700	10.900	13.400	9.000
7.	60	74	88	102	116	130	144	158	172	186	200	214	3	17	31
	15.500	14.400	11.930	12.700	10.400	14.600	12.300	[illegible]	11.500	[illegible]	11.700	11.920	11.700	12.200	11.111
8.	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211
	17.400	16.000	17.500	11.700	14.200	11.700	14.900	15.200	12.400	15.300	15.900	16.100	15.300	11.400	9.200
9.	225	14	28	42	56	70	84	98	112	126	140	154	168	182	196
	10.550	14.700	13.000	15.100	12.600	13.100	15.100	11.200	13.500	15.100	11.176	11.300	9.700	12.500	14.200
10.	135	149	163	177	191	205	219	8	22	35	50	64	78	92	106
	14.000	12.720	12.100	10.900	14.330	14.900	13.300	12.700	13.900	13.100	15.000	9.600	15.300	14.200	15.600
11.	165	179	193	207	221	13	24	19	52	66	80	94	108	122	136
	11.300	9.100	12.400	14.700	11.700	10.500	16.700	13.400	11.100	15.500	11.600	15.500	13.400	11.800	14.700
12.	120	134	148	162	176	190	204	218	7	21	35	48	62	77	91
	10.400	13.100	12.900	12.200	11.600	9.100	13.120	13.550	13.170	9.100	12.400	12.600	9.200	14.100	10.900
13.	32	44	58	72	86	100	114	128	142	156	170	184	199	212	1
	10.500	10.774	13.100	11.500	12.700	11.400	12.600	11.100	15.600	12.300	9.400	11.100	13.000	12.000	15.800
14.	75	89	103	117	131	145	159	173	187	201	215	4	18	33	46
	11.800	13.400	13.600	13.600	12.100	11.500	13.900	11.100	9.900	11.600	11.110	[illegible]	13.100	7.500	12.900
15.	210	224	13	27	41	55	69	83	97	111	125	139	153	167	181
	11.900	12.400	9.400	12.400	11.300	11.600	12.100	9.700	12.040	10.000	11.200	9.600	12.700	13.100	14.600

APPENDIX VIII Number of spikelets per spike at Ellerslie

EXPERIMENT REPLICATION 1. NUMBER OF SPIKELETS PER SPIKE

(Block)															
1.	181 13.533	182 13.000	183 14.133	184 15.100	185 13.700	186 14.400	187 15.433	188 13.500	189 14.733	190 12.133	191 14.100	192 13.467	193 13.101	194 13.733	195 14.433
2.	16 11.467	17 13.700	18 16.400	19 13.467	20 12.433	21 14.333	22 12.967	23 12.200	24 12.467	25 13.567	26 14.667	27 15.133	28 14.167	29 14.633	30 14.467
3.	211 11.333	212 13.467	213 11.933	214 11.567	215 13.633	216 12.400	217 14.767	218 14.233	219 14.367	220 15.333	221 13.267	222 14.500	223 13.733	224 14.767	225 13.733
4.	46 14.533	47 13.333	48 11.633	49 14.133	50 14.367	51 15.100	52 15.000	53 14.333	54 15.233	55 11.500	56 14.667	57 14.433	58 15.533	59 15.567	60 14.667
5.	106 14.300	107 14.567	108 13.733	109 14.500	110 15.467	111 14.267	112 14.633	113 13.975	114 15.333	115 12.545	116 13.000	117 13.933	118 13.833	119 13.267	120 13.333
6.	121 14.667	122 15.433	123 15.733	124 13.133	125 14.567	126 14.767	127 15.767	128 14.667	129 15.000	130 15.567	131 15.133	132 14.133	133 15.367	134 13.833	135 14.333
7.	91 14.733	92 12.633	93 14.667	94 15.733	95 13.400	96 15.133	97 14.633	98 11.033	99 13.633	100 15.733	101 12.433	102 14.133	103 15.133	104 13.267	105 14.767
8.	61 14.400	62 15.933	63 14.833	64 15.700	65 14.167	66 12.700	67 15.333	68 14.500	69 13.700	70 14.467	71 14.467	72 14.200	73 15.100	74 13.500	75 14.567
9.	151 12.667	152 13.733	153 15.000	154 15.133	155 15.133	156 15.433	157 15.600	158 15.767	159 14.133	160 13.333	161 15.433	162 15.233	163 14.333	164 13.133	165 15.200
10.	1 13.300	2 12.700	3 15.400	4 14.367	5 12.433	6 14.204	7 14.333	8 14.167	9 16.633	10 11.833	11 13.467	12 15.500	13 12.167	14 17.433	15 12.357
11.	196 12.567	197 13.633	198 14.433	199 11.167	200 15.467	201 12.357	202 13.533	203 11.833	204 12.167	205 12.733	206 12.733	207 12.933	208 11.267	209 11.333	210 12.500
12.	31 13.167	32 13.267	33 11.500	34 13.300	35 11.700	36 14.333	37 11.700	38 12.767	39 14.333	40 15.267	41 12.833	42 13.333	43 12.733	44 15.433	45 15.433
13.	136 13.300	137 15.633	138 13.467	139 13.567	140 14.333	141 13.433	142 12.367	143 17.567	144 13.067	145 12.[illegible]	146 13.570	147 13.067	148 15.533	149 13.167	150 11.567
14.	76 15.157	77 12.567	78 14.200	79 11.533	80 14.433	81 13.067	82 14.433	83 12.567	84 14.733	85 13.567	86 15.733	87 15.433	88 14.100	89 13.467	90 14.250
15.	166 15.100	167 11.767	168 14.500	169 12.533	170 12.557	171 14.567	172 13.533	173 14.333	174 15.933	175 12.600	176 15.200	177 12.933	178 15.433	179 11.533	180 13.733

REPLICATION 2.

1.	14 15.133	29 13.700	44 14.567	59 13.633	74 13.667	89 15.667	104 14.633	119 13.933	134 15.000	149 [illegible]	164 12.567	179 12.967	194 12.333	209 15.233	224 15.033
2.	1 12.957	16 13.633	31 14.296	46 12.433	61 13.100	76 14.000	91 14.300	106 14.633	121 15.133	136 12.133	151 12.000	166 15.167	181 13.533	196 12.733	211 12.037
3.	9 15.400	24 12.167	39 12.733	54 14.133	69 13.567	84 14.133	99 15.667	114 15.433	129 14.500	144 11.533	159 12.033	174 15.100	189 12.533	204 12.733	219 14.037
4.	2 12.833	17 13.461	32 12.067	47 12.613	62 15.200	77 12.875	92 12.467	107 13.500	122 13.067	137 15.250	152 14.567	167 11.233	182 13.067	197 14.733	212 14.367
5.	6 12.633	21 15.630	36 15.133	51 15.167	66 12.633	81 13.833	96 15.267	111 14.400	126 15.200	141 12.924	156 13.567	171 14.300	186 14.200	201 13.067	216 15.500
6.	11 13.733	26 11.600	41 12.133	56 15.333	71 14.433	86 15.433	101 12.933	116 13.233	131 13.133	146 13.933	161 14.387	176 14.167	191 15.500	206 12.200	221 13.267
7.	10 12.300	25 13.967	40 15.300	55 13.444	70 13.262	85 14.433	100 13.367	115 13.433	130 12.633	145 11.000	160 12.300	175 12.433	190 13.057	205 15.133	220 14.704
8.	8 13.267	23 13.933	38 12.000	53 15.133	68 11.216	83 12.633	98 14.5[illegible]	113 13.533	128 13.333	143 14.100	158 14.200	173 12.267	188 13.167	203 13.100	218 14.233
9.	3 14.333	18 14.733	33 13.067	48 12.267	63 13.633	78 14.933	93 15.567	108 15.200	123 15.057	138 13.533	153 13.433	168 15.100	183 12.733	198 14.267	213 15.257
10.	13 13.133	28 15.257	43 13.267	58 11.700	73 15.333	88 15.067	103 12.200	118 13.467	133 12.367	148 14.233	163 13.557	178 12.500	193 13.133	208 15.247	223 14.733
11.	12 14.733	27 15.267	42 14.067	57 13.933	72 13.700	87 14.600	102 13.667	117 14.233	132 15.133	147 14.233	162 14.333	177 13.933	192 13.400	207 13.733	222 14.[illegible]
12.	5 15.033	20 14.333	35 12.933	50 14.967	65 14.633	80 14.700	95 14.267	215 14.057	200 13.400	185 15.574	170 14.133	155 15.167	140 14.233	125 13.633	[illegible]
13.	4 15.033	19 15.300	34 11.267	49 12.467	64 15.100	79 14.067	94 15.567	109 [illegible]	124 14.300	139 15.400	154 15.726	169 15.733	184 12.367	199 13.5[illegible]	[illegible]
14.	7 15.333	22 14.467	37 14.500	52 13.296	67 15.633	82 12.533	97 12.633	112 15.257	127 14.567	142 14.000	157 12.933	172 13.400	187 14.033	[illegible]	[illegible]
15.	15 13.967	30 12.700	45 13.367	60 14.233	75 14.267	90 14.400	105 14.167	120 14.733	135 13.733	150 12.600	165 14.267	180 15.567	195 13.633	[illegible]	225 [illegible]

REPLICATION 3.

1.	45 13.300	59 16.433	73 15.300	87 15.267	101 14.467	115 12.833	129 14.370	143 13.433	157 14.167	171 11.557	185 13.467	199 11.500	213 11.567	[illegible]	[illegible]
2.	153 14.267	154 14.133	179 11.733	192 16.733	224 15.333	223 15.433	9 14.357	21 14.733	37 15.233	51 15.500	65 14.533	77 15.533	91 14.033	[illegible]	[illegible]
3.	90 14.767	104 14.900	119 14.400	132 12.900	146 13.767	160 13.400	174 15.333	189 13.[illegible]	202 [illegible]	215 11.900	5 15.257	19 12.700	31 12.233	[illegible]	
4.	195 12.900	229 14.900	223 14.600	12 13.900	26 13.133	40 14.633	[illegible]	63 14.598	82 14.900	95 14.100	110 13.461	124 14.133	138 15.533	152 14.533	166 13.300
5.	105 14.267	119 15.367	133 13.667	147 14.433	161 [illegible]	175 13.367	189 15.333	231 14.267	217 14.233	4 14.267	20 15.767	36 13.833	49 13.757	62 15.567	76 15.933
6.	190 15.500	136 13.100	229 14.400	222 14.033	11 13.400	25 14.233	39 13.767	51 13.533	67 14.267	81 14.400	95 14.557	109 14.533	123 15.667	137 15.733	151 12.300
7.	60 16.400	74 14.833	88 15.600	102 14.400	116 13.333	130 15.400	144 14.533	158 12.357	172 15.767	186 15.100	200 14.233	214 14.233	3 14.333	17 15.257	31 14.111
8.	15 15.367	29 15.667	43 14.167	57 15.167	71 15.467	85 15.467	99 15.367	113 15.400	127 15.000	141 14.933	155 16.400	169 15.433	183 14.567	197 13.333	211 14.667
9.	225 15.467	14 11.700	28 14.700	42 14.267	56 14.767	70 14.100	84 15.433	61 15.167	112 15.733	125 14.933	143 14.133	158 12.300	164 11.867	162 15.557	196 14.357
10.	135 16.000	149 13.633	163 15.267	177 14.200	191 15.167	225 15.433	219 14.167	4 13.633	22 15.267	36 14.267	50 14.633	64 14.733	78 14.600	42 14.767	136 17.700
11.	165 15.033	178 13.567	193 15.600	207 15.467	221 14.100	10 13.433	24 14.733	14 13.433	52 14.733	66 14.600	80 14.133	94 14.967	129 14.533	128 14.867	134 14.067
12.	120 15.067	134 13.467	148 17.533	162 14.400	176 13.167	119 12.567	234 14.767	218 13.467	7 13.667	21 14.200	35 13.100	49 15.533	63 14.200	77 14.933	91 13.600
13.	30 14.933	44 13.667	58 14.300	72 14.633	86 14.833	100 13.667	114 14.267	128 15.167	142 11.500	156 15.267	170 11.533	184 12.471	199 17.467	212 13.900	1 15.433
14.	75 14.300	89 14.233	103 13.533	117 15.502	131 14.167	145 14.900	159 14.703	173 15.200	187 14.033	201 15.567	215 13.667	6 14.767	18 13.267	32 13.667	46 13.633
15.	210 14.000	220 14.967	13 13.767	27 17.100	41 14.767	55 14.167	69 14.267	83 14.833	97 14.400	111 15.233	125 15.267	139 14.433	153 14.533	167 14.233	181 15.267

APPENDIX IX Number of seeds per spike at Ellerslie

ELLERSLIE REPLICATION-1. NUMBER OF SEEDS PER SPIKE

(Block)															
	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195
1.	44.667	49.833	44.667	57.433	44.067	47.133	49.033	36.757	49.600	40.700	44.667	51.733	42.193	44.500	57.367
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
2.	43.233	45.[illegible]	[illegible].133	49.133	44.767	40.067	57.433	41.933	44.500	49.233	53.600	42.067	44.400	49.000	40.933
	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
3.	52.967	36.815	52.467	43.433	47.467	50.300	51.433	41.333	46.333	52.057	39.400	41.333	43.167	43.333	50.457
	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
4.	46.500	37.500	39.467	33.700	42.367	48.057	47.067	41.200	47.433	40.400	55.500	48.367	50.933	45.000	53.733
	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
5.	49.267	41.667	43.100	52.567	53.933	54.567	42.833	46.203	44.134	47.746	42.433	43.733	44.067	50.300	45.000
	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
6.	50.667	50.033	49.767	43.500	51.067	51.233	43.267	45.433	52.700	40.133	47.100	38.400	53.767	42.700	41.757
	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
7.	50.667	47.533	52.057	52.167	46.933	51.300	43.467	44.450	51.533	43.933	49.567	46.35[illegible]	44.400	51.187	45.200
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
8.	44.100	50.667	49.433	61.730	46.833	47.767	55.157	41.833	37.433	49.400	54.133	43.257	52.367	42.700	56.193
	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165
9.	47.733	47.700	47.133	50.900	41.033	55.133	47.000	52.833	43.067	43.733	54.900	52.433	42.700	45.333	49.133
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10.	45.433	52.433	57.033	51.533	45.033	40.209	42.400	45.233	56.233	33.613	41.200	53.233	36.333	55.357	43.433
	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
11.	42.433	40.100	57.667	44.333	40.400	47.467	42.733	45.533	50.467	45.067	47.767	42.533	43.133	44.267	43.667
	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
12.	43.933	50.433	39.267	35.300	41.300	53.133	45.333	44.257	49.900	44.431	37.5[illegible]	42.457	42.333	47.133	41.000
	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
13.	40.587	53.567	48.033	47.233	53.400	42.933	41.100	55.747	39.233	40.900	45.200	53.357	44.967	42.533	53.357
	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
14.	43.000	34.600	51.033	42.500	45.133	44.057	37.500	33.657	44.167	42.657	47.700	51.367	45.500	47.433	47.317
	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
15.	56.033	34.773	61.533	39.269	40.367	44.533	44.757	44.357	50.500	36.533	47.400	47.700	41.167	43.067	40.700

REPLICATION-2.

	14	29	44	59	74	89	104	119	134	149	164	179	194	209	224
1.	51.733	53.433	45.257	44.557	46.067	63.733	47.267	49.333	53.700	45.370	46.333	42.257	45.933	59.367	49.700
	1	16	31	46	61	76	91	106	121	136	151	166	181	196	211
2.	44.533	49.100	43.731	44.500	43.733	53.333	54.300	51.067	55.433	44.100	44.333	46.333	39.961	4[illegible].357	45.741
	9	24	39	54	69	84	99	114	129	144	159	174	189	204	219
3.	58.133	39.667	42.200	49.467	41.333	50.067	50.700	44.833	50.100	38.100	44.334	47.567	47.467	44.333	47.444
	2	17	32	47	62	77	92	107	122	137	152	167	182	197	212
4.	51.233	50.589	50.433	38.857	53.067	[illegible]	43.533	40.300	47.967	47.367	39.733	34.000	47.333	4[illegible].757	45.967
	6	21	36	51	66	81	96	111	126	141	156	171	186	201	216
5.	53.557	57.333	52.157	48.067	46.467	51.4[illegible]	53.767	53.767	49.567	42.533	48.033	45.333	43.533	44.133	57.633
	11	26	41	56	71	86	101	116	131	146	161	176	191	206	221
6.	49.467	35.233	37.300	54.167	36.733	45.257	41.200	37.433	43.333	44.433	50.257	43.733	37.333	53.467	42.457
	10	25	40	55	70	85	100	115	130	145	160	175	190	205	220
7.	39.233	49.667	53.500	46.704	45.000	42.500	40.233	47.7[illegible]	34.700	44.967	45.133	43.100	50.633	46.000	54.741
	8	23	38	53	68	83	98	113	128	143	158	173	188	203	218
8.	47.433	43.500	37.667	51.300	43.593	44.257	54.200	44.067	55.233	52.567	46.457	41.167	41.100	44.500	44.367
	3	18	33	48	63	78	93	108	123	138	153	168	183	198	213
9.	59.233	43.433	41.723	36.467	46.703	45.767	44.467	35.933	41.033	44.733	42.203	44.733	43.833	57.457	52.733
	13	28	43	58	73	88	103	118	133	148	163	178	193	208	223
10.	38.533	47.500	40.667	44.733	44.267	45.500	42.457	44.167	36.433	51.357	43.767	41.333	47.657	51.667	47.147
	12	27	42	57	72	87	102	117	132	147	162	177	192	207	222
11.	53.033	41.367	43.467	53.300	45.167	53.167	44.200	44.367	43.933	40.500	42.767	44.933	43.133	42.[illegible]	4[illegible].433
	5	20	35	50	65	80	95	215	200	185	170	155	140	125	110
12.	49.767	49.657	38.567	47.167	45.557	43.257	41.633	49.833	53.733	55.373	44.733	44.633	45.367	44.757	43.133
	4	19	34	49	64	79	94	129	124	119	154	169	184	199	214
13.	49.100	45.167	45.667	47.267	52.967	47.533	47.633	37.933	45.167	47.133	51.222	47.200	41.557	41.333	49.833
	7	22	37	52	67	82	97	112	127	142	157	172	187	202	217
14.	48.900	45.733	50.600	41.259	38.356	41.433	41.367	48.200	59.367	44.925	49.900	42.267	41.533	58.000	44.3[illegible]
	15	30	45	60	75	90	105	120	135	150	165	110	135	210	225
15.	49.300	40.333	43.967	39.500	55.067	44.267	42.300	44.733	37.033	45.067	42.500	37.933	40.767	39.167	43.167

REPLICATION-3.

	45	59	73	87	101	115	129	143	157	171	185	199	213	2	16
1.	44.457	43.433	49.600	48.467	49.467	44.533	54.367	47.367	47.500	43.600	41.657	50.311	45.333	44.033	43.500
	150	164	178	192	206	220	9	23	37	51	65	79	93	107	121
2.	42.200	50.400	41.200	51.367	53.133	55.[illegible]31	49.733	42.257	58.133	54.033	45.367	55.733	43.400	44.357	43.333
	90	104	118	132	146	160	174	188	202	216	5	19	33	47	61
3.	56.967	55.400	57.533	44.167	51.767	46.533	44.357	45.070	40.233	52.257	51.767	41.133	44.733	44.100	47.167
	195	209	223	12	26	40	54	68	82	96	110	124	138	152	166
4.	47.100	54.433	45.500	47.167	41.765	44.133	50.400	46.342	46.533	44.200	46.542	49.567	52.633	44.000	41.700
	105	119	133	147	161	175	189	203	217	6	20	34	48	62	76
5.	42.767	53.600	47.100	40.267	45.733	39.500	51.133	41.333	45.933	44.467	48.067	47.357	45.300	52.233	52.167
	190	204	208	222	11	25	39	53	67	81	95	109	123	137	151
6.	51.500	42.033	45.367	45.[illegible]33	47.233	45.033	43.133	34.033	51.757	49.200	44.767	46.700	43.730	53.133	45.133
	60	74	88	102	116	130	144	158	172	186	200	214	3	17	31
7.	50.557	42.867	55.233	47.367	42.200	44.733	41.063	37.257	51.567	51.400	43.633	44.457	49.267	41.057	41.407
	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211
8.	53.857	47.733	42.533	53.167	50.967	42.433	47.333	44.233	50.557	43.200	47.400	45.567	43.733	42.400	52.033
	225	14	28	42	56	70	84	98	112	126	140	154	168	182	196
9.	53.800	43.467	49.067	41.400	56.433	45.457	48.400	47.457	46.000	52.533	54.221	44.467	40.600	44.433	54.467
	135	149	163	177	191	205	219	8	22	36	50	64	78	92	106
10.	43.367	37.733	44.233	44.357	44.200	47.267	43.457	45.233	45.300	44.167	43.267	45.033	52.833	45.333	54.100
	165	179	193	207	221	10	24	38	52	66	80	94	108	122	136
11.	51.900	43.200	53.500	45.167	46.400	37.233	46.467	46.500	51.333	49.457	45.400	43.067	42.467	52.133	42.967
	120	134	148	162	176	190	204	218	7	21	35	49	63	77	91
12.	51.467	46.900	51.533	43.700	44.933	53.167	55.400	43.533	43.100	43.733	33.967	41.400	43.133	41.833	41.867
	30	44	58	72	86	100	114	128	142	156	170	184	198	212	1
13.	49.433	49.000	45.700	41.100	47.000	41.267	44.233	44.587	41.833	44.267	41.200	42.633	61.833	36.300	45.900
	75	89	103	117	131	145	159	173	187	201	215	4	18	32	46
14.	51.233	46.167	39.867	51.200	51.967	41.733	55.467	49.433	43.733	48.833	43.133	47.633	44.767	47.900	49.400
	210	224	13	27	41	55	69	83	97	111	125	139	153	167	181
15.	45.533	46.833	40.967	46.567	46.700	45.267	49.300	47.067	47.200	45.500	53.733	50.467	41.933	40.333	52.533

APPENDIX X Weight of seeds per spike at Ellerslie

[illegible]

(Block)															
1.	181 1.822	182 2.601	183 1.656	184 2.417	185 1.856	186 2.145	187 2.024	188 1.665	189 2.147	190 1.763	191 1.873	192 1.791	193 1.535	194 1.711	195 2.159
2.	16 1.396	17 2.041	18 1.775	19 1.755	20 1.625	21 2.111	22 2.256	23 1.466	24 1.958	25 1.544	26 2.325	27 1.515	28 1.711	29 2.051	30 1.553
3.	211 2.544	212 1.626	213 1.820	214 1.548	215 2.362	216 2.322	217 2.251	218 1.399	219 1.764	220 2.316	221 1.873	222 2.394	223 1.765	224 1.570	225 1.769
4.	46 1.957	47 1.817	48 1.752	49 1.419	50 1.901	51 1.444	52 2.211	53 1.552	54 1.734	55 1.574	56 2.358	57 1.517	58 1.373	59 1.442	60 1.856
5.	106 1.776	107 1.256	108 1.705	109 1.546	110 1.897	111 1.849	112 2.126	113 1.656	114 1.531	115 1.966	116 1.557	117 1.813	118 1.753	119 1.440	120 1.503
6.	121 1.443	122 2.143	123 1.651	124 1.163	125 1.437	126 1.823	127 2.216	128 1.666	129 2.035	130 1.522	131 1.699	132 1.427	133 2.132	134 1.539	135 1.742
7.	91 2.267	92 1.383	93 1.867	94 1.812	95 1.932	96 2.344	97 1.312	98 1.619	99 1.979	100 1.723	101 1.993	102 1.312	103 1.918	104 1.322	105 1.632
8.	61 1.836	62 1.796	63 1.936	64 2.329	65 1.623	66 1.867	67 1.735	68 1.937	69 1.443	70 1.451	71 1.735	72 1.933	73 1.341	74 1.657	75 2.263
9.	151 1.751	152 1.697	153 1.561	154 1.533	155 1.466	156 1.755	157 1.511	158 1.619	159 1.677	160 1.561	161 1.454	162 1.747	163 2.365	164 1.561	165 1.573
10.	1 1.347	2 1.923	3 2.227	4 1.993	5 1.749	6 1.493	7 1.615	8 1.654	9 1.757	10 1.359	11 1.569	12 1.716	13 1.397	14 1.496	15 1.513
11.	196 1.417	197 1.461	198 1.755	199 1.235	200 1.522	201 1.474	202 1.553	203 1.741	204 1.340	205 1.524	206 1.794	207 1.833	208 1.556	209 1.623	210 1.333
12.	31 1.455	32 1.938	33 1.576	34 1.159	35 1.554	36 1.715	37 1.315	38 1.523	39 1.944	40 1.579	41 1.523	42 1.545	43 1.435	44 1.528	45 2.027
13.	136 1.627	137 1.413	138 1.976	139 1.373	140 1.447	141 1.727	142 1.565	143 2.255	144 1.421	145 1.465	146 1.956	147 1.922	148 1.513	149 1.741	150 1.479
14.	76 1.283	77 1.352	78 1.685	79 1.522	80 1.534	81 1.576	82 1.353	83 1.413	84 1.572	85 1.747	86 1.456	87 1.757	88 1.538	89 1.758	90 2.223
15.	166 1.953	167 1.325	168 1.699	169 1.559	170 1.452	171 1.641	172 1.473	173 1.573	174 1.152	175 1.371	176 1.527	177 1.632	178 1.457	179 1.624	180 1.573

[illegible]

1.	14 1.689	29 1.625	44 1.553	59 1.576	74 1.699	85 2.375	100 1.374	119 1.671	134 1.914	141 1.357	164 1.475	179 2.163	188 1.545	207 2.434	224 1.762
2.	1 1.537	16 1.426	33 1.685	46 1.552	61 1.695	76 1.924	91 2.101	106 1.736	121 2.172	136 1.573	151 2.133	166 2.331	181 1.473	196 1.525	211 1.735
3.	9 1.949	28 1.578	39 1.427	54 1.769	69 1.602	78 2.112	94 2.254	114 1.670	129 2.022	148 1.576	158 1.933	174 1.799	183 2.045	208 1.324	219 1.542
4.	2 1.872	17 2.133	32 2.099	47 1.625	62 1.624	77 1.173	92 1.572	117 1.374	122 1.727	137 1.714	152 1.454	167 1.445	182 1.335	197 1.563	212 1.576
5.	6 2.262	21 1.654	36 1.873	53 1.527	66 1.694	81 1.731	96 2.362	111 1.862	124 1.555	139 1.530	156 1.671	171 1.375	186 1.841	201 1.763	216 2.431
6.	11 2.123	26 1.511	41 1.567	56 2.123	71 1.676	86 1.611	101 1.353	116 1.924	131 1.347	146 1.643	161 1.779	175 1.562	191 1.224	205 2.044	221 1.236
7.	10 1.341	25 1.634	40 1.393	55 1.441	70 1.457	85 1.216	103 1.472	115 2.026	132 1.540	145 1.925	163 2.337	178 1.252	192 1.251	203 1.716	223 2.175
8.	8 2.331	23 1.785	38 1.873	53 1.316	64 1.546	83 1.678	98 1.352	113 1.672	128 2.132	141 1.576	154 1.526	177 1.497	184 1.121	203 1.322	219 1.729
9.	3 2.337	18 1.476	33 1.743	49 1.623	63 1.933	79 1.526	93 1.756	109 1.446	123 1.779	144 1.524	153 1.625	168 1.911	188 1.492	194 1.827	221 1.433
10.	13 1.497	29 1.572	43 1.145	54 1.543	73 1.549	89 1.545	101 1.443	119 1.832	133 1.325	149 1.555	152 1.631	173 1.658	193 1.575	209 1.825	221 1.712
11.	12 1.712	27 1.472	42 1.939	57 1.497	72 1.393	87 1.747	102 1.513	117 1.656	132 1.571	147 1.453	162 1.704	173 1.658	192 1.670	207 1.537	222 1.728
12.	5 1.825	20 1.622	35 1.205	53 1.514	65 1.779	80 1.625	95 1.423	115 2.275	130 1.734	145 2.757	170 1.515	155 1.549	183 1.451	195 1.721	210 1.443
13.	4 1.913	19 1.427	34 1.640	49 1.723	66 2.003	79 1.711	94 1.542	109 1.443	123 1.563	138 2.259	154 1.372	169 1.513	184 1.517	191 1.562	214 1.833
14.	7 1.949	22 1.462	37 1.913	52 1.625	67 1.220	82 1.511	97 1.479	112 1.456	127 2.216	142 1.724	157 1.556	172 1.121	187 1.755	202 1.922	217 1.793
15.	15 1.666	30 1.454	45 1.550	60 1.446	75 2.105	90 1.683	105 1.311	120 1.442	135 1.857	150 1.975	165 1.330	180 1.514	185 1.538	213 1.619	225 1.331

[illegible]

1.	45 1.646	59 1.515	73 1.925	87 1.775	101 2.279	115 1.375	129 1.142	143 1.742	157 1.755	171 1.511	185 1.452	199 2.251	213 1.416	2 1.742	16 1.455
2.	150 1.644	164 2.075	178 1.726	192 1.515	206 2.254	220 1.219	9 1.542	23 1.747	37 2.576	51 2.276	65 2.722	79 1.644	93 1.552	107 1.335	121 2.472
3.	90 2.267	104 2.267	118 2.453	132 1.546	146 2.149	160 2.172	174 1.252	188 2.214	202 1.993	216 2.160	5 2.504	19 1.431	33 1.545	47 1.664	61 1.675
4.	195 1.765	209 2.213	223 1.629	12 1.414	26 1.420	40 1.721	54 1.647	68 1.724	82 2.155	96 1.734	110 1.149	124 1.412	138 2.167	152 1.616	166 1.612
5.	105 1.759	119 2.026	133 1.710	147 1.413	161 1.755	175 1.541	189 1.358	203 1.626	217 1.612	6 1.761	20 1.725	34 1.721	48 1.342	62 1.754	76 1.761
6.	180 1.782	194 1.543	208 1.658	222 1.412	11 1.750	25 1.740	39 1.549	53 1.166	67 1.927	81 1.665	95 1.665	109 1.571	123 1.761	137 1.724	151 1.647
7.	60 1.575	74 1.450	88 2.261	102 1.659	116 1.522	130 1.760	144 1.161	158 1.551	172 2.011	186 2.310	200 1.706	214 1.541	3 1.311	17 1.724	31 1.776
8.	15 1.927	29 1.776	43 1.364	57 2.249	71 1.645	85 1.573	99 1.756	113 1.649	127 1.775	141 1.516	155 1.659	169 1.640	183 1.416	197 1.655	211 2.174
9.	225 2.112	14 1.639	28 1.076	42 1.659	56 2.142	70 1.731	84 1.747	98 1.759	112 1.692	126 1.784	140 2.697	154 1.555	168 1.635	182 2.071	196 2.158
10.	135 1.940	149 1.578	163 1.575	177 1.550	191 1.733	205 1.976	219 1.521	8 1.925	22 1.419	36 1.561	50 1.962	64 1.621	78 1.705	92 1.331	106 1.659
11.	165 2.019	179 1.646	193 1.662	207 1.623	221 1.686	10 1.182	24 1.413	38 1.651	52 2.246	66 1.977	80 1.646	94 1.311	108 2.126	122 2.046	136 1.717
12.	120 1.571	134 1.513	148 1.781	162 1.449	176 1.711	190 1.452	204 2.762	218 1.526	7 1.557	21 1.697	35 1.110	49 1.701	63 1.761	77 1.773	91 1.633
13.	30 1.627	44 1.364	58 1.636	72 1.636	86 1.626	100 1.446	114 1.491	128 1.766	142 1.622	156 1.543	170 1.541	184 1.561	198 2.024	212 1.344	1 1.526
14.	75 1.850	89 1.572	103 1.309	117 1.750	131 1.910	145 1.567	159 2.225	173 1.977	187 1.739	201 1.205	215 1.816	4 1.929	18 1.561	32 1.667	46 1.719
15.	210 1.661	224 1.610	13 1.620	27 1.458	41 1.616	55 1.443	69 1.655	83 1.910	97 1.516	111 1.612	125 2.343	139 1.996	153 1.610	167 1.529	181 1.966

APPENDIX XI 1000-kernel weight at Ellerslie

ELLERSLIE REPLICATION-1. 1000-KERNEL WEIGHT

(BLOCK)															
1.	181 44.360	182 41.459	183 37.369	184 41.511	185 43.367	186 44.240	187 40.471	188 44.764	189 43.358	190 44.455	191 40.306	192 35.455	193 37.353	194 38.772	195 41.058
2.	16 35.421	17 42.059	18 36.260	19 35.492	20 41.359	21 35.066	22 33.389	23 42.362	24 44.011	25 39.511	26 45.723	27 36.027	28 36.547	29 41.469	30 36.387
3.	211 39.236	212 42.769	213 35.421	214 42.461	215 43.303	216 43.484	217 34.531	218 41.418	219 42.627	220 38.1[illegible]	221 37.586	222 42.167	223 39.420	224 35.021	225 34.397
4.	46 33.967	47 45.855	48 46.177	49 35.727	50 44.716	51 39.299	52 42.643	53 36.276	54 37.196	55 39.700	56 41.479	57 43.027	58 37.638	59 32.470	60 30.935
5.	106 35.358	107 28.928	108 34.423	109 31.351	110 35.203	111 34.545	112 33.651	113 35.468	114 31.555	115 43.2[illegible]3	116 16.372	117 36.147	118 37.566	119 37.716	120 35.674
6.	121 33.213	122 37.173	123 29.236	124 27.647	125 37.530	126 35.131	127 35.082	128 41.515	129 37.764	130 38.367	131 35.187	132 37.711	133 42.015	134 35.715	135 37.959
7.	91 44.266	92 41.811	93 35.516	94 35.242	95 42.421	96 43.029	97 32.729	98 35.797	99 36.527	100 39.648	101 40.733	102 41.101	103 41.023	104 39.232	105 35.848
8.	61 40.737	62 35.409	63 36.539	64 [illegible]	65 32.544	66 37.713	67 32.541	68 38.153	69 39.637	70 31.943	71 32.377	72 35.261	73 35.471	74 38.595	75 40.233
9.	151 37.225	152 35.508	153 33.632	154 [illegible].732	155 33.178	156 32.389	157 32.362	158 33.547	159 37.533	160 35.628	161 33.638	162 33.265	163 32.230	164 34.377	165 34.857
10.	1 34.419	2 34.435	3 33.479	4 34.553	5 37.[illegible]	6 33.292	7 32.305	8 41.171	9 33.327	10 35.464	11 33.744	12 34.145	13 37.797	14 32.237	15 35.352
11.	196 32.741	197 38.647	198 33.449	199 35.261	200 31.261	201 31.137	202 34.769	203 37.937	204 39.365	205 31.474	206 33.131	207 35.273	208 32.339	209 36.647	210 31.006
12.	31 34.743	32 37.309	33 43.470	34 32.640	35 37.369	36 34.746	37 40.262	38 35.055	39 39.373	40 32.141	41 34.343	42 37.567	43 34.133	44 35.11[illegible]	45 33.473
13.	136 34.427	137 33.646	138 41.029	139 37.772	140 37.370	141 40.135	142 39.276	143 43.057	144 41.073	145 35.915	146 40.201	147 34.611	148 34.239	149 40.5[illegible]4	150 36.436
14.	76 27.724	77 39.346	78 33.143	79 47.571	80 33.724	81 [illegible]	82 35.128	83 40.443	84 35.949	85 37.251	86 30.722	87 33.573	88 37.217	89 37.159	90 40.220
15.	166 35.003	167 38.369	168 35.725	169 34.472	170 36.429	171 37.315	172 44.283	173 43.577	174 33.622	175 37.435	176 33.737	177 35.474	178 35.288	179 36.335	180 35.495

REPLICATION-2.

1.	14 32.234	29 39.505	44 34.731	59 35.594	74 36.314	89 37.233	104 37.997	119 33.243	134 39.125	149 43.626	154 43.173	173 31.356	194 33.833	209 41.695	224 35.292
2.	7 33.727	16 34.521	31 33.651	56 34.038	61 39.037	76 35.443	91 42.223	106 35.675	121 [illegible].103	135 43.653	151 50.151	165 35.361	181 42.377	195 38.274	211 37.520
3.	9 33.477	24 39.513	39 34.574	54 35.365	67 41.627	84 42.443	99 41.226	116 37.411	123 40.061	144 44.576	159 44.1[illegible]	174 35.137	183 41.020	201 40.047	219 37.356
4.	2 35.521	17 42.023	32 41.571	47 41.351	62 32.356	77 33.179	92 34.371	107 34.228	122 35.753	137 36.923	152 35.561	167 37.721	182 37.314	197 33.547	212 35.630
5.	6 34.347	21 32.503	36 34.291	51 37.313	66 40.421	81 34.713	96 43.354	111 34.422	126 34.375	141 35.915	156 34.971	171 33.208	186 37.364	201 35.570	216 42.623
6.	11 42.523	26 39.575	41 42.513	56 34.275	71 34.192	86 35.224	101 42.450	116 38.277	131 39.139	146 17.975	161 33.456	176 32.316	191 35.637	206 43.423	221 33.784
7.	12 33.759	25 33.099	40 27.645	55 35.653	70 37.956	85 43.703	100 35.505	115 42.724	130 33.644	145 41.063	160 41.365	175 42.157	190 36.343	205 35.312	220 37.509
8.	8 42.273	23 43.643	38 37.457	53 35.229	68 37.735	83 35.313	98 33.315	113 37.433	128 39.311	143 37.577	158 32.413	173 33.434	188 41.615	203 40.575	218 33.511
9.	3 39.336	18 33.945	33 43.474	48 44.150	63 35.249	78 33.275	93 35.027	108 34.552	124 33.442	138 36.796	153 38.335	168 33.353	183 35.623	198 31.724	213 33.336
10.	13 29.753	28 31.423	43 34.570	58 33.346	73 35.303	88 32.023	103 33.041	118 27.439	133 34.237	148 32.424	163 33.251	178 33.118	193 33.242	208 35.573	223 33.392
11.	12 32.546	27 34.343	42 37.524	57 33.381	72 41.454	87 33.493	102 42.451	117 35.614	132 36.252	147 36.252	162 34.732	177 35.454	192 39.527	207 37.115	222 35.393
12.	5 36.743	20 32.324	35 34.354	50 28.210	65 39.561	80 32.622	95 36.224	215 46.912	200 35.555	125 36.753	170 34.547	155 35.456	140 36.459	125 37.652	110 33.692
13.	4 39.724	19 33.767	34 34.379	44 35.152	64 37.770	80 35.470	94 32.711	109 33.776	124 34.063	139 43.015	154 33.617	169 34.399	184 36.156	199 37.712	214 36.745
14.	7 33.248	22 36.151	37 37.487	52 33.296	67 25.179	82 34.551	97 34.111	112 39.359	127 34.232	142 38.479	157 33.571	172 43.722	187 42.372	202 34.365	217 39.178
15.	15 33.739	30 35.552	45 37.224	60 37.675	75 38.227	90 35.452	105 33.972	120 32.865	135 39.066	150 43.253	165 33.125	180 33.481	195 34.291	210 35.954	225 33.447

REPLICATION-3.

1.	45 27.132	30 [illegible]	73 37.542	47 44.118	101 45.219	175 43.143	129 36.791	143 36.751	157 37.465	171 34.709	185 36.367	149 45.255	211 35.273	2 37.396	16 33.756
2.	153 33.951	158 43.211	178 42.[illegible]	192 37.177	205 42.241	223 35.435	9 33.234	23 44.517	37 44.403	51 36.413	65 42.129	73 35.115	91 37.496	107 43.714	121 45.329
3.	77 35.464	124 40.537	135 42.542	132 35.738	165 44.236	15[illegible] 44.173	174 37.255	193 45.933	202 43.150	216 43.971	5 47.169	19 35.125	31 44.392	47 36.916	61 35.522
4.	195 35.851	207 43.783	221 37.506	12 35.205	25 42.377	42 37.781	54 33.426	69 34.056	82 44.571	95 39.035	110 37.411	124 34.248	139 49.218	152 37.205	166 34.322
5.	175 32.106	176 37.466	131 [illegible]	147 43.707	161 37.742	175 36.345	190 35.143	203 39.369	217 39.131	6 41.932	20 35.030	34 35.131	49 38.213	62 34.106	76 33.567
6.	182 35.377	198 35.493	224 42.523	222 44.932	11 37.550	25 33.753	39 37.321	53 35.945	67 33.679	81 34.523	95 38.367	109 33.464	123 35.315	137 35.727	151 36.949
7.	63 33.245	76 35.289	38 42.337	202 33.742	216 35.542	133 35.[illegible]43	144 33.381	154 41.354	172 34.748	135 33.069	200 34.993	214 35.278	3 39.323	17 35.958	33 35.311
8.	15 24.926	29 37.197	41 31.555	57 44.816	71 37.224	85 39.[illegible]41	99 35.777	113 34.572	127 35.135	141 37.957	155 34.533	169 37.[illegible]91	183 35.417	197 38.342	211 33.619
9.	225 39.[illegible]59	18 37.976	28 34.252	42 42.217	55 38.562	72 34.[illegible]37	86 34.123	98 36.816	112 32.455	126 32.856	140 38.118	154 38.630	168 35.362	182 42.944	196 33.619
10.	135 43.427	169 37.367	163 35.656	177 36.316	191 38.261	205 41.460	219 41.655	8 41.957	22 39.360	36 39.166	50 43.329	64 36.031	78 35.386	92 39.571	106 29.440
11.	165 39.216	179 39.219	193 35.320	207 35.930	221 36.515	10 31.564	24 34.322	38 39.969	52 42.054	66 40.066	83 33.641	94 33.100	109 47.931	122 39.327	136 35.443
12.	122 30.370	136 32.558	148 34.448	162 37.157	176 39.149	192 34.446	206 34.715	210 34.345	7 36.023	21 38.477	35 39.723	49 43.419	63 40.053	77 37.619	91 33.560
13.	33 35.933	44 37.740	58 35.460	72 42.332	86 39.300	100 35.493	114 30.779	128 36.616	142 41.271	156 36.160	170 37.035	184 37.076	198 32.923	212 36.540	1 33.158
14.	75 36.125	90 30.115	103 39.367	117 33.975	131 30.548	145 35.236	159 36.466	173 40.102	187 39.459	201 37.117	215 42.520	4 39.105	18 35.037	32 35.119	46 36.105
15.	213 38.437	220 39.525	13 30.653	27 31.652	41 38.993	55 32.297	69 33.120	83 42.750	97 37.914	111 33.391	125 34.467	139 39.243	153 33.779	167 38.318	181 33.023

APPENDIX XII Yield per plant at Ellerslie

ELLERSLIE REPLICATION-1 YIELD PER PLANT

(Block)															
	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195
1.	20.010	13.910	16.168	22.956	21.632	17.581	13.566	13.610	15.172	17.731	15.479	12.117	15.510	16.735	14.107
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
2.	12.247	11.896	15.951	16.670	16.415	13.235	13.716	14.520	15.449	15.974	14.119	14.177	15.511	13.369	12.445
	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
3.	12.612	13.550	15.513	13.724	16.131	16.135	14.111	12.710	15.674	15.691	12.365	11.558	14.125	14.936	13.921
	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
4.	11.727	16.452	17.360	13.761	17.712	15.765	14.336	13.676	13.311	13.420	14.281	10.733	16.172	13.312	14.402
	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
5.	14.817	8.417	15.155	11.823	14.348	15.496	23.138	22.247	13.624	14.551	15.656	14.363	13.374	17.032	11.592
	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
6.	19.515	15.604	12.826	10.622	16.642	12.991	15.310	13.263	14.225	15.317	15.926	15.112	13.738	12.103	17.537
	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
7.	21.035	17.376	15.016	16.512	16.779	10.744	13.465	20.540	17.273	14.253	14.550	16.810	22.834	14.073	14.435
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
8.	13.153	16.752	13.678	15.762	13.726	12.523	14.522	22.974	13.217	[illegible]	13.655	12.515	13.755	14.073	17.463
	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165
9.	13.762	16.235	11.517	11.367	13.270	10.451	8.453	12.224	12.231	11.424	15.544	13.016	12.516	13.832	17.537
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10.	11.676	11.982	12.934	15.647	13.567	12.833	13.823	12.544	[illegible]	9.653	13.267	12.552	12.553	13.845	12.316
	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
11.	9.540	13.064	11.535	8.025	12.342	7.417	8.325	10.511	11.753	8.272	11.042	9.311	8.153	8.457	13.241
	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
12.	10.175	13.113	11.565	7.337	12.263	13.613	10.705	11.774	15.573	11.552	12.464	12.341	11.722	13.113	12.716
	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
13.	13.092	11.187	17.624	13.673	14.656	16.922	9.311	16.727	11.775	9.440	11.775	13.113	11.728	13.233	11.254
	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
14.	8.046	11.525	16.711	8.522	10.323	9.743	13.114	11.745	12.457	11.446	12.572	11.711	11.175	13.276	15.456
	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
15.	13.432	8.938	16.976	4.171	13.316	12.197	15.247	17.020	11.262	12.973	11.432	11.673	11.435	11.249	12.557

REPLICATION-2.

	14	29	44	59	74	89	104	119	134	149	164	179	194	209	224
1.	11.306	11.297	10.156	11.155	13.542	16.357	15.115	12.952	11.239	17.192	14.115	17.357	13.041	15.103	16.124
	1	16	31	46	61	76	91	106	121	136	151	166	181	196	211
2.	12.540	16.333	15.252	11.631	15.249	16.778	14.127	12.722	[illegible]	12.452	16.524	15.745	13.974	15.529	13.521
	9	24	39	54	69	84	99	114	129	144	159	174	189	204	219
3.	15.925	14.592	15.565	13.731	15.424	14.711	21.342	13.243	15.431	17.352	22.156	20.373	17.435	21.671	21.133
	2	17	32	47	62	77	92	107	122	137	152	167	182	197	212
4.	17.219	16.734	11.940	11.455	14.526	11.724	15.775	13.675	15.526	13.533	15.021	12.333	13.637	17.733	14.225
	6	21	36	51	66	81	96	111	126	141	156	171	186	201	216
5.	21.332	15.423	34.195	23.072	15.023	12.516	17.257	14.172	15.459	13.614	20.554	16.644	17.457	15.703	23.741
	11	26	41	56	71	86	101	116	131	146	161	176	191	206	221
6.	16.914	12.637	18.269	17.355	18.454	14.156	17.575	13.831	16.115	13.740	[illegible]	12.721	17.253	14.324	14.740
	10	25	40	55	70	85	100	115	130	145	160	175	190	205	220
7.	9.774	11.506	11.656	12.029	17.711	18.255	12.545	14.647	7.452	13.440	11.126	12.022	13.249	15.272	21.543
	8	23	38	53	68	83	98	113	128	143	158	173	188	203	218
8.	13.937	21.335	14.271	14.755	24.795	15.643	15.251	14.733	22.937	12.323	10.249	13.643	14.301	12.734	20.220
	3	18	33	48	63	78	93	108	123	138	153	168	183	198	213
9.	18.653	13.326	16.446	15.777	17.734	15.354	14.213	11.745	16.199	11.219	15.529	20.017	11.732	12.427	15.612
	13	28	43	58	73	88	103	118	133	148	163	178	193	208	223
10.	13.937	14.000	15.639	11.949	12.376	14.615	11.515	11.263	15.641	15.521	21.564	17.153	14.397	12.031	22.445
	12	27	42	57	72	87	102	117	132	147	162	177	192	207	222
11.	17.953	13.205	19.342	15.773	11.306	14.955	[illegible]	14.662	11.345	14.343	17.113	14.322	17.134	13.254	15.447
	5	20	35	50	65	80	95	215	110	185	170	155	140	125	210
12.	13.275	18.256	13.432	12.160	14.443	15.672	23.674	25.473	12.675	23.372	12.581	16.522	13.654	13.127	17.474
	4	19	34	49	64	79	94	109	124	139	154	169	184	199	214
13.	15.721	13.751	18.660	16.719	14.575	12.511	14.148	8.611	9.269	13.329	13.780	12.278	11.523	14.474	15.623
	7	22	37	52	67	82	97	112	127	142	157	172	187	202	217
14.	11.435	12.739	13.329	15.454	11.717	14.165	15.447	19.637	12.548	13.354	15.442	22.723	11.355	11.746	12.595
	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225
15.	13.354	12.165	11.716	11.029	15.353	17.824	12.191	11.192	13.319	14.566	15.054	14.142	14.525	13.122	12.733

REPLICATE N-3.

	45	59	73	87	101	115	129	143	157	171	185	199	213	2	16
1.	17.441	17.626	14.490	17.618	22.527	24.181	22.237	19.310	15.475	27.748	13.427	17.252	27.247	22.226	15.662
	153	164	178	192	206	220	9	23	37	51	65	79	93	107	121
2.	20.942	21.515	15.736	21.058	22.569	17.612	13.315	20.812	11.531	13.275	13.313	22.254	12.433	13.451	14.757
	90	104	118	132	146	160	174	188	202	216	5	19	33	47	61
3.	20.594	21.503	17.903	24.529	14.243	13.149	16.513	19.373	[illegible]	[illegible]	14.915	14.152	17.920	16.165	[illegible]
	195	209	223	12	26	40	54	68	82	96	110	124	138	152	166
4.	22.076	22.987	16.527	16.420	17.038	20.876	16.445	19.767	[illegible]	21.924	17.517	[illegible]	21.724	22.128	24.443
	105	119	133	147	161	175	189	203	217	6	20	34	48	62	76
5.	11.339	17.932	22.606	23.777	21.552	19.245	21.216	16.656	19.133	19.665	19.177	21.319	[illegible]	22.575	14.313
	180	194	208	222	11	25	39	53	67	81	95	109	123	137	151
6.	15.173	13.263	21.873	17.693	14.419	21.213	14.446	13.178	13.273	14.653	14.571	19.245	12.292	13.276	15.083
	60	74	88	102	116	130	144	158	172	186	200	214	3	17	31
7.	14.055	14.393	17.760	14.619	11.251	11.373	18.237	16.337	23.267	15.251	15.560	15.257	21.313	16.945	13.767
	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211
8.	20.240	19.806	20.872	17.175	19.031	17.936	21.079	23.927	11.159	14.239	16.779	16.623	17.377	13.233	15.733
	225	14	28	42	56	70	84	98	112	126	140	154	168	182	196
9.	14.915	21.038	21.931	16.076	24.381	18.957	17.213	16.147	13.124	[illegible]	[illegible]	[illegible]	13.455	24.835	23.776
	135	149	163	177	191	205	219	8	22	36	50	64	78	92	106
10.	13.207	15.468	15.947	23.348	16.007	13.207	13.228	15.125	10.569	22.311	22.199	16.558	21.283	16.323	15.718
	165	179	193	207	221	10	24	38	52	66	80	94	108	122	136
11.	14.816	15.190	15.966	15.347	17.445	21.102	26.331	19.776	17.226	20.225	21.617	[illegible]	17.427	16.792	24.495
	120	134	148	162	176	190	204	218	7	21	35	49	63	77	91
12.	11.361	19.933	13.832	17.091	15.816	16.153	15.766	15.337	16.746	16.615	12.351	14.700	15.730	20.912	20.920
	30	44	58	72	86	100	114	128	142	156	170	184	198	212	1
13.	13.239	13.161	15.269	17.734	11.016	13.264	16.735	14.196	13.224	13.273	13.760	16.610	12.143	12.481	13.260
	75	89	103	117	131	145	159	173	187	201	215	4	18	32	46
14.	14.465	20.732	16.236	16.650	15.803	15.401	16.211	16.991	13.137	16.622	[illegible]	17.032	15.729	13.136	17.720
	210	224	13	27	41	55	69	83	97	111	125	139	153	167	181
15.	9.610	15.089	9.867	15.618	20.569	15.720	10.553	16.968	13.720	15.043	16.558	16.263	15.532	19.170	20.558

APPENDIX XIII Onset-of-heading at Parkland

REPLICATE 1.

(Block)															
1.	181 45.000	182 44.000	183 54.000	184 52.000	185 49.000	186 49.000	187 49.000	188 48.000	189 52.000	190 49.000	191 49.000	192 44.000	193 51.000	194 51.000	195 49.000
2.	16 48.000	17 44.000	18 56.000	19 49.000	20 53.000	21 53.000	22 49.000	23 49.000	24 46.000	25 52.000	26 47.000	27 51.000	28 54.000	29 50.000	30 52.000
3.	211 50.000	212 48.000	213 54.000	214 49.000	215 48.000	216 48.000	217 52.000	218 44.000	219 46.000	220 52.000	221 49.000	222 49.000	223 53.000	224 54.000	225 52.000
4.	46 52.000	47 44.000	48 45.000	49 52.000	50 48.000	51 48.000	52 49.000	53 51.000	54 52.000	55 48.000	56 50.000	57 49.000	58 49.000	59 56.000	60 57.000
5.	106 50.000	107 55.000	108 50.000	109 52.000	110 57.000	111 55.000	112 54.000	113 52.000	114 55.000	115 48.000	116 52.000	117 51.000	118 51.000	119 49.000	120 52.000
6.	121 52.000	122 52.000	123 53.000	124 51.000	125 49.000	126 52.000	127 51.000	128 49.000	129 49.000	130 52.000	131 51.000	132 49.000	133 48.000	134 51.000	135 47.000
7.	91 51.000	92 51.000	93 57.000	94 51.000	95 49.000	96 51.000	97 57.000	98 57.000	99 50.000	100 50.000	101 48.000	102 55.000	103 52.000	104 49.000	105 53.000
8.	61 52.000	62 57.000	63 52.000	64 49.000	65 53.000	66 45.000	67 55.000	68 49.000	69 49.000	70 46.000	71 54.000	72 53.000	73 56.000	74 49.000	75 52.000
9.	151 48.000	152 52.000	153 49.000	154 52.000	155 55.000	156 52.000	157 57.000	158 55.000	159 48.000	160 46.000	161 45.000	162 52.000	163 53.000	164 51.000	165 53.000
10.	1 53.000	2 50.000	3 49.000	4 52.000	5 49.000	6 49.000	7 54.000	8 54.000	9 58.000	10 51.000	11 45.000	12 51.000	13 52.000	14 59.000	15 49.000
11.	196 53.000	197 55.000	198 54.000	199 52.000	200 51.000	201 51.000	202 52.000	203 43.000	204 49.000	205 54.000	206 51.000	207 54.000	208 52.000	209 52.000	210 54.000
12.	31 53.000	32 47.000	33 52.000	34 55.000	35 49.000	36 54.000	37 51.000	38 52.000	39 52.000	40 52.000	41 53.000	42 49.000	43 51.000	44 47.000	45 54.000
13.	136 49.000	137 59.000	138 57.000	139 52.000	140 52.000	141 55.000	142 43.000	143 54.000	144 53.000	145 57.000	146 52.000	147 52.000	148 57.000	149 50.000	150 51.000
14.	76 57.000	77 53.000	78 55.000	79 59.000	80 55.000	81 55.000	82 54.000	83 41.000	84 54.000	85 55.000	86 57.000	87 52.000	88 51.000	89 56.000	90 51.000
15.	166 55.000	167 53.000	168 55.000	169 55.000	170 54.000	171 56.000	172 53.000	173 53.000	174 58.000	175 51.000	176 57.000	177 51.000	178 54.000	179 52.000	180 54.000

REPLICATE 2

1.	18 68.000	23 55.000	44 57.000	59 53.000	78 45.000	99 54.000	104 56.000	119 57.000	134 57.000	149 56.000	164 57.000	171 57.000	193 58.000	203 54.000	224 57.000
2.	1 57.000	15 53.000	31 57.000	46 57.000	51 57.000	76 57.000	91 59.000	125 60.000	121 57.000	135 54.000	151 59.000	165 60.000	191 56.000	195 57.000	211 53.000
3.	9 49.000	20 57.000	39 57.000	54 51.000	67 56.000	25 57.000	98 53.000	114 54.000	128 54.000	144 56.000	150 62.000	174 54.000	187 57.000	204 56.000	219 56.000
4.	2 59.000	17 56.000	32 55.000	47 55.000	62 63.000	77 57.000	92 57.000	107 [illegible]	122 59.000	132 57.000	152 57.000	167 57.000	182 56.000	197 53.000	212 64.000
5.	6 54.000	21 62.000	36 59.000	51 57.000	65 57.000	81 58.000	95 57.000	111 59.000	126 53.000	141 57.000	155 59.000	171 59.000	186 57.000	201 57.000	215 57.000
6.	11 57.000	26 57.000	41 54.000	55 57.000	71 54.000	96 64.000	127 56.000	136 49.000	131 54.000	146 53.000	161 53.000	176 71.000	191 54.000	225 57.000	221 57.000
7.	10 58.000	25 57.000	42 60.000	55 57.000	70 53.000	85 50.000	100 65.000	115 55.000	132 60.000	145 54.000	143 54.000	175 54.000	190 55.000	205 57.000	220 57.000
8.	8 56.000	23 55.000	38 57.000	53 55.000	63 56.000	93 56.000	94 57.000	113 57.000	143 55.000	161 53.000	154 61.000	173 56.000	189 55.000	203 56.000	214 55.000
9.	3 54.000	18 53.000	33 54.000	43 57.000	53 54.000	79 53.000	73 59.000	124 54.000	128 53.000	134 54.000	153 57.000	169 57.000	183 56.000	179 63.000	213 59.000
10.	13 57.000	29 54.000	43 57.000	58 58.000	73 59.000	88 57.000	102 53.000	116 54.000	133 56.000	148 59.000	163 59.000	178 57.000	193 57.000	203 56.000	223 51.000
11.	12 61.000	27 57.000	42 56.000	57 57.000	72 54.000	97 57.000	132 54.000	117 54.000	132 58.000	147 57.000	162 57.000	177 55.000	192 58.000	207 59.000	222 56.000
12.	5 57.000	20 58.000	35 56.000	50 59.000	65 57.000	90 61.000	95 57.000	110 61.000	125 57.000	140 57.000	155 59.000	170 56.000	185 54.000	200 57.000	215 55.000
13.	4 58.000	19 56.000	34 53.000	49 53.000	54 57.000	79 59.000	94 57.000	139 52.000	124 59.000	139 57.000	154 60.000	169 58.000	184 51.000	199 57.000	214 57.000
14.	7 63.000	22 57.000	37 54.000	52 59.000	57 54.000	82 59.000	97 63.000	112 54.000	127 54.000	142 56.000	157 60.000	172 57.000	197 57.000	202 54.000	217 63.000
15.	15 59.000	20 60.000	45 53.000	63 70.000	75 53.000	90 53.000	105 60.000	120 59.000	135 59.000	170 59.000	165 57.000	180 59.000	195 53.000	210 59.000	225 57.000

REPLICATE 3.

1.	45 55.000	51 58.000	71 52.000	37 49.000	127 44.000	135 53.000	129 51.000	141 53.000	157 49.000	171 49.000	115 44.000	133 49.000	211 50.000	2 49.000	16 52.000
2.	150 52.000	164 57.000	178 53.000	192 49.000	221 57.000	223 54.000	7 57.000	21 52.000	37 52.000	51 53.000	56 52.000	79 53.000	91 51.000	107 57.000	121 54.000
3.	90 53.000	124 44.000	114 49.000	132 53.000	145 49.000	163 47.000	174 51.000	184 47.000	202 53.000	215 49.000	5 41.000	19 53.000	31 49.000	47 47.000	61 51.000
4.	195 50.000	203 47.000	221 54.000	12 57.000	15 43.000	42 54.000	58 54.000	64 44.000	32 56.000	96 57.000	113 55.000	128 51.000	134 47.000	172 54.000	185 51.000
5.	105 54.000	119 52.000	131 46.000	147 44.000	161 54.000	175 49.000	174 53.000	201 42.000	217 51.000	6 44.000	29 54.000	34 51.000	44 51.000	62 58.000	76 51.000
6.	180 52.000	136 51.000	209 45.000	222 47.000	11 40.000	25 52.000	39 52.000	53 53.000	67 55.000	81 54.000	95 51.000	109 51.000	124 55.000	137 51.000	151 49.000
7.	60 55.000	74 53.000	89 53.000	102 52.000	116 52.000	130 54.000	144 49.000	158 54.000	172 52.000	186 52.000	200 52.000	216 49.000	1 53.000	17 49.000	31 53.000
8.	35 47.000	23 49.000	43 50.000	57 44.000	71 54.000	85 53.000	99 52.000	113 44.000	127 55.000	141 53.000	155 55.000	169 54.000	183 47.000	197 51.000	211 50.000
9.	225 52.000	18 54.000	28 51.000	42 45.000	56 53.000	70 47.000	84 52.000	98 51.000	112 53.000	126 53.000	140 41.000	154 43.000	168 52.000	182 44.000	196 53.000
10.	139 44.000	149 46.000	163 51.000	177 52.000	191 49.000	205 53.000	219 49.000	8 44.000	22 50.000	36 53.000	50 44.000	64 52.000	78 55.000	92 48.000	106 51.000
11.	165 52.000	179 49.000	193 53.000	207 53.000	221 47.000	12 51.000	24 48.000	38 53.000	52 46.000	66 46.000	80 54.000	94 49.000	108 49.000	122 53.000	135 48.000
12.	120 53.000	134 53.000	148 57.000	162 43.000	176 55.000	190 53.000	204 44.000	218 49.000	7 57.000	21 53.000	35 49.000	49 53.000	63 44.000	77 44.000	91 50.000
13.	30 50.000	46 52.000	59 49.000	73 52.000	86 54.000	112 52.000	110 54.000	124 52.000	142 45.000	156 53.000	171 52.000	180 53.000	198 55.000	212 55.000	1 53.000
14.	75 52.000	87 50.000	103 45.000	117 49.000	111 53.000	145 51.000	159 52.000	173 49.000	187 52.000	231 46.000	215 46.000	8 47.000	18 51.000	72 49.000	46 53.000
15.	210 52.000	224 54.000	33 48.000	27 53.000	61 48.000	55 53.000	89 49.000	83 48.000	97 58.000	111 48.000	125 52.000	119 50.000	153 47.000	167 48.000	181 48.000

APPENDIX XIV Final heading at Parkland

PARKLAND REPLICATION 1.

(Block)															
1.	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195
	57.000	56.000	59.000	57.000	57.000	59.000	[illegible]	59.000	57.000	60.000	53.000	59.000	59.000	[illegible]	58.000
2.	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	60.000	57.000	61.000	59.000	59.000	53.000	[illegible]	57.000	57.000	59.000	57.000	58.000	61.000	59.000	61.000
3.	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225
	59.000	57.000	61.000	56.000	58.000	57.000	61.000	[illegible]	[illegible]	60.000	53.000	57.000	59.000	61.000	57.000
4.	46	47	48	49	50	51	52	53	[illegible]	[illegible]	56	57	58	59	60
	58.000	56.000	57.000	57.000	59.000	51.000	57.000	57.000	[illegible]	[illegible]	56.000	53.000	54.000	53.000	61.000
5.	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
	57.000	66.000	56.000	59.000	61.000	59.000	57.000	57.000	66.000	57.000	57.000	53.000	57.000	56.000	57.000
6.	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135
	59.000	59.000	57.000	57.000	57.000	59.000	59.000	56.000	58.000	59.000	59.000	57.000	57.000	57.000	56.000
7.	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105
	57.000	59.000	63.000	59.000	57.000	57.000	61.000	61.000	63.000	59.000	57.000	61.000	59.000	53.000	62.000
8.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
	53.000	61.000	58.000	59.000	56.000	57.000	53.000	59.000	59.000	59.000	53.000	64.000	61.000	57.000	57.000
9.	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165
	57.000	57.000	58.000	59.000	61.000	53.000	61.000	66.000	58.000	57.000	54.000	51.000	59.000	59.000	57.000
10.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	59.000	57.050	55.000	57.000	55.000	56.000	59.000	57.000	62.000	61.000	55.000	[illegible]	58.000	59.000	57.000
11.	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210
	59.000	57.000	61.000	56.000	57.000	54.000	57.000	55.000	56.000	59.000	57.000	57.000	59.000	55.000	58.000
12.	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
	59.000	57.000	56.000	60.000	53.000	56.000	59.000	54.000	51.000	53.000	55.000	55.000	59.000	57.000	54.000
13.	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
	58.000	63.000	57.000	58.000	60.000	53.000	59.000	54.000	57.000	54.000	57.000	[illegible]	59.000	55.000	57.000
14.	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
	61.000	58.000	70.000	59.000	63.000	62.000	51.000	56.000	63.000	51.000	57.000	51.000	53.000	57.000	53.000
15.	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180
	62.000	59.000	53.000	57.000	60.000	60.000	59.000	56.000	64.000	53.000	67.000	53.000	52.000	57.000	59.000

REPLICATION-2.

1.	14	29	44	59	74	89	104	119	134	149	164	179	194	209	224
	58.000	63.000	65.000	55.000	59.000	[illegible]	53.000	52.000	63.000	46.000	57.000	64.000	58.000	63.000	53.000
2.	1	16	31	46	61	76	91	106	121	136	151	166	181	196	211
	51.000	58.000	49.000	51.000	49.000	[illegible]	52.000	57.000	53.000	56.000	61.000	55.000	61.000	63.000	53.000
3.	9	24	39	54	69	84	99	114	129	144	159	174	189	204	219
	57.000	61.000	52.000	57.000	63.000	53.000	59.000	55.000	61.000	49.000	57.000	64.000	53.000	62.000	49.000
4.	2	17	32	47	62	77	92	107	122	137	152	167	182	197	212
	63.000	43.000	63.000	64.000	55.000	61.000	57.000	57.000	53.000	55.000	53.000	64.000	64.000	53.000	55.000
5.	6	21	36	51	66	81	96	111	126	141	156	171	186	201	216
	49.000	54.000	53.000	49.000	67.000	52.000	52.000	53.000	51.000	53.000	51.000	54.000	52.000	52.000	52.000
6.	11	26	41	56	71	86	101	116	131	146	161	176	191	206	221
	52.000	67.000	45.000	51.000	51.000	55.000	63.000	57.000	52.000	59.000	55.000	54.000	47.000	51.000	59.000
7.	10	25	40	55	70	85	100	115	130	145	160	175	190	205	220
	52.000	52.000	56.000	49.000	53.000	52.000	56.000	49.000	53.000	50.000	47.000	64.000	52.000	51.000	53.000
8.	8	23	38	53	68	83	98	113	128	143	158	173	188	203	218
	52.000	49.000	50.000	53.000	47.000	63.000	57.000	53.000	47.000	52.000	53.000	47.000	49.000	44.000	64.000
9.	3	18	33	48	63	78	93	108	123	138	153	168	183	198	213
	49.000	52.000	46.000	45.000	53.000	57.000	51.000	63.000	57.000	49.000	61.000	57.000	43.000	53.000	57.000
10.	13	28	43	58	73	88	103	118	133	148	163	178	193	208	223
	55.000	54.000	63.000	49.000	51.000	53.000	49.000	53.000	43.000	51.000	44.000	57.000	51.000	64.000	55.000
11.	12	27	42	57	72	87	102	117	132	147	162	177	192	207	222
	53.000	52.000	49.000	48.000	53.000	41.000	52.000	61.000	52.000	48.000	52.000	55.000	52.000	52.000	64.000
12.	5	20	35	50	65	80	95	110	125	140	155	170	185	200	215
	64.000	52.000	53.000	52.000	52.000	54.000	51.000	54.000	53.000	[illegible]	55.000	47.000	49.000	64.000	49.000
13.	4	19	34	49	64	79	94	109	124	139	154	169	184	199	214
	53.000	53.000	53.000	54.000	61.000	63.000	43.000	53.000	52.000	53.000	54.000	62.000	64.000	63.000	61.000
14.	7	22	37	52	67	82	97	112	127	142	157	172	187	202	217
	54.000	47.000	51.000	48.000	52.000	57.000	51.000	64.000	51.000	45.000	55.000	51.000	41.000	52.000	56.000
15.	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225
	49.000	54.000	52.000	53.000	48.000	52.000	56.000	52.000	64.000	57.000	51.000	53.000	52.000	52.000	52.000

REPLICATION 3.

1.	45	59	73	87	101	115	129	143	157	171	185	199	213	2	16
	59.000	62.000	57.000	55.000	56.000	55.000	55.000	55.000	57.000	54.000	57.000	55.000	57.000	56.000	57.000
2.	150	164	178	192	206	220	9	23	37	51	65	79	93	107	121
	59.000	63.000	59.000	56.000	54.000	53.000	65.000	56.000	57.000	54.000	54.000	55.000	55.000	61.000	58.000
3.	90	104	118	132	146	160	174	188	202	216	5	19	33	47	61
	55.000	54.000	56.000	55.000	56.000	57.000	57.000	51.000	56.000	57.000	57.000	45.000	57.000	52.000	59.000
4.	195	209	223	12	26	40	54	68	82	96	110	124	138	152	166
	59.000	52.000	59.000	61.000	53.000	63.000	51.000	52.000	61.000	61.000	52.000	51.000	52.000	52.000	56.000
5.	105	119	133	147	161	175	189	203	217	6	20	34	48	62	76
	59.000	54.000	53.000	51.000	60.000	54.000	51.000	54.000	51.000	57.000	61.000	53.000	57.000	64.000	55.000
6.	180	194	208	222	11	25	39	53	67	81	95	109	123	137	151
	54.000	63.000	56.000	53.000	51.000	57.000	57.000	62.000	51.000	[illegible]	57.000	53.000	57.000	56.000	55.000
7.	60	74	88	102	116	130	144	158	172	186	200	214	3	17	31
	65.000	60.000	59.000	57.000	53.000	60.000	63.000	65.000	57.000	57.000	58.000	56.000	55.000	56.000	55.000
8.	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211
	53.000	53.000	57.000	59.000	61.000	55.000	59.000	55.000	63.000	54.000	62.000	54.000	57.000	54.000	52.000
9.	225	14	28	42	56	70	84	98	112	126	140	154	168	182	196
	58.000	65.000	58.000	51.000	56.000	51.000	57.000	58.000	56.000	56.000	51.000	55.000	51.000	51.000	54.000
10.	135	149	163	177	191	205	219	8	22	36	50	64	78	92	106
	51.000	52.000	56.000	53.000	56.000	56.000	51.000	51.000	56.000	56.000	53.000	56.000	61.000	58.000	57.000
11.	165	179	193	207	221	10	24	38	52	66	80	94	108	122	136
	53.000	54.000	56.000	54.000	51.000	55.000	53.000	58.000	50.000	57.000	64.000	55.000	53.000	55.000	56.000
12.	120	134	148	162	176	190	204	218	7	21	35	49	63	77	91
	56.000	54.000	64.000	56.000	62.000	55.000	54.000	56.000	60.000	54.000	55.000	58.000	57.000	56.000	58.000
13.	30	44	58	72	86	100	114	128	142	156	170	184	198	212	1
	55.000	54.000	55.000	58.000	61.000	57.000	61.000	58.000	55.000	56.000	54.000	60.000	57.000	62.000	59.000
14.	75	89	103	117	131	145	159	173	187	201	215	4	18	32	46
	58.000	55.000	56.000	55.000	56.000	56.000	56.000	53.000	57.000	53.000	56.000	55.000	67.000	56.000	53.000
15.	210	224	13	27	41	55	69	83	97	111	125	139	153	167	181
	59.000	61.000	53.000	60.000	53.000	56.000	56.000	53.000	65.000	56.000	59.000	56.000	53.000	55.000	56.000

APPENDIX XV Heading-span at Parkland

PARKLAND REPLICATION-1.

(Block)															
1.	181 11.000	182 8.000	183 5.000	184 5.000	185 8.000	186 9.000	187 10.000	188 9.000	189 5.000	190 11.000	191 10.000	192 11.000	193 7.000	194 7.000	195 9.000
2.	16 12.000	17 9.000	18 9.[illegible]	[illegible]	20 8.000	21 6.000	22 9.000	23 9.000	24 11.000	25 9.000	26 10.000	27 8.000	28 7.000	29 8.000	30 9.000
3.	211 9.000	212 9.000	213 5.[illegible]	[illegible]	215 10.000	216 9.000	217 10.000	218 13.000	219 6.000	220 6.000	221 11.000	222 9.000	223 6.000	224 6.000	225 5.000
4.	46 6.000	47 8.000	48 9.000	[illegible]	50 10.000	51 10.000	52 7.000	53 8.000	54 7.000	55 9.000	56 6.000	57 9.000	58 10.000	59 6.000	60 12.000
5.	106 7.000	107 11.000	108 8.000	109 9.000	110 6.000	111 4.000	112 9.000	113 5.000	114 11.000	115 8.000	116 8.000	117 6.000	118 6.000	119 9.000	120 5.000
6.	121 6.000	122 6.000	123 6.000	124 6.000	125 4.000	126 7.000	127 5.000	128 7.000	129 4.000	130 6.000	131 7.000	132 10.000	133 9.000	134 4.000	135 7.000
7.	91 4.000	92 6.000	93 3.000	94 6.000	95 8.000	96 4.000	97 4.000	98 6.000	99 10.000	100 8.000	101 9.000	102 6.000	103 7.000	104 9.000	105 7.000
8.	61 6.000	62 12.000	63 6.000	64 10.000	65 4.000	66 11.000	67 4.000	68 10.000	69 12.000	70 11.000	71 6.000	72 12.000	73 5.000	74 11.000	75 7.000
9.	151 9.000	152 7.000	153 9.000	154 7.000	155 11.000	156 6.000	157 10.000	158 11.000	159 10.000	160 9.000	161 3.000	162 6.000	163 5.000	164 6.000	165 7.000
10.	1 6.000	2 9.000	3 7.000	4 5.000	5 9.000	6 7.000	7 11.000	8 9.000	9 4.000	10 8.000	11 10.000	12 7.000	13 6.000	14 10.000	15 9.000
11.	196 6.000	197 5.000	198 6.000	199 4.000	200 8.000	201 4.000	202 5.000	203 7.000	204 7.000	205 5.000	206 4.000	207 5.000	208 5.000	209 4.000	210 5.000
12.	31 9.000	32 4.000	33 6.000	34 5.000	35 10.000	36 5.000	37 9.000	38 6.000	39 5.000	40 4.000	41 6.000	42 9.000	43 5.000	44 8.000	45 7.000
13.	136 9.000	137 10.000	138 4.000	139 6.000	140 5.000	141 4.000	142 9.000	143 5.000	144 7.000	145 5.000	146 5.000	147 4.000	148 11.000	149 4.000	150 4.000
14.	76 4.000	77 5.000	78 12.000	79 7.000	80 11.000	81 5.000	82 5.000	83 7.000	84 5.000	85 3.000	86 11.000	87 7.000	88 5.000	89 5.000	90 5.000
15.	166 6.000	167 5.000	168 3.000	169 4.000	170 6.000	171 5.000	172 5.000	173 3.000	174 10.000	175 6.000	176 10.000	177 5.000	178 6.000	179 5.000	180 5.000

REPLICATION-2.

1.	14 10.000	29 7.000	44 9.000	59 5.000	74 12.000	89 4.000	104 9.000	119 5.000	134 9.000	149 7.000	164 4.000	179 9.000	194 4.000	209 7.000	224 4.000
2.	1 6.000	16 5.000	31 8.000	46 4.000	61 3.000	76 7.000	91 6.000	106 3.000	121 7.000	136 5.000	151 10.000	166 5.000	181 7.000	196 9.000	211 9.000
3.	9 11.000	24 9.000	39 5.000	54 4.000	69 9.000	84 7.000	99 7.000	114 9.000	129 10.000	144 6.000	159 5.000	174 11.000	189 7.000	204 9.000	219 7.000
4.	2 9.000	17 8.000	32 7.000	47 9.000	62 5.000	77 3.000	92 5.000	107 11.000	122 5.000	137 4.000	152 4.000	167 9.000	182 7.000	197 7.000	212 9.000
5.	6 8.000	21 6.000	36 6.000	51 8.000	66 10.000	81 4.000	96 5.000	111 5.000	126 5.000	141 4.000	156 6.000	171 5.000	186 5.000	201 5.000	216 7.000
6.	11 5.000	26 9.000	41 10.000	56 4.000	71 5.000	86 9.000	101 4.000	116 7.000	131 4.000	146 3.000	[illegible]	176 11.000	191 10.000	206 4.000	221 4.000
7.	10 6.000	25 5.000	40 6.000	55 4.000	70 5.000	85 4.000	100 9.000	115 7.000	130 10.000	145 5.000	160 3.000	175 8.000	190 6.000	205 5.000	220 4.000
8.	8 5.000	23 8.000	38 7.000	53 5.000	68 7.000	83 7.000	98 4.000	113 7.000	128 4.000	143 6.000	158 11.000	173 7.000	188 4.000	203 4.000	218 12.000
9.	3 7.000	18 7.000	33 12.000	48 11.000	63 4.000	78 7.000	93 5.000	108 7.000	123 4.000	138 8.000	153 9.000	168 5.000	183 3.000	198 5.000	213 7.000
10.	13 4.000	28 4.000	43 8.000	58 10.000	73 8.000	88 7.000	103 9.000	118 8.000	133 4.000	148 6.000	163 9.000	178 4.000	193 4.000	208 7.000	223 4.000
11.	12 7.000	27 5.000	42 7.000	57 9.000	72 4.000	87 3.000	102 4.000	117 9.000	132 5.000	147 9.000	162 5.000	177 3.000	192 6.000	207 7.000	222 7.000
12.	5 9.000	20 9.000	35 6.000	50 6.000	65 5.000	80 5.000	95 6.000	110 7.000	125 7.000	140 7.000	155 3.000	170 7.000	185 4.000	200 9.000	215 7.000
13.	4 [illegible]	19 5.000	34 6.000	49 5.000	64 9.000	79 9.000	94 8.000	109 7.000	124 7.000	139 5.000	154 6.000	169 5.000	184 4.000	199 8.000	214 4.000
14.	7 11.000	22 8.000	37 7.000	52 4.000	67 7.000	82 4.000	97 11.000	112 10.000	127 5.000	142 4.000	157 5.000	172 9.000	187 8.000	202 4.000	217 6.000
15.	15 13.000	30 4.000	45 4.000	60 12.000	75 10.000	90 4.000	105 4.000	120 7.000	135 11.000	150 6.000	165 6.000	180 8.000	195 8.000	210 4.000	225 5.000

REPLICATION-3.

1.	45 2.000	59 3.000	73 5.000	87 6.000	101 5.000	115 5.000	129 5.000	143 4.000	157 9.000	171 4.000	185 9.000	199 7.000	213 7.000	2 9.000	16 5.000
2.	150 4.000	164 6.000	178 4.000	192 7.000	206 4.000	220 5.000	9 4.000	23 4.000	37 5.000	51 5.000	65 6.000	79 5.000	93 7.000	107 6.000	121 4.000
3.	90 5.000	104 6.000	118 5.000	132 5.000	146 5.000	160 4.000	174 4.000	188 4.000	202 4.000	216 5.000	5 4.000	19 5.000	33 5.000	47 5.000	61 5.000
4.	195 5.000	209 5.000	223 6.000	12 4.000	26 5.000	40 5.000	54 5.000	68 4.000	82 5.000	96 4.000	110 7.000	124 5.000	138 5.000	152 6.000	166 4.000
5.	105 5.000	119 7.000	133 5.000	147 5.000	161 4.000	175 6.000	189 5.000	203 9.000	217 5.000	6 4.000	20 4.000	34 5.000	48 6.000	62 5.000	76 7.000
6.	180 7.000	194 7.000	208 6.000	222 4.000	11 5.000	25 5.000	39 5.000	53 5.000	67 4.000	81 7.000	95 6.000	109 7.000	123 6.000	137 4.000	151 5.000
7.	60 7.000	74 7.000	88 5.000	102 5.000	116 6.000	130 6.000	144 7.000	158 7.000	172 5.000	186 5.000	200 6.000	214 5.000	3 3.000	17 5.000	31 6.000
8.	15 6.000	29 5.000	43 7.000	57 5.000	71 7.000	85 5.000	99 4.000	113 6.000	127 5.000	141 8.000	155 3.000	169 4.000	183 6.000	197 4.000	211 10.000
9.	225 8.000	14 7.000	28 5.000	42 5.000	56 6.000	70 4.000	84 7.000	98 6.000	112 5.000	126 7.000	140 5.000	154 4.000	168 7.000	182 5.000	196 9.000
10.	135 5.000	149 4.000	163 5.000	177 7.000	191 8.000	205 4.000	219 5.000	8 5.000	22 4.000	36 6.000	50 9.000	64 4.000	78 3.000	92 8.000	106 8.000
11.	165 7.000	179 5.000	193 5.000	207 5.000	221 6.000	10 5.000	24 5.000	38 5.000	52 8.000	66 5.000	80 8.000	94 6.000	108 5.000	122 6.000	136 6.000
12.	120 6.000	134 5.000	148 7.000	162 5.000	176 7.000	190 6.000	204 8.000	218 4.000	7 7.000	21 6.000	35 6.000	49 5.000	63 5.000	77 8.000	91 8.000
13.	30 5.000	44 4.000	58 6.000	72 4.000	86 4.000	100 5.000	114 7.000	128 6.000	142 5.000	156 5.000	170 6.000	184 7.000	198 [illegible]	212 7.000	1 8.000
14.	75 4.000	89 5.000	103 8.000	117 6.000	131 6.000	145 5.000	159 6.000	173 4.000	187 5.000	201 5.000	215 6.000	4 6.000	18 [illegible]	32 5.000	46 6.000
15.	210 7.000	224 5.000	13 3.000	27 2.000	41 5.000	55 6.000	69 5.000	83 5.000	97 7.000	111 8.000	125 6.000	139 4.000	153 4.000	167 7.000	181 6.000

APPENDIX XVI Plant height at Parkland

PARKLAND REPLICATION 1. PLANT HEIGHT

(Block)

1.	181 73.950	182 73.550	183 [illegible]	184 [illegible]	185 [illegible]	186 [illegible]	187 75.890	188 74.550	189 [illegible]	190 76.450	191 75.960	192 95.310	193 94.870	194 101.520	195 102.630
2.	16 74.040	17 75.250	18 [illegible]	19 93.270	20 111.050	21 115.310	22 77.290	23 41.810	24 76.510	25 109.860	26 [illegible]	27 115.370	28 115.100	29 93.040	30 107.250
3.	211 90.150	212 95.680	213 90.700	214 74.540	215 76.720	216 [illegible]	217 131.100	218 77.310	219 76.310	220 [illegible]	221 [illegible]	222 74.540	223 93.710	224 [illegible]	225 [illegible]
4.	46 102.570	47 74.440	48 87.710	49 [illegible]	50 95.910	51 107.170	52 91.440	53 132.330	54 118.370	55 101.170	56 105.790	57 77.460	58 [illegible]	59 120.740	60 113.410
5.	106 104.360	107 120.950	108 77.140	109 [illegible]	110 127.310	111 124.402	112 [illegible]	113 [illegible]	114 124.260	115 76.970	116 [illegible]	117 [illegible]	118 40.450	119 [illegible]	120 [illegible]
6.	121 [illegible]	122 93.410	123 127.220	124 77.450	125 [illegible]	126 [illegible]	127 122.260	128 82.710	129 [illegible]	130 [illegible]	131 [illegible]	132 [illegible]	133 76.170	134 97.720	135 71.940
7.	91 76.800	92 82.240	93 [illegible]	94 111.520	95 64.540	96 74.440	97 [illegible]	98 112.340	99 [illegible]	100 [illegible]	101 75.360	102 [illegible]	103 [illegible]	104 [illegible]	105 [illegible]
8.	61 [illegible]	62 120.750	63 [illegible]	64 93.010	65 [illegible]	66 75.750	67 117.570	68 [illegible]	69 [illegible]	70 [illegible]	71 115.710	72 [illegible]	73 117.370	74 [illegible]	75 [illegible]
9.	151 [illegible]	152 112.010	153 [illegible]	154 [illegible]	155 [illegible]	156 [illegible]	157 [illegible]	158 [illegible]	159 [illegible]	160 [illegible]	161 [illegible]	162 [illegible]	163 93.440	164 [illegible]	165 [illegible]
10.	1 [illegible]	2 73.210	3 [illegible]	4 115.240	5 [illegible]	6 [illegible]	7 [illegible]	8 74.140	9 125.160	10 [illegible]	11 71.290	12 [illegible]	13 97.340	14 [illegible]	15 47.670
11.	196 97.760	197 97.210	198 [illegible]	199 [illegible]	200 [illegible]	201 [illegible]	202 [illegible]	203 [illegible]	204 [illegible]	205 [illegible]	206 [illegible]	207 [illegible]	208 97.350	209 [illegible]	210 [illegible]
12.	31 78.500	32 77.360	33 [illegible]	34 [illegible]	35 [illegible]	36 [illegible]	37 [illegible]	38 [illegible]	39 70.220	40 [illegible]	41 [illegible]	42 [illegible]	43 94.410	44 [illegible]	45 [illegible]
13.	136 81.950	137 124.660	138 [illegible]	139 [illegible]	140 [illegible]	141 [illegible]	142 [illegible]	143 [illegible]	144 [illegible]	145 [illegible]	146 [illegible]	147 [illegible]	148 123.340	149 [illegible]	150 [illegible]
14.	76 124.420	77 95.210	78 [illegible]	79 [illegible]	80 [illegible]	81 [illegible]	82 [illegible]	83 [illegible]	84 [illegible]	85 [illegible]	86 [illegible]	87 [illegible]	88 [illegible]	89 [illegible]	90 73.610
15.	166 110.150	167 [illegible]	168 [illegible]	169 [illegible]	170 115.240	171 [illegible]	172 [illegible]	173 80.230	174 [illegible]	175 [illegible]	176 [illegible]	177 [illegible]	178 [illegible]	179 40.140	180 [illegible]

REPLICATION-2.

1.	14 112.670	29 67.030	44 [illegible]	59 [illegible]	74 [illegible]	89 [illegible]	104 [illegible]	119 41.440	134 [illegible]	149 [illegible]	164 [illegible]	179 [illegible]	194 53.140	209 72.510	224 [illegible]
2.	1 95.220	16 73.900	31 [illegible]	46 [illegible]	61 [illegible]	76 [illegible]	91 [illegible]	106 117.150	121 [illegible]	136 [illegible]	151 [illegible]	166 [illegible]	181 57.310	196 [illegible]	211 [illegible]
3.	9 117.350	24 74.540	39 [illegible]	54 [illegible]	69 [illegible]	84 [illegible]	99 [illegible]	114 [illegible]	129 [illegible]	144 [illegible]	159 [illegible]	174 [illegible]	189 [illegible]	204 [illegible]	219 74.160
4.	2 78.350	17 74.520	32 [illegible]	47 [illegible]	62 [illegible]	77 [illegible]	92 [illegible]	107 [illegible]	122 [illegible]	137 [illegible]	152 [illegible]	167 [illegible]	182 70.100	197 [illegible]	212 [illegible]
5.	6 [illegible]	21 115.370	36 [illegible]	51 [illegible]	66 [illegible]	81 [illegible]	96 [illegible]	111 [illegible]	126 [illegible]	141 [illegible]	156 [illegible]	171 [illegible]	186 75.120	201 [illegible]	216 [illegible]
6.	11 [illegible]	26 [illegible]	41 [illegible]	56 [illegible]	71 [illegible]	86 [illegible]	101 [illegible]	116 [illegible]	131 [illegible]	146 [illegible]	161 [illegible]	176 [illegible]	191 [illegible]	206 [illegible]	221 [illegible]
7.	10 77.930	25 100.950	40 [illegible]	55 [illegible]	70 [illegible]	85 [illegible]	100 [illegible]	115 [illegible]	130 [illegible]	145 [illegible]	160 [illegible]	175 [illegible]	190 71.200	205 [illegible]	220 [illegible]
8.	8 [illegible]	23 91.900	38 [illegible]	53 [illegible]	68 [illegible]	83 [illegible]	98 [illegible]	113 [illegible]	128 [illegible]	143 [illegible]	158 [illegible]	173 [illegible]	188 [illegible]	203 [illegible]	218 [illegible]
9.	3 [illegible]	18 [illegible]	33 [illegible]	48 [illegible]	63 [illegible]	78 [illegible]	93 [illegible]	108 [illegible]	123 [illegible]	138 [illegible]	153 [illegible]	168 [illegible]	183 [illegible]	198 [illegible]	213 [illegible]
10.	13 [illegible]	28 [illegible]	43 [illegible]	58 [illegible]	73 [illegible]	88 [illegible]	103 [illegible]	118 [illegible]	133 [illegible]	148 [illegible]	163 [illegible]	178 [illegible]	193 [illegible]	208 [illegible]	223 [illegible]
11.	12 [illegible]	27 115.680	42 [illegible]	57 [illegible]	72 [illegible]	87 [illegible]	102 [illegible]	117 [illegible]	132 [illegible]	147 [illegible]	162 [illegible]	177 [illegible]	192 [illegible]	207 [illegible]	222 [illegible]
12.	5 [illegible]	20 100.110	35 [illegible]	50 92.540	65 [illegible]	80 [illegible]	95 [illegible]	110 [illegible]	125 [illegible]	140 [illegible]	155 [illegible]	170 [illegible]	185 95.410	200 [illegible]	215 [illegible]
13.	4 [illegible]	19 [illegible]	34 [illegible]	49 [illegible]	64 [illegible]	79 [illegible]	94 [illegible]	109 [illegible]	124 [illegible]	139 [illegible]	154 [illegible]	169 [illegible]	184 47.540	199 [illegible]	214 75.170
14.	7 [illegible]	22 [illegible]	37 [illegible]	52 [illegible]	67 [illegible]	82 [illegible]	97 [illegible]	112 [illegible]	127 111.170	142 [illegible]	157 [illegible]	172 [illegible]	187 31.640	202 [illegible]	217 [illegible]
15.	15 [illegible]	30 [illegible]	45 [illegible]	60 [illegible]	75 [illegible]	90 [illegible]	105 111.550	120 [illegible]	135 [illegible]	150 [illegible]	165 [illegible]	180 [illegible]	195 [illegible]	210 [illegible]	225 [illegible]

REPLICATION-3.

1.	45 [illegible]	59 [illegible]	73 [illegible]	87 [illegible]	101 77.540	115 [illegible]	129 [illegible]	143 [illegible]	157 [illegible]	171 92.810	185 [illegible]	199 [illegible]	211 [illegible]	2 73.220	16 74.140
2.	150 85.460	164 73.520	178 [illegible]	192 [illegible]	206 [illegible]	220 [illegible]	9 [illegible]	23 [illegible]	37 [illegible]	51 30.750	65 [illegible]	79 [illegible]	93 [illegible]	107 137.420	121 [illegible]
3.	90 79.470	104 [illegible]	118 [illegible]	132 [illegible]	146 [illegible]	160 [illegible]	174 [illegible]	188 75.970	202 [illegible]	216 [illegible]	5 77.490	19 45.520	33 74.260	47 73.540	61 80.150
4.	195 [illegible]	209 77.440	223 [illegible]	12 112.910	26 [illegible]	40 111.520	54 [illegible]	68 73.570	82 [illegible]	96 81.720	110 127.440	124 [illegible]	138 73.190	152 [illegible]	166 126.640
5.	105 [illegible]	119 44.700	133 [illegible]	147 [illegible]	161 [illegible]	175 47.440	189 [illegible]	203 43.240	217 111.750	6 76.440	20 104.240	34 [illegible]	48 [illegible]	62 [illegible]	76 [illegible]
6.	163 102.560	177 109.150	191 [illegible]	222 77.280	11 91.170	25 [illegible]	39 87.310	53 [illegible]	67 [illegible]	81 121.540	95 [illegible]	109 [illegible]	123 [illegible]	137 114.490	151 73.430
7.	60 116.360	74 [illegible]	88 [illegible]	102 [illegible]	116 93.740	130 [illegible]	144 76.440	158 124.710	172 [illegible]	186 [illegible]	200 [illegible]	214 [illegible]	3 73.510	17 77.650	31 95.120
8.	15 [illegible]	29 72.240	43 [illegible]	57 [illegible]	71 111.770	85 107.420	99 [illegible]	113 97.750	127 114.410	141 [illegible]	155 113.580	169 104.040	183 94.350	197 107.340	211 53.780
9.	225 [illegible]	14 121.560	28 117.440	42 [illegible]	56 [illegible]	70 [illegible]	84 121.470	98 114.670	112 [illegible]	126 [illegible]	140 [illegible]	154 90.520	168 [illegible]	182 73.570	196 81.740
10.	135 [illegible]	149 76.210	163 [illegible]	177 [illegible]	191 [illegible]	205 101.710	219 74.520	8 [illegible]	22 [illegible]	36 125.240	50 [illegible]	64 [illegible]	78 113.140	92 [illegible]	106 104.640
11.	165 [illegible]	179 76.360	193 [illegible]	207 76.240	221 [illegible]	10 47.410	24 [illegible]	38 111.640	52 [illegible]	66 76.110	80 116.240	94 [illegible]	108 77.600	122 [illegible]	136 77.440
12.	120 81.440	134 101.540	148 [illegible]	162 [illegible]	176 [illegible]	190 83.240	204 41.540	218 [illegible]	7 [illegible]	21 115.360	35 [illegible]	49 [illegible]	63 79.480	77 [illegible]	91 74.720
13.	30 80.910	44 139.160	58 [illegible]	72 77.670	86 [illegible]	100 [illegible]	114 [illegible]	128 [illegible]	142 [illegible]	156 [illegible]	170 [illegible]	184 [illegible]	198 116.290	212 [illegible]	1 101.230
14.	75 83.520	89 [illegible]	103 [illegible]	117 [illegible]	131 [illegible]	145 [illegible]	159 [illegible]	173 [illegible]	187 56.780	201 [illegible]	215 [illegible]	4 [illegible]	18 114.720	32 76.390	46 97.830
15.	210 100.540	224 128.580	13 81.910	27 114.040	41 81.300	55 109.430	69 [illegible]	83 [illegible]	97 125.340	111 113.120	125 95.270	139 76.540	153 91.310	167 [illegible]	181 76.120

APPENDIX XVII Number of tillers per plant at Parkland

PARKLAND REPLICATION-1 NUMBER OF TILLERS PER PLANT

(Block)															
1.	181 15.400	182 12.200	183 13.200	184 12.400	185 16.000	186 11.800	187 12.200	188 12.400	189 11.100	190 11.700	191 11.670	192 13.700	193 12.700	194 15.200	195 11.000
2.	16 12.900	17 12.700	18 14.400	19 14.100	20 13.500	21 14.700	22 12.700	23 12.800	24 11.900	25 13.700	26 11.100	27 14.800	28 14.100	29 11.200	30 12.400
3.	211 12.500	212 14.400	213 14.300	214 12.570	215 13.600	216 13.200	217 17.000	218 12.700	219 13.400	220 15.900	221 12.600	222 8.900	223 14.100	224 13.200	225 13.300
4.	46 14.600	47 11.500	48 12.000	49 13.400	50 15.600	51 14.500	52 12.600	53 15.700	54 12.200	55 13.400	56 12.100	57 12.200	58 12.900	59 15.700	60 14.300
5.	106 15.667	107 13.100	108 13.600	109 12.900	110 11.270	111 15.600	112 10.400	113 13.500	114 14.900	115 11.110	116 12.410	117 15.200	118 12.100	119 11.100	120 11.200
6.	121 15.400	122 12.400	123 12.600	124 14.300	125 10.400	126 12.400	127 11.700	128 11.000	129 11.200	130 12.100	131 14.200	132 14.900	133 12.600	134 10.600	135 12.700
7.	91 10.200	92 13.100	93 14.100	94 12.200	95 8.200	96 10.500	97 15.800	98 11.100	99 14.200	100 13.000	101 11.100	102 12.900	103 13.900	104 13.400	105 11.500
8.	61 15.100	62 14.200	63 13.300	64 10.700	65 13.600	66 14.400	67 11.700	68 11.900	69 14.300	70 12.500	71 14.000	72 10.100	73 14.400	74 14.700	75 11.600
9.	151 11.700	152 14.100	153 12.900	154 12.700	155 11.200	156 11.600	157 14.600	158 12.100	159 11.500	160 13.400	161 11.300	162 11.600	163 12.700	164 13.100	165 12.500
10.	1 15.300	2 17.100	3 10.400	4 13.400	5 11.900	6 11.700	7 11.300	8 10.300	9 13.400	10 13.100	11 11.400	12 11.400	13 14.100	14 12.000	15 11.600
11.	196 17.100	197 14.200	198 13.100	199 11.100	200 11.700	201 12.400	202 15.400	203 12.900	204 13.900	205 13.400	206 13.400	207 13.000	208 14.400	209 14.200	210 14.500
12.	31 15.500	32 12.100	33 15.700	34 14.200	35 15.300	36 16.000	37 11.400	38 11.300	39 11.300	40 12.600	41 14.400	42 11.300	43 15.300	44 15.500	45 13.300
13.	136 16.300	137 15.700	138 13.100	139 13.400	140 12.500	141 15.100	142 11.300	143 13.900	144 12.400	145 13.100	146 12.400	147 12.500	148 11.200	149 15.900	150 12.700
14.	76 18.900	77 11.000	78 14.400	79 12.700	80 13.200	81 12.600	82 13.400	83 14.600	84 11.900	85 15.100	86 14.500	87 11.400	88 12.000	89 15.100	90 15.000
15.	166 14.700	167 13.300	168 11.400	169 15.400	170 16.400	171 15.200	172 [illegible]	173 12.500	174 13.600	175 14.200	176 13.600	177 13.700	178 15.100	179 10.556	180 15.100

REPLICATION-2

(Block)															
1.	14 13.700	29 9.000	44 14.100	59 15.100	74 10.400	89 11.700	104 13.400	119 11.200	134 15.300	149 9.100	164 11.500	179 8.300	194 12.400	209 9.200	224 11.300
2.	1 15.300	16 11.100	31 12.600	46 13.200	61 12.400	76 11.600	91 11.200	106 13.500	121 9.000	136 12.400	151 10.700	166 12.200	181 9.600	196 10.300	211 11.600
3.	9 16.400	24 15.100	39 11.000	54 14.600	69 11.100	84 12.400	99 12.400	114 11.500	129 12.000	144 11.700	159 10.100	174 11.500	189 13.100	204 13.400	219 17.100
4.	2 15.700	17 13.900	32 11.400	47 13.400	62 14.400	77 12.200	92 12.400	107 17.000	122 11.200	137 12.167	152 12.100	167 12.600	182 8.300	197 13.300	212 13.200
5.	6 11.500	21 12.400	36 10.200	51 13.700	66 13.700	81 12.900	96 4.500	111 14.500	126 12.700	141 12.100	156 14.300	171 13.100	186 8.700	201 12.300	216 17.556
6.	11 9.400	26 13.200	41 16.500	56 12.400	71 13.400	86 11.400	101 11.700	116 15.900	131 13.300	146 11.400	161 14.200	176 13.200	191 11.000	206 13.500	221 11.900
7.	10 11.600	25 11.300	40 9.700	55 12.600	70 14.100	85 11.400	100 11.900	115 9.500	130 14.000	145 12.400	160 8.400	175 11.400	190 11.200	205 9.400	220 10.200
8.	8 11.400	23 14.200	38 9.100	53 9.400	68 11.200	83 8.400	98 11.700	113 9.500	128 9.600	143 12.300	158 12.500	173 11.700	188 11.400	203 13.600	218 12.000
9.	3 9.100	18 11.300	33 10.300	48 12.600	63 10.300	78 10.300	93 10.444	108 11.900	123 13.100	138 9.000	153 9.100	168 11.200	183 9.500	198 11.200	213 13.400
10.	13 22.667	28 23.444	43 17.100	58 10.222	73 13.500	88 11.400	103 12.700	118 9.400	133 10.900	148 11.900	163 9.100	178 17.000	193 7.100	208 11.100	223 12.300
11.	12 12.800	27 13.470	42 8.100	57 7.100	72 8.600	87 9.400	102 12.100	117 10.400	132 10.200	147 8.900	162 15.200	177 8.400	192 11.000	207 9.600	222 13.400
12.	5 9.100	20 12.000	35 11.100	50 11.100	65 8.100	80 12.700	95 9.000	110 11.500	125 9.100	140 12.200	155 11.100	170 8.500	185 12.100	200 13.400	215 12.700
13.	4 16.400	19 14.700	34 13.900	49 14.100	64 12.200	79 10.200	94 14.700	109 10.906	124 16.400	139 11.400	154 15.500	169 14.400	184 12.500	199 13.400	214 14.200
14.	7 19.200	22 12.100	37 11.100	52 9.800	67 12.000	82 11.400	97 11.400	112 12.400	127 15.100	142 10.300	157 12.500	172 11.900	187 11.400	202 11.500	217 13.400
15.	15 15.800	30 11.222	45 11.100	60 14.800	75 11.200	90 10.400	105 12.400	120 13.400	135 14.200	150 9.500	165 10.900	180 10.500	195 8.700	210 12.700	225 12.200

REPLICATION-3

(Block)															
1.	45 15.300	59 14.400	73 15.900	87 14.300	101 15.200	115 11.500	129 16.600	143 11.200	157 12.800	171 5.700	185 11.375	199 14.200	213 11.500	2 14.300	16 14.800
2.	150 11.000	164 13.400	178 15.800	192 12.400	206 11.700	220 13.444	9 11.100	23 13.444	37 13.700	51 11.100	65 14.000	79 13.500	93 17.200	107 12.700	121 11.170
3.	90 13.200	104 11.100	118 8.100	132 16.500	146 12.400	160 9.500	174 13.000	188 11.300	202 10.500	216 11.800	5 9.400	19 15.700	33 12.400	47 12.000	61 11.200
4.	195 11.100	209 13.200	223 14.400	12 17.000	26 11.000	40 15.300	54 12.200	68 13.400	82 12.300	96 9.550	110 14.500	124 14.200	138 13.000	152 12.900	166 13.200
5.	105 15.300	119 10.400	133 9.800	147 10.700	161 12.000	175 7.400	189 11.270	203 12.700	217 14.900	6 9.100	20 15.100	34 11.667	48 10.900	62 12.500	76 13.000
6.	180 14.900	194 12.700	208 12.200	222 9.700	11 8.100	25 13.000	39 11.000	53 13.300	67 11.000	81 10.300	95 9.500	109 9.900	123 14.500	137 13.600	151 10.600
7.	60 20.500	74 12.600	88 11.900	102 14.000	116 11.900	130 10.400	144 10.400	158 13.400	172 11.900	186 13.410	200 11.400	214 11.600	3 9.200	17 11.200	31 8.778
8.	15 15.100	29 16.400	43 12.400	57 9.900	71 14.500	85 12.100	99 10.600	113 9.200	127 12.700	141 10.800	155 13.400	169 11.700	183 13.500	197 13.900	211 11.000
9.	225 9.500	14 13.400	28 11.100	42 11.100	56 8.500	70 10.400	84 11.470	98 13.000	112 8.600	126 9.400	140 11.500	154 8.900	168 12.300	182 9.000	196 11.300
10.	135 15.700	149 10.670	163 12.300	177 10.600	191 11.100	205 10.600	219 10.400	8 10.400	22 11.900	36 10.700	50 8.600	64 10.800	78 11.600	92 11.400	106 13.200
11.	165 9.700	179 10.660	193 13.100	207 8.400	221 11.200	10 10.444	24 11.300	38 12.500	52 11.700	66 13.100	80 12.100	94 12.100	108 10.900	122 14.100	136 14.300
12.	120 11.400	134 9.100	148 13.000	162 13.300	176 9.700	190 15.370	204 11.900	218 12.400	7 12.700	21 12.900	35 10.100	49 11.500	63 12.200	77 10.900	91 11.300
13.	30 11.300	44 12.900	58 13.000	72 13.400	86 14.900	100 10.100	114 13.600	128 7.700	142 11.500	156 12.100	170 7.700	184 10.500	198 11.100	212 9.100	1 12.100
14.	75 9.375	89 11.400	103 12.600	117 8.400	131 10.700	145 11.400	159 11.900	173 10.300	187 9.889	201 10.060	215 10.500	4 11.200	18 12.100	32 13.600	46 11.300
15.	210 13.300	224 11.100	13 10.300	27 11.400	41 11.200	55 12.600	69 11.200	83 10.445	97 13.400	111 10.100	125 10.100	139 8.300	153 10.300	167 10.000	181 11.200

APPENDIX XVIII Number of spikelets per spike at Parkland

[illegible]

(Block)															
1.	181 13.667	182 14.400	183 13.200	184 13.933	185 13.667	186 13.933	187 14.133	188 14.667	189 13.733	190 12.800	191 14.200	192 12.767	193 13.333	194 14.333	195 14.467
2.	16 12.367	17 13.100	18 15.767	19 14.400	20 15.167	21 14.133	22 13.467	23 12.700	24 17.333	25 13.400	26 13.733	27 15.433	28 15.167	29 13.367	30 13.933
3.	211 14.533	212 13.067	213 13.333	214 12.433	215 12.967	216 13.467	217 14.733	218 12.667	219 13.367	220 13.400	221 15.100	222 13.333	223 13.300	224 12.433	225 14.333
4.	46 15.000	47 13.233	48 [illegible]	49 14.433	50 15.400	51 12.333	52 13.767	53 14.433	56 15.600	55 13.767	54 15.467	57 11.733	58 14.167	59 15.533	60 14.367
5.	106 16.633	107 14.567	108 13.467	109 14.500	110 14.533	111 16.167	112 14.700	113 13.667	114 13.267	115 13.133	116 14.433	117 14.933	118 15.133	119 15.333	120 14.333
6.	121 15.300	122 14.400	123 15.333	124 14.433	125 12.400	126 14.533	127 15.200	128 14.033	129 14.933	130 13.333	131 15.267	132 16.533	133 13.333	134 15.333	135 14.333
7.	91 14.400	92 12.733	93 [illegible]	94 14.933	95 12.367	96 14.133	97 15.467	98 13.500	99 14.833	100 13.400	101 12.833	102 14.233	103 13.567	104 14.700	105 12.933
8.	61 14.200	62 14.400	63 12.267	64 14.733	65 13.433	66 13.400	67 15.200	68 14.567	69 14.700	70 13.600	71 15.700	72 13.433	73 14.933	74 14.167	75 15.433
9.	151 13.633	152 14.767	153 14.733	154 14.367	155 [illegible]	156 14.467	157 17.200	158 13.500	159 14.233	160 13.433	161 15.467	162 14.200	163 12.467	164 13.467	165 15.367
10.	1 14.633	2 15.100	3 15.433	4 15.370	5 15.267	6 14.367	7 16.300	8 13.733	9 14.600	10 12.300	11 13.733	12 13.500	13 14.333	14 15.433	15 15.233
11.	196 15.533	197 14.767	198 [illegible]	199 13.433	200 14.333	201 [illegible]	202 15.767	203 14.600	204 14.567	205 14.567	206 15.533	207 14.967	208 13.233	209 15.333	210 15.467
12.	31 14.800	32 13.467	33 14.433	34 15.367	35 13.433	36 [illegible]	37 14.500	38 13.533	39 13.533	40 13.400	41 13.333	42 12.600	43 14.400	44 14.300	45 15.267
13.	136 15.333	137 14.400	138 13.767	139 14.200	140 14.433	141 14.333	142 14.767	143 15.467	144 14.333	145 13.933	146 13.133	147 13.400	148 14.133	149 15.200	150 15.100
14.	76 15.533	77 12.267	78 14.467	79 15.333	80 15.133	81 14.133	82 13.367	83 13.433	84 13.600	85 14.433	86 [illegible]	87 13.067	88 15.233	89 14.200	90 14.233
15.	166 14.300	167 13.933	168 [illegible]	169 14.400	170 14.700	171 14.733	172 13.433	173 [illegible]	174 14.267	175 13.467	176 [illegible]	177 13.933	178 14.733	179 14.733	180 13.467

[illegible]

1.	18 14.700	29 13.767	44 [illegible]	59 14.433	74 13.233	89 11.767	104 13.933	119 13.267	134 12.867	149 11.933	164 12.567	179 14.367	194 12.467	209 14.833	224 11.533
2.	7 13.320	16 12.933	31 12.933	46 12.567	61 [illegible]	76 15.467	91 14.233	106 15.233	121 12.300	136 12.567	151 12.667	166 14.333	181 13.633	196 17.333	211 14.567
3.	9 14.467	24 13.367	39 [illegible]	54 13.357	87 13.333	[illegible]	59 13.433	112 14.200	123 13.533	144 12.267	161 13.267	174 11.667	119 12.133	201 13.467	213 11.467
4.	2 14.233	17 13.533	33 13.933	47 13.733	62 [illegible]	73 12.467	32 14.467	137 12.233	122 13.267	137 15.133	[illegible]	167 13.333	182 13.133	187 12.533	272 13.733
5.	6 14.233	21 [illegible]	35 [illegible]	51 14.433	69 13.233	91 14.467	95 13.467	111 15.567	124 13.400	141 13.233	157 13.467	171 14.433	185 14.500	201 14.267	218 [illegible]
6.	11 13.800	26 13.367	43 14.433	56 15.233	73 13.433	36 15.267	101 [illegible]	116 14.533	131 14.767	146 14.333	152 [illegible]	175 15.433	191 15.133	205 14.067	221 13.433
7.	15 14.367	25 15.433	82 14.267	55 14.467	72 14.267	85 12.567	100 [illegible]	115 [illegible]	140 11.700	145 14.767	163 14.467	165 14.367	190 12.467	206 13.200	220 13.433
8.	8 12.373	23 13.333	[illegible]	53 15.100	68 13.733	83 13.267	98 13.567	113 14.233	128 12.467	143 14.133	153 14.467	173 13.333	186 13.267	201 14.467	214 13.333
9.	3 13.333	19 13.467	33 [illegible]	49 13.467	63 15.467	74 15.433	93 14.333	129 [illegible]	127 13.167	139 15.033	154 [illegible]	164 14.467	181 13.433	194 12.433	211 14.233
10.	13 13.233	28 15.533	43 14.733	58 [illegible]	73 15.533	99 12.467	103 12.900	118 12.833	133 13.233	148 15.633	163 13.567	179 11.433	193 13.767	205 14.333	223 13.533
11.	12 14.367	27 13.633	42 12.767	57 13.233	72 [illegible]	97 14.433	102 13.567	187 14.733	132 12.633	187 12.567	162 14.333	177 13.633	182 12.567	207 12.467	222 13.467
12.	5 14.400	22 14.633	39 15.733	52 13.433	65 13.433	80 15.733	75 13.433	110 15.767	125 15.267	140 13.233	155 14.433	170 13.333	185 13.967	205 14.533	215 12.467
13.	4 13.767	19 13.467	38 13.667	49 13.767	68 14.333	79 13.933	88 14.233	129 13.467	128 14.733	138 12.533	158 [illegible]	157 14.633	184 14.433	199 13.067	213 12.400
14.	7 15.167	22 14.333	37 15.133	52 [illegible]	57 14.267	92 13.333	97 14.533	112 15.533	127 15.433	142 12.433	157 14.467	172 12.700	197 13.333	[illegible]	217 15.267
15.	15 14.867	35 14.533	45 14.333	63 14.433	75 15.467	93 14.833	125 13.133	120 14.533	135 15.433	150 14.333	165 15.233	180 15.533	195 14.567	210 15.133	225 13.733

[illegible]

1.	65 13.467	26 15.267	71 14.267	87 14.433	127 12.400	135 13.833	129 13.333	141 15.767	157 14.267	171 12.200	185 [illegible]	196 13.600	211 13.267	2 13.733	16 13.433
2.	153 14.767	156 [illegible]	[illegible]	182 12.233	216 [illegible]	[illegible]	9 14.133	21 13.867	47 13.467	51 13.733	65 13.633	71 11.467	83 14.233	197 12.867	141 12.233
3.	63 12.433	126 13.367	179 13.567	112 14.533	155 13.067	170 [illegible]	176 13.667	159 13.467	202 [illegible]	216 13.467	5 12.267	20 14.333	11 13.333	57 [illegible]	57 13.300
4.	195 14.433	219 12.367	221 14.433	72 14.433	26 13.533	63 13.633	54 [illegible]	44 12.367	52 14.233	95 13.633	112 14.733	24 12.333	113 13.433	142 12.567	126 13.433
5.	205 14.333	110 13.533	113 [illegible]	167 13.433	161 13.333	175 13.433	149 13.467	233 14.767	217 14.167	6 13.467	[illegible]	34 12.367	44 [illegible]	62 14.267	75 14.557
6.	140 13.633	154 13.333	214 [illegible]	222 12.767	11 13.467	35 13.433	19 14.333	53 13.167	67 13.333	81 15.500	95 13.300	137 13.267	121 14.333	152 15.733	181 14.233
7.	63 13.567	36 13.467	[illegible]	[illegible]	116 13.333	112 13.433	144 14.133	158 13.567	172 13.767	186 12.133	213 14.533	218 13.433	3 13.267	17 13.233	33 13.567
8.	15 13.333	29 14.567	43 13.933	47 12.467	77 14.733	85 13.933	89 15.133	111 13.933	127 14.433	141 15.233	155 13.567	164 14.167	181 13.567	197 14.300	211 13.533
9.	225 13.433	70 14.533	26 15.333	42 13.433	56 14.433	70 13.500	86 14.067	99 14.457	112 [illegible]	126 15.333	140 13.467	154 13.467	168 14.133	182 14.033	196 13.933
10.	155 13.567	169 12.167	183 12.533	197 13.167	211 12.867	[illegible]	218 13.367	4 13.667	22 13.433	36 14.467	53 14.767	64 14.267	79 14.457	92 13.500	105 [illegible]
11.	155 13.933	170 14.633	181 14.633	[illegible]	[illegible]	13 14.933	26 14.267	[illegible]	52 12.833	65 13.367	80 13.500	94 14.233	103 12.967	122 15.667	136 13.767
12.	120 14.733	130 14.033	149 13.100	162 14.500	176 14.433	192 14.333	206 13.633	214 13.633	7 15.133	21 15.000	35 14.733	49 15.933	63 13.928	77 13.333	91 14.233
13.	33 13.833	48 15.267	60 14.367	74 13.333	86 13.767	100 13.433	114 14.833	128 14.300	142 14.933	156 14.767	170 14.133	184 14.967	191 14.067	212 13.667	1 13.733
14.	25 14.610	89 12.833	103 13.233	117 13.567	131 13.967	145 13.133	159 13.667	173 13.133	187 15.111	201 13.567	215 13.233	6 15.633	19 14.833	32 13.067	46 12.700
15.	210 15.633	224 12.633	13 12.233	27 13.267	61 14.067	55 13.267	49 13.833	83 12.933	97 14.400	111 15.167	125 14.767	139 [illegible]	153 12.267	162 14.133	181 12.833

APPENDIX XIX Number of seeds per spike at Parkland

PARKLAND REPLICATION-1. MEAN # OF SEEDS PER SPIKE

(Block)															
1.	141 32.857	142 42.433	143 40.467	144 47.200	145 41.433	146 42.533	147 44.167	148 50.600	189 41.100	190 44.733	191 41.267	192 41.200	193 47.400	194 43.267	195 51.333
2.	16 47.433	17 47.200	18 46.533	19 44.267	20 43.767	21 51.467	22 41.333	23 37.267	24 37.500	25 44.667	26 51.333	27 47.100	28 46.633	29 44.333	30 46.467
3.	211 43.533	212 41.267	213 45.133	214 39.267	215 44.433	216 45.567	217 50.233	218 42.033	219 45.533	220 43.200	221 46.767	222 42.300	223 41.600	224 44.533	225 41.567
4.	46 46.333	47 43.267	48 47.267	49 44.467	50 49.567	51 39.333	52 45.033	53 45.733	54 44.133	55 43.400	56 55.067	57 43.767	58 45.400	59 46.733	60 49.500
5.	106 49.000	107 41.733	108 41.333	109 44.733	110 46.433	111 48.167	112 45.700	113 47.233	114 44.567	115 41.467	116 45.067	117 45.767	118 51.100	119 48.167	120 52.467
6.	121 53.633	122 45.533	123 47.733	124 44.467	125 46.467	126 44.433	127 49.233	128 53.100	129 50.433	130 35.467	131 45.033	132 53.200	133 46.133	134 47.400	135 44.400
7.	91 45.533	92 43.733	93 47.133	94 49.433	95 45.133	96 46.067	97 45.433	98 46.233	99 46.400	100 47.933	101 44.467	102 41.700	103 43.267	104 49.967	105 42.267
8.	61 43.433	62 49.467	63 50.533	64 51.557	65 45.533	66 47.633	67 [illegible]	68 46.700	69 36.167	70 40.933	71 43.633	72 47.633	73 53.000	74 45.567	75 51.467
9.	151 47.933	152 46.367	153 41.233	154 51.167	155 42.133	156 44.757	157 41.867	158 43.467	159 40.400	160 41.700	161 44.567	162 [illegible]	163 41.000	164 47.400	165 51.533
10.	1 43.857	2 43.400	3 35.367	4 45.733	5 51.233	6 47.571	7 42.433	8 47.133	9 44.433	10 32.133	11 47.233	12 44.467	13 40.467	14 36.400	15 44.800
11.	196 53.867	197 48.267	198 54.433	199 45.557	200 47.467	201 47.333	202 45.467	203 39.433	204 51.267	205 43.333	206 54.167	207 41.633	208 44.457	209 52.433	210 47.300
12.	31 46.533	32 44.500	33 45.767	34 42.233	35 37.433	36 45.467	37 47.133	38 45.233	39 42.700	40 46.500	41 44.967	42 45.567	43 43.257	44 45.533	45 51.467
13.	136 44.457	137 41.533	138 45.200	139 [illegible]	140 47.467	141 45.533	142 52.567	143 53.767	144 49.333	145 36.267	146 46.533	147 36.233	148 44.700	149 45.467	150 54.433
14.	76 45.767	77 32.733	78 51.533	79 45.433	80 43.133	81 45.233	82 44.467	83 45.467	84 40.167	85 41.033	86 45.400	87 45.833	88 53.200	89 45.767	90 44.200
15.	166 53.633	167 37.333	168 42.467	169 44.533	170 34.500	171 47.200	172 45.700	173 44.057	174 37.633	175 41.433	176 47.333	177 43.300	178 33.267	179 47.366	180 53.367

REPLICATION-2.

1.	16 46.333	29 34.400	44 42.233	57 42.200	74 35.533	87 43.167	104 37.133	119 32.467	134 43.467	149 40.233	156 44.400	173 44.700	196 42.033	207 45.367	224 43.733
2.	1 45.767	15 44.767	31 41.433	45 43.457	61 41.433	75 53.867	91 39.233	106 44.400	121 45.433	135 40.767	151 40.433	166 56.000	181 33.767	194 44.100	211 43.967
3.	9 40.333	24 41.520	33 42.557	54 41.400	69 39.367	94 44.900	99 34.200	116 44.933	123 47.433	144 39.567	159 50.133	174 42.700	189 41.033	204 45.600	219 41.233
4.	2 53.533	17 45.267	32 44.300	47 42.133	62 47.433	77 37.167	92 46.533	107 46.267	122 49.767	137 43.533	152 44.167	167 41.367	182 33.833	197 36.233	212 34.600
5.	6 52.100	21 55.757	36 49.400	51 47.333	66 45.757	81 43.550	96 43.767	111 51.733	126 45.433	141 41.267	156 46.500	171 33.767	186 41.100	201 45.067	216 47.961
6.	11 47.933	26 45.800	41 45.200	56 52.233	71 44.957	86 48.500	101 45.400	116 45.367	131 47.533	146 53.433	161 44.267	176 52.333	191 45.233	206 43.767	221 44.500
7.	10 42.333	25 52.420	40 55.467	55 44.433	70 41.567	85 42.633	100 43.500	115 47.233	130 43.133	145 45.267	160 40.357	175 44.567	190 40.267	205 44.133	222 59.833
8.	8 33.755	23 32.633	38 46.900	53 44.333	68 42.333	83 43.400	98 44.100	113 42.367	128 43.733	143 44.633	158 49.100	173 45.733	188 41.467	203 43.467	218 41.367
9.	3 53.533	18 44.200	33 45.400	48 43.167	63 53.257	78 45.533	93 47.741	108 35.037	123 42.767	138 45.400	153 43.400	168 41.433	183 34.167	198 41.067	213 51.600
10.	13 43.333	28 43.844	43 42.200	58 42.444	73 45.833	88 46.200	103 42.333	118 44.933	133 42.133	148 52.457	163 40.900	178 42.300	193 42.667	208 43.567	223 45.757
11.	12 53.333	27 45.233	42 35.567	57 44.333	72 45.767	87 47.267	102 44.833	117 45.457	132 45.400	147 47.157	162 45.767	177 33.557	192 39.133	207 33.567	222 41.600
12.	5 47.333	20 48.500	35 35.733	50 45.300	65 44.400	80 45.967	95 44.300	110 44.833	125 43.333	140 42.067	155 44.467	170 45.200	185 44.733	200 46.033	215 49.133
13.	14 47.467	19 47.400	34 47.557	49 42.767	64 46.367	79 46.333	94 37.700	109 46.705	124 45.067	139 44.600	154 49.500	169 47.200	184 44.133	199 45.633	214 44.467
14.	7 49.857	22 49.200	37 54.400	52 45.267	67 52.800	82 45.667	97 44.733	112 50.267	127 50.867	142 42.433	157 42.767	172 44.133	187 44.633	202 53.433	217 53.533
15.	15 42.420	30 42.815	45 50.767	60 43.433	75 47.700	90 44.533	105 42.533	120 46.733	135 47.233	150 47.233	165 55.533	180 41.367	195 41.667	210 45.467	225 42.800

REPLICATION-3.

1.	45 44.433	59 43.767	73 45.733	87 37.733	101 37.200	115 44.767	129 44.200	141 42.533	157 51.467	171 33.527	185 41.833	197 43.400	211 45.557	2 45.567	16 50.133
2.	152 43.733	164 45.533	174 45.467	182 45.267	206 43.833	220 44.767	4 44.267	21 35.724	37 42.167	51 44.433	65 40.267	78 43.333	93 43.100	107 37.433	121 45.033
3.	42 46.733	130 47.233	170 44.467	182 44.557	196 44.333	160 39.433	176 42.700	188 38.467	202 50.567	216 37.433	5 43.500	17 45.333	33 33.500	47 36.200	61 35.200
4.	135 53.433	209 44.400	223 46.267	12 52.800	26 43.233	43 45.333	54 44.733	64 42.400	82 44.233	95 49.300	110 42.333	124 45.233	139 39.767	152 41.067	166 44.167
5.	105 44.233	119 47.700	133 39.233	147 32.457	161 45.533	175 47.333	187 43.500	203 42.433	217 45.867	6 37.357	20 42.400	34 35.333	48 33.767	62 44.133	76 49.533
6.	123 47.333	134 40.367	224 45.433	217 34.333	11 49.333	25 44.700	39 43.467	53 43.933	67 43.333	81 47.367	95 35.300	109 44.433	123 48.633	137 46.767	151 44.533
7.	63 43.133	78 47.467	89 45.433	102 44.257	116 44.457	130 40.433	144 44.400	158 41.633	172 42.467	186 43.233	200 52.167	214 23.533	3 47.333	17 38.333	31 43.000
8.	75 43.757	29 45.233	43 38.467	57 45.767	71 53.467	85 42.700	99 47.433	113 45.467	127 52.400	141 42.333	155 41.500	169 52.133	183 47.500	197 46.367	211 40.300
9.	225 47.500	14 51.167	28 45.467	42 44.767	56 49.633	70 49.433	84 44.133	98 43.100	112 47.357	126 47.800	140 41.033	154 41.657	168 42.157	182 49.100	196 47.400
10.	135 45.733	149 39.467	163 33.533	177 42.733	191 30.657	205 39.967	219 [illegible]	8 41.233	22 46.533	36 44.533	50 42.933	64 53.267	79 44.533	92 41.400	106 44.700
11.	165 42.267	179 45.333	193 47.433	207 34.233	221 35.500	10 41.933	24 44.457	38 41.700	52 43.057	66 42.867	80 37.700	94 44.433	108 33.333	122 49.833	136 47.900
12.	120 43.633	134 41.967	148 40.667	162 44.433	178 [illegible]	192 44.167	204 42.267	218 26.533	7 43.667	21 45.567	35 45.100	49 46.767	63 41.133	77 32.333	91 53.467
13.	19 46.133	144 43.167	58 48.833	72 42.500	86 [illegible]	100 37.233	114 47.533	128 45.467	142 41.133	156 50.433	170 47.633	184 49.800	198 55.567	212 37.167	1 43.467
14.	75 50.520	89 43.733	103 44.267	117 51.500	131 45.333	145 39.533	159 45.233	173 42.733	187 46.170	201 43.833	215 49.233	4 52.500	18 45.500	32 40.400	46 34.167
15.	210 46.767	226 42.857	13 42.767	27 45.433	41 43.300	55 43.833	69 46.733	83 43.442	97 49.133	111 47.433	125 52.833	139 45.300	153 35.633	167 46.433	181 41.500

APPENDIX XX Weight of seeds per spike at Parkland

PARKLAND REPLICATION 1 [illegible]

(Block)															
1.	181 1.567	182 1.611	183 1.569	184 [illegible]	185 1.560	186 1.764	187 1.545	188 1.505	189 1.654	190 1.724	191 1.476	192 1.604	193 1.259	194 1.619	195 1.817
2.	16 1.753	17 1.618	18 1.661	19 1.536	20 1.536	21 1.641	22 1.760	23 1.661	24 1.539	25 1.677	26 2.148	27 1.723	28 1.640	29 1.767	30 1.615
3.	211 1.789	212 1.563	213 1.771	214 1.652	215 1.956	216 1.649	217 1.748	218 1.613	219 1.916	220 1.723	221 1.798	222 1.547	223 1.676	224 1.647	225 1.868
4.	46 1.754	47 1.570	48 1.999	49 1.631	50 2.259	51 1.657	52 1.523	53 1.735	54 1.751	55 [illegible]	56 2.211	57 1.525	58 1.723	59 1.515	60 1.717
5.	106 1.552	107 1.646	108 1.693	109 1.716	110 1.455	111 1.462	112 1.526	113 1.676	114 1.519	115 1.545	116 1.758	117 1.625	118 1.964	119 1.552	120 1.518
6.	121 1.453	122 1.697	123 1.732	124 1.715	125 1.777	126 [illegible]	127 1.755	128 1.561	129 1.612	130 1.470	131 1.665	132 1.771	133 1.694	134 1.641	135 1.618
7.	91 1.843	92 1.573	93 1.701	94 1.539	95 1.748	96 1.552	97 1.507	98 1.628	99 1.454	100 1.510	101 1.626	102 1.565	103 1.556	104 1.513	105 1.569
8.	61 1.520	62 1.553	63 1.753	64 1.426	65 1.773	66 1.665	67 1.765	68 1.720	69 1.726	70 1.459	71 1.705	72 1.613	73 1.434	74 1.511	75 1.372
9.	151 1.971	152 1.563	153 1.694	154 1.567	155 1.576	156 1.575	157 1.571	158 1.345	159 1.217	160 1.616	161 1.711	162 1.458	163 1.755	164 1.741	165 1.318
10.	1 1.615	2 1.744	3 2.118	4 1.533	5 1.772	6 1.641	7 1.515	8 1.518	9 1.665	10 0.572	11 1.791	12 [illegible]	13 1.436	14 [illegible]	15 1.612
11.	196 1.553	197 1.532	198 1.466	199 1.574	200 1.502	201 1.651	202 1.725	203 1.647	204 2.721	205 1.517	206 2.745	207 1.415	208 1.521	209 1.773	210 1.574
12.	31 1.466	32 1.762	33 1.633	34 1.348	35 1.375	36 1.424	37 1.573	38 1.673	39 1.426	40 [illegible]	41 1.756	42 1.523	43 1.329	44 1.547	45 1.299
13.	136 1.655	137 1.665	138 1.479	139 1.579	140 1.675	141 1.762	142 1.674	143 1.645	144 2.576	145 1.127	146 1.563	147 1.672	148 1.393	149 1.525	150 1.645
14.	76 1.446	77 1.765	78 1.569	79 1.648	80 [illegible]	81 [illegible]	82 1.517	83 1.657	84 1.355	85 1.612	86 1.615	87 1.753	88 1.523	89 1.655	90 1.547
15.	166 1.713	167 1.556	168 1.462	169 1.626	170 1.714	171 1.772	172 1.665	173 1.742	174 1.327	175 1.235	176 1.523	177 1.525	178 1.451	179 1.567	180 [illegible]

REPLICATION 2.

1.	14 1.352	29 1.667	44 1.504	59 1.524	74 1.375	89 [illegible]	104 1.533	119 1.172	134 1.411	149 1.476	164 1.556	179 1.641	194 1.224	209 1.512	224 1.554
2.	1 1.755	16 1.673	31 1.553	46 [illegible]	61 1.502	76 [illegible]	91 1.322	106 1.563	121 1.544	136 1.279	151 1.564	166 1.974	181 1.292	196 1.714	211 1.643
3.	9 1.336	24 1.561	39 1.661	54 1.326	69 1.425	84 1.625	99 1.573	114 1.372	129 1.375	144 1.699	159 2.112	174 1.641	189 1.512	204 1.421	219 1.451
4.	2 2.111	17 1.752	32 1.625	47 1.501	62 1.627	77 1.221	92 1.312	107 1.542	122 1.517	137 1.567	152 1.623	167 1.625	182 1.566	197 [illegible]	212 1.267
5.	6 2.176	21 1.976	36 1.627	51 1.723	65 1.555	81 1.411	96 1.461	111 1.616	126 [illegible]	141 1.752	156 1.312	171 [illegible]	186 1.713	201 [illegible]	216 [illegible]
6.	11 1.671	26 1.784	41 2.077	56 [illegible]	71 1.748	86 1.702	101 1.749	116 1.552	131 1.367	146 [illegible]	161 1.556	176 1.795	191 1.765	205 1.269	221 1.526
7.	13 1.423	25 1.243	43 1.547	55 1.524	73 1.475	85 1.423	102 1.446	115 1.515	142 1.515	145 1.657	160 1.534	175 1.672	193 1.469	206 [illegible]	220 1.790
8.	8 1.510	23 1.565	39 1.517	53 1.543	[illegible] 1.756	[illegible] [illegible]	98 1.464	113 1.642	123 1.655	143 1.411	159 1.729	173 1.721	188 1.664	[illegible] [illegible]	218 1.470
9.	3 2.051	18 1.722	33 1.960	48 1.627	63 1.451	78 1.724	93 1.611	108 1.653	121 1.541	138 1.648	153 [illegible]	158 [illegible]	161 1.511	196 [illegible]	213 1.513
10.	11 [illegible]	28 1.569	43 1.733	54 1.412	71 1.453	73 1.461	98 1.126	118 1.638	133 1.611	181 [illegible]	163 1.632	178 1.617	193 1.636	224 [illegible]	223 1.642
11.	12 1.754	27 1.723	42 1.669	57 1.922	72 1.635	87 1.713	102 1.711	117 1.640	132 1.775	147 1.642	162 1.777	177 1.326	192 1.345	207 1.643	222 1.655
12.	5 1.644	20 1.739	35 1.377	53 1.376	65 1.057	80 1.459	95 1.367	110 1.622	125 [illegible]	140 1.337	155 1.541	170 1.720	185 1.557	200 1.511	215 1.769
13.	4 1.613	19 1.667	36 1.457	47 1.145	66 1.516	75 1.766	96 1.625	139 1.659	[illegible] 1.555	129 1.723	154 1.612	169 1.735	[illegible] 1.592	190 [illegible]	214 1.417
14.	7 1.536	22 1.713	37 2.116	52 1.473	67 1.731	82 1.657	97 [illegible]	112 1.736	127 1.522	142 1.769	157 1.622	172 1.710	187 1.556	202 [illegible]	217 [illegible]
15.	15 1.672	30 1.674	45 1.872	60 1.564	75 1.696	90 [illegible]	105 1.617	120 1.725	135 1.745	150 1.275	165 1.360	180 [illegible]	195 1.567	210 1.612	225 1.593

REPLICATION 3.

1.	85 1.663	53 1.252	77 [illegible]	97 [illegible]	121 1.252	135 [illegible]	[illegible] [illegible]	143 1.632	157 2.122	171 [illegible]	185 1.518	[illegible] [illegible]	213 [illegible]	2 [illegible]	16 1.578
2.	150 1.622	166 1.556	178 1.762	172 1.253	226 [illegible]	222 [illegible]	8 1.317	23 [illegible]	37 1.613	51 1.669	65 1.631	[illegible]	[illegible]	137 1.321	129 1.378
3.	33 1.673	124 2.166	118 1.553	132 [illegible]	146 1.712	[illegible] [illegible]	174 1.265	188 1.725	203 2.133	[illegible] 1.693	5 1.715	[illegible] 1.611	[illegible] [illegible]	47 [illegible]	61 1.755
4.	115 1.918	[illegible] [illegible]	223 1.772	12 1.765	26 [illegible]	40 [illegible]	54 1.512	68 1.726	82 1.625	96 1.655	110 1.662	124 1.324	138 1.529	152 1.553	166 1.522
5.	125 1.553	119 1.252	133 1.663	147 1.378	161 1.565	175 1.725	189 1.564	203 1.667	217 1.676	6 1.658	20 1.255	34 1.311	48 [illegible]	62 1.264	76 1.362
6.	140 1.508	154 1.573	220 1.716	222 1.253	11 1.526	25 1.617	39 1.573	53 1.666	67 1.245	81 1.665	95 1.276	109 1.545	123 1.657	137 1.557	151 1.552
7.	60 1.557	76 1.675	64 1.669	102 1.652	115 1.611	113 1.256	118 1.717	148 1.603	122 [illegible]	145 1.519	[illegible] 1.753	216 1.743	3 2.244	17 1.721	31 1.723
8.	15 1.591	29 1.169	43 1.661	57 1.713	71 1.590	85 1.417	99 1.765	111 1.665	127 1.576	141 1.613	155 1.631	169 1.727	183 1.526	197 1.772	211 1.697
9.	225 1.646	14 1.761	28 1.655	42 1.541	56 2.116	70 1.661	84 1.657	98 2.051	112 1.647	126 1.766	140 1.551	154 1.756	168 1.569	182 1.671	196 1.690
10.	135 1.735	149 1.716	163 1.565	177 2.110	191 1.326	205 [illegible]	219 1.557	8 2.669	22 1.617	36 1.656	50 1.517	64 1.768	78 1.663	92 1.526	106 1.291
11.	165 1.617	179 1.711	193 2.026	207 1.570	221 1.656	10 1.517	24 1.736	38 1.600	52 1.675	66 1.658	80 1.256	94 1.551	108 1.181	122 1.712	136 1.523
12.	123 1.591	116 1.651	166 1.541	162 1.676	175 1.676	142 1.670	216 1.596	218 1.568	7 1.335	21 1.593	35 1.736	49 1.255	63 1.718	77 1.721	91 2.172
13.	30 1.713	44 1.557	58 1.761	72 1.623	86 1.642	100 1.626	114 1.531	128 1.669	142 1.565	156 1.719	170 1.677	184 1.591	198 1.616	212 1.376	1 1.691
14.	75 1.751	89 1.611	103 1.765	117 1.715	131 1.756	145 1.538	159 1.710	173 1.723	187 1.652	201 1.650	215 1.650	4 1.978	18 1.372	32 1.591	46 1.627
15.	210 1.712	224 1.527	13 1.586	27 1.818	41 1.621	55 1.626	69 1.639	83 1.676	97 1.702	111 1.737	125 1.938	139 1.733	153 1.385	167 1.638	181 1.572

APPENDIX XXI 1000-kernel weight at Parkland

PARKLAND REPLICATE NO. 1. 1000-KERNEL WEIGHT

(Block)															
1.	181 33.696	182 30.363	183 32.167	184 36.626	185 37.926	186 41.615	187 34.225	188 34.123	189 39.860	190 29.422	191 35.357	192 44.103	193 37.742	194 35.578	195 35.836
2.	16 36.363	17 39.589	18 34.032	19 26.363	20 21.719	21 32.725	22 19.553	23 25.756	24 42.618	25 37.552	26 42.263	27 32.034	28 36.326	29 37.611	30 30.563
3.	211 36.912	212 35.212	213 41.266	214 33.748	215 43.741	216 42.564	217 38.613	218 37.673	219 42.667	220 35.453	221 35.311	222 35.844	223 38.216	224 33.549	225 38.511
4.	46 37.452	47 35.938	48 42.332	49 34.537	50 41.556	51 36.915	52 21.729	53 30.603	54 35.769	55 35.772	56 42.926	57 37.523	58 37.652	59 37.719	60 30.595
5.	106 39.962	107 35.518	108 31.335	109 35.423	110 33.624	111 34.262	112 35.759	113 35.523	114 34.224	115 36.913	116 35.711	117 35.276	118 36.615	119 38.772	120 21.905
6.	121 40.777	122 37.238	123 35.352	124 35.154	125 35.541	126 33.157	127 35.156	128 34.352	129 30.926	130 32.836	131 35.463	132 35.312	133 33.314	134 37.690	135 36.566
7.	91 39.333	92 37.306	93 34.076	94 31.712	95 33.453	96 37.532	97 33.615	98 33.228	99 45.354	100 38.577	101 36.611	102 35.346	103 36.133	104 31.653	105 36.113
8.	61 34.565	62 31.743	63 34.362	64 35.316	65 34.319	66 36.174	67 37.653	68 35.755	69 37.211	70 33.747	71 34.453	72 37.333	73 29.726	74 33.235	75 33.575
9.	151 40.591	152 35.497	153 37.525	154 32.654	155 35.465	156 35.347	157 32.345	158 37.701	159 37.235	160 33.925	161 35.616	162 36.595	163 36.743	164 35.313	165 37.371
10.	1 39.818	2 39.423	3 38.419	4 22.553	5 33.653	6 37.047	7 30.655	8 34.745	9 30.955	10 24.153	11 29.363	12 31.135	13 33.665	14 29.675	15 33.325
11.	196 37.271	197 33.114	198 34.571	199 34.539	200 33.591	201 39.335	202 34.735	203 43.244	204 34.631	205 35.135	206 37.743	207 36.365	208 34.639	209 33.996	210 23.337
12.	31 33.745	32 37.688	33 35.325	34 32.536	35 35.620	36 31.437	37 33.722	38 26.773	39 32.327	40 33.451	41 42.555	42 37.607	43 36.249	44 35.272	45 34.712
13.	136 42.786	137 35.756	138 37.943	139 35.424	140 35.643	141 37.652	142 34.337	143 37.553	144 42.339	145 32.445	146 35.239	147 32.766	148 24.363	149 33.471	150 37.455
14.	76 33.623	77 33.637	78 35.437	79 37.219	80 32.442	81 37.222	82 33.723	83 37.36	84 29.094	85 36.442	86 31.735	87 36.325	88 27.333	89 33.743	90 34.565
15.	166 32.467	167 33.213	168 22.127	169 36.733	170 24.277	171 36.563	172 33.615	173 29.565	174 33.056	175 33.527	176 34.328	177 35.754	178 36.622	179 36.341	180 22.407

REPLICATE-2.

1.	14 32.473	29 37.462	44 34.715	59 35.135	74 32.275	89 34.325	104 35.463	119 35.521	134 29.716	149 35.526	164 34.769	179 35.439	194 33.175	209 33.761	224 37.420
2.	1 40.056	16 42.633	31 35.337	46 43.463	61 34.515	76 35.352	91 24.372	106 22.368	121 31.232	136 33.321	151 43.433	166 22.450	181 37.210	196 33.122	211 24.732
3.	9 27.251	24 43.456	39 33.193	54 33.649	69 24.326	84 36.153	99 35.371	114 32.653	129 30.455	144 42.555	159 42.275	174 33.731	189 32.644	204 37.217	219 35.353
4.	2 42.759	17 27.835	32 43.760	47 27.321	62 33.636	77 32.453	92 33.442	107 31.475	122 36.075	137 33.412	152 33.342	167 34.365	182 34.754	197 34.576	212 32.844
5.	6 42.127	21 35.167	36 35.453	51 35.825	66 43.429	81 35.731	96 41.611	111 32.564	126 35.165	141 42.477	156 37.562	171 33.417	186 39.574	201 34.712	216 40.843
6.	11 37.573	26 42.523	41 45.451	56 37.345	71 43.523	86 34.334	101 37.221	116 33.674	131 34.545	146 42.711	161 32.526	176 35.143	191 37.720	206 37.253	221 32.912
7.	10 43.312	25 35.241	40 32.636	55 32.744	70 37.646	85 34.329	100 35.714	115 41.723	130 34.670	145 37.135	160 32.923	175 37.632	190 34.773	205 32.636	220 33.642
8.	8 33.750	23 39.273	38 45.394	53 32.233	68 47.174	83 37.167	98 35.557	113 34.355	128 34.427	143 41.269	158 36.619	173 35.854	188 36.623	203 33.649	218 35.335
9.	3 41.274	18 33.753	33 43.463	48 43.977	63 34.739	78 33.652	93 35.333	108 42.547	123 35.224	138 [illegible]	153 35.356	168 47.236	183 37.593	198 34.644	213 36.136
10.	13 36.433	28 30.946	43 41.255	58 33.643	73 32.727	88 40.255	103 32.725	118 43.463	133 41.559	148 34.126	163 34.673	178 35.464	193 33.443	208 33.719	223 35.191
11.	12 31.326	27 37.461	42 35.465	57 40.325	72 41.210	87 36.706	102 37.467	117 35.575	132 34.533	147 33.515	162 37.425	177 32.553	192 27.373	207 37.633	222 34.363
12.	5 35.415	20 35.423	35 37.472	50 43.543	65 41.637	80 [illegible]	95 41.667	110 34.745	125 34.254	140 37.412	155 34.755	170 37.738	185 37.772	200 35.354	215 41.673
13.	4 33.618	19 35.115	34 36.164	49 33.626	64 33.447	79 34.262	94 36.363	109 35.367	124 37.579	139 47.417	154 32.759	169 35.423	184 32.433	199 36.566	214 33.642
14.	7 37.342	22 32.933	37 33.554	52 41.223	67 33.457	82 36.553	97 32.345	112 35.946	127 35.766	142 41.527	157 33.520	172 36.720	187 34.725	202 35.505	217 33.126
15.	15 38.551	30 35.741	45 37.258	60 35.431	75 35.443	90 33.175	105 33.642	120 34.676	135 33.256	150 35.561	165 30.731	180 34.553	195 37.225	210 35.579	225 [illegible]

REPLICATE-3.

1.	45 29.338	57 27.376	71 32.332	87 29.142	121 32.713	115 41.645	129 33.135	143 37.315	157 39.356	171 34.542	185 35.765	199 27.365	213 26.147	2 42.619	16 37.516
2.	153 33.923	154 33.329	179 29.517	132 37.572	226 34.226	223 30.617	6 23.360	21 45.445	37 37.473	51 30.123	65 [illegible]	79 37.352	93 36.334	107 33.213	121 33.110
3.	92 35.936	104 43.773	119 33.446	142 33.677	146 42.337	160 33.320	171 21.440	186 41.242	202 42.542	215 35.261	5 43.742	310 34.332	33 35.945	47 43.267	51 33.573
4.	175 38.647	233 43.377	221 42.673	12 34.642	25 37.376	40 36.752	56 34.355	64 37.737	82 33.743	95 37.566	110 35.242	124 43.337	139 35.5 9	152 35.595	166 33.765
5.	125 34.5 9	139 25.924	178 37.015	147 27.593	161 33.574	175 35.332	189 43.551	203 43.553	217 30.959	6 39.676	22 35.246	36 33.236	49 39.675	62 27.551	76 23.333
6.	133 33.391	170 34.321	225 39.105	222 33.192	11 32.219	25 31.650	39 37.544	53 32.741	67 32.656	81 32.237	95 35.310	120 35.755	142 31.741	157 32.675	151 39.332
7.	62 32.359	76 39.076	88 33.345	102 32.737	115 39.771	132 37.272	146 34.556	159 32.273	172 40.335	186 37.552	20 33.431	216 43.921	3 44.750	17 45.233	31 37.752
8.	15 33.496	29 35.423	43 33.657	57 43.417	71 [illegible]	85 35.720	99 37.454	113 33.795	127 36.295	141 33.443	155 30.720	153 33.493	181 34.672	197 37.166	211 35.302
9.	225 34.466	14 35.324	28 33.430	42 34.767	56 42.653	70 35.495	84 32.653	98 33.391	112 34.333	126 35.371	140 39.553	154 42.273	168 [illegible]	182 37.719	196 35.301
10.	115 34.948	147 44.065	161 37.135	177 45.166	191 35.455	205 40.773	218 42.671	8 42.843	22 39.497	36 30.228	50 46.673	64 33.301	78 35.576	92 35.976	106 27.600
11.	165 35.581	179 37.723	193 42.421	207 37.133	221 41.317	10 35.545	24 35.674	38 33.365	52 42.122	66 39.201	80 36.073	94 34.655	108 41.674	122 33.441	136 35.611
12.	123 32.969	138 38.237	148 32.620	162 36.345	176 33.652	190 42.965	204 34.235	218 43.562	7 33.300	21 34.761	35 34.766	49 35.466	63 44.016	77 35.613	91 42.571
13.	33 36.723	46 [illegible]	58 35.711	72 37.923	85 36.340	100 34.632	114 33.469	126 33.550	142 34.335	156 36.292	172 35.476	199 36.301	199 33.611	212 35.326	1 39.669
14.	75 36.212	89 35.449	103 35.652	117 35.356	131 33.526	145 37.129	158 [illegible]	171 43.625	187 35.497	201 37.315	215 42.656	4 35.235	18 36.375	32 37.492	46 34.922
15.	210 35.635	224 36.740	13 37.331	27 33.532	41 33.541	55 32.978	69 36.516	83 33.347	97 [illegible]	111 36.416	125 35.193	139 30.323	153 40.648	167 36.960	181 37.792

APPENDIX XXII Yield per plant at Parkland

PARKLAND REPLICATION 1 YIELD PER PLANT

(Block)															
1.	181 16.540	182 20.171	183 16.555	184 17.144	185 22.561	186 13.033	187 17.917	188 15.669	189 16.346	190 15.351	191 15.232	192 12.251	193 15.014	194 15.419	195 24.457
2.	16 16.561	17 17.710	18 16.232	19 11.558	20 12.309	21 14.533	22 19.536	23 11.091	24 14.666	25 11.357	26 17.135	27 21.111	28 17.123	29 21.231	30 17.469
3.	211 18.419	212 17.196	213 16.327	214 12.157	215 14.735	216 15.975	217 13.061	218 11.735	219 15.373	220 16.062	221 17.561	222 12.135	223 15.306	224 13.726	225 16.749
4.	46 17.755	47 14.057	48 16.437	49 22.531	50 25.113	51 15.161	52 19.436	53 15.625	54 14.419	55 13.672	56 15.876	57 18.533	58 13.056	59 11.562	60 17.359
5.	106 19.321	107 16.326	108 14.022	109 15.365	110 15.676	111 20.425	112 13.328	113 11.691	114 22.246	115 12.331	116 22.919	117 13.755	118 13.687	119 13.746	120 19.418
6.	121 17.626	122 11.547	123 17.916	124 11.763	125 14.662	126 12.603	127 15.363	128 16.677	129 17.742	130 11.257	131 24.775	132 16.783	133 14.219	134 11.716	135 20.332
7.	91 17.415	92 15.776	93 15.051	94 12.695	95 13.360	96 14.372	97 19.091	98 16.151	99 19.151	100 17.975	101 11.613	102 17.621	103 15.511	104 15.566	105 15.233
8.	61 16.622	62 13.106	63 14.053	64 11.261	65 12.652	66 13.453	67 15.216	68 16.357	69 16.326	70 11.753	71 15.075	72 12.153	73 15.268	74 13.727	75 13.329
9.	151 16.847	152 13.613	153 15.531	154 13.653	155 13.630	156 12.300	157 15.395	158 11.936	159 13.726	160 11.711	161 12.453	162 13.163	163 12.671	164 12.723	165 15.335
10.	1 17.931	2 26.412	3 15.671	4 17.135	5 16.776	6 15.239	7 13.303	8 12.762	9 11.759	10 9.178	11 14.323	12 13.226	13 14.741	14 13.221	15 13.823
11.	196 15.111	197 13.532	198 14.663	199 13.775	200 12.133	201 15.456	202 15.211	203 11.135	204 14.219	205 15.231	206 14.432	207 12.712	208 13.151	209 15.519	210 17.566
12.	31 14.961	32 14.139	33 15.322	34 13.361	35 20.220	36 15.175	37 12.531	38 11.427	39 12.213	40 14.611	41 15.566	42 12.566	43 13.343	44 14.316	45 13.443
13.	136 15.516	137 15.247	138 17.255	139 12.945	140 16.114	141 13.289	142 15.744	143 16.755	144 13.222	145 12.195	146 12.511	147 12.652	148 11.714	149 15.332	150 14.155
14.	76 16.691	77 11.576	78 12.636	79 11.453	80 11.721	81 11.521	82 13.733	83 14.735	84 8.156	85 16.363	86 12.563	87 12.532	88 13.676	89 13.443	90 17.062
15.	166 16.176	167 14.762	168 15.567	169 15.403	170 16.147	171 15.555	172 14.257	173 17.157	174 12.313	175 14.717	176 14.227	177 15.621	178 14.335	179 14.533	180 [illegible]

REPLICATION 2

1.	14 9.759	29 12.024	44 16.127	59 14.765	74 9.517	89 17.511	104 13.761	119 15.073	134 11.425	149 13.227	164 11.443	179 12.353	194 13.731	209 13.714	224 11.938
2.	1 17.122	16 14.433	31 17.219	46 12.573	61 11.445	76 14.653	91 13.261	106 11.442	121 11.241	136 15.676	151 12.544	166 11.136	181 9.434	196 13.455	211 11.623
3.	9 13.507	24 15.062	39 16.353	54 11.931	69 13.754	84 15.655	99 13.576	114 14.242	129 14.325	144 16.715	159 15.473	174 13.257	189 12.151	204 13.613	219 12.372
4.	2 10.133	17 13.541	12 14.925	47 12.265	62 14.532	77 11.135	92 15.272	107 16.911	122 12.372	137 [illegible]	152 13.273	167 11.731	182 9.423	197 13.515	212 11.134
5.	6 15.511	21 15.136	36 12.163	51 14.442	66 [illegible]	81 15.525	96 13.515	111 [illegible]	126 12.472	141 11.331	156 13.776	171 [illegible]	186 20.434	201 13.612	216 17.323
6.	11 15.513	26 14.238	41 22.167	56 15.468	71 [illegible]	86 11.774	101 11.373	116 17.027	131 [illegible]	146 [illegible]	161 13.441	176 15.356	191 [illegible]	206 15.345	221 17.737
7.	13 11.475	28 13.336	43 11.155	58 [illegible]	73 14.520	88 12.431	103 15.641	118 12.215	133 12.776	148 14.571	160 [illegible]	178 11.262	193 [illegible]	208 [illegible]	223 12.725
8.	8 11.047	23 20.267	38 13.235	53 15.231	68 15.536	83 14.473	98 16.137	113 12.552	128 15.775	143 [illegible]	158 16.467	173 11.568	188 15.233	203 [illegible]	218 12.265
9.	3 16.313	18 [illegible]	33 13.746	48 23.155	63 11.771	78 [illegible]	93 14.122	108 14.274	123 13.274	138 15.262	153 12.115	168 15.656	183 11.271	198 11.744	213 17.772
10.	13 21.773	24 25.[illegible]	43 26.464	54 13.667	73 15.318	38 15.532	103 [illegible]	114 17.443	133 17.747	148 15.526	163 12.177	179 15.755	193 13.637	229 11.651	223 14.352
11.	12 12.421	27 14.635	42 10.172	57 11.545	72 12.265	87 17.413	102 14.314	117 16.657	112 [illegible]	147 11.564	162 14.515	177 11.276	192 [illegible]	207 [illegible]	222 15.240
12.	5 12.228	20 17.229	35 10.916	50 15.765	65 11.519	80 16.235	95 16.251	110 13.166	125 11.457	140 13.913	155 [illegible]	170 [illegible]	185 [illegible]	200 13.541	215 20.415
13.	4 15.768	19 13.721	34 15.635	49 [illegible]	64 14.374	79 12.735	94 13.420	109 15.293	124 13.271	139 [illegible]	154 [illegible]	169 [illegible]	184 17.027	199 13.563	214 13.912
14.	7 16.367	22 15.267	37 10.559	52 11.223	67 11.460	82 12.272	97 14.320	112 14.576	127 14.363	142 13.653	157 12.453	172 14.174	187 13.743	202 [illegible]	217 12.675
15.	15 12.135	30 13.277	45 13.626	60 17.429	75 13.225	90 16.450	105 [illegible]	120 15.745	135 20.425	150 [illegible]	165 14.426	180 [illegible]	195 11.200	210 15.461	225 [illegible]

REPLICATION 3

1.	65 12.815	55 [illegible]	73 14.661	47 9.554	131 [illegible]	115 14.191	128 12.558	141 11.163	157 [illegible]	171 11.929	195 15.262	134 14.221	223 14.326	2 13.362	15 11.443
2.	210 [illegible]	156 12.575	174 17.691	112 9.543	216 [illegible]	220 11.691	9 [illegible]	21 12.169	37 [illegible]	51 17.534	65 15.511	74 8.191	[illegible]	[illegible]	121 13.269
3.	70 12.765	[illegible]	118 12.341	132 [illegible]	146 15.663	[illegible]	176 [illegible]	[illegible] 13.235	202 14.465	216 [illegible]	[illegible] 13.503	11 17.423	31 [illegible]	47 [illegible]	61 [illegible]
4.	135 15.363	[illegible] 13.611	221 15.161	12 15.457	25 13.731	40 15.356	54 [illegible]	[illegible] 13.333	82 11.474	95 14.116	[illegible] 12.762	[illegible] 17.107	111 13.769	152 16.753	166 11.357
5.	105 11.713	[illegible] 13.452	133 12.632	147 16.322	[illegible] 13.125	175 12.681	[illegible] 12.630	[illegible] 12.073	217 14.363	5 12.515	[illegible] 11.555	36 9.357	[illegible] 13.241	[illegible] 9.176	[illegible] 9.259
6.	[illegible] 11.463	116 11.762	[illegible] 14.515	222 [illegible]	11 13.723	[illegible] 11.261	[illegible] 20.295	53 12.071	67 4.951	81 9.911	[illegible] 9.234	109 12.011	123 [illegible]	137 [illegible]	[illegible]
7.	63 13.526	76 11.296	[illegible] 15.222	132 13.393	[illegible]	[illegible] 8.717	[illegible] 14.647	154 11.573	172 15.441	[illegible] 12.225	[illegible] 17.231	219 13.136	[illegible] 13.475	17 11.546	[illegible] 12.523
8.	15 12.973	24 [illegible]	43 13.516	57 13.776	71 [illegible]	85 14.236	93 14.515	111 12.065	[illegible] 15.216	[illegible]	155 [illegible]	[illegible]	181 12.235	[illegible] 17.311	211 14.972
9.	225 11.712	16 19.221	28 13.657	[illegible] 12.213	[illegible] 16.266	70 11.957	[illegible]	99 13.266	112 13.260	125 14.626	143 14.665	[illegible] 12.752	169 20.318	[illegible] 12.731	[illegible]
10.	115 23.854	[illegible]	[illegible] 13.754	177 14.590	[illegible] 13.754	[illegible] 15.231	219 12.555	8 15.274	22 16.376	[illegible] 12.142	50 13.168	64 15.047	78 11.453	92 11.031	[illegible] 8.920
11.	165 15.715	179 16.676	193 13.691	207 7.545	221 13.165	10 15.618	24 20.264	38 15.093	52 12.356	66 14.321	[illegible] 13.192	96 18.919	[illegible]	122 16.677	[illegible] 15.711
12.	[illegible] 15.320	[illegible] 10.765	148 13.567	162 13.672	176 12.161	190 11.963	[illegible] 17.124	218 [illegible]	7 11.541	21 [illegible]	35 12.581	[illegible] 12.572	63 13.065	77 10.502	91 17.211
13.	30 15.565	44 16.912	58 16.721	72 13.625	[illegible] 15.159	100 11.026	114 16.527	[illegible] 11.255	142 15.368	156 17.169	173 12.369	[illegible] 19.889	194 13.567	212 10.772	1 22.520
14.	75 11.130	89 13.595	103 13.955	117 11.031	131 13.939	145 13.986	159 15.040	173 15.176	187 15.151	201 15.025	215 15.511	[illegible] 17.757	[illegible] 13.055	32 11.351	46 13.623
15.	210 16.890	224 15.070	13 13.735	27 15.167	41 16.580	55 11.610	63 15.275	[illegible] 15.472	97 16.643	111 15.077	125 15.627	139 11.292	153 11.137	167 15.326	181 16.348