SELECTION AMONG SEGREGATING POPULATIONS OF WHEAT

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DECLARATION

This thesis is my own work and has not been published previously for the award of a degree in any university.

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SUMMARY

1. A study was made of factors affecting the efficiency of selection for yield of single plants in an F_2 segregating population of wheat and of selecting between plots of genotype at the F_7 generation.

2. Three experiments comparing F_2 plants with their parents P_1 and P_2 were conducted at the Waite Agricultural Research Institute in 1978 and 1979. Seeds were sown at 3.5 cm X 17.5 cm a spacing which provides the commercial density in this environment. In Experiment 1 the seeds of P_1, P_2 and F_2 were sown in separate plots, but in Experiments 2 and 3 P_1, F_2 and P_2 were in sequence in each row of the plots.

3. Each seed in Experiment 1 was weighed and seedling emergence recorded. At harvest the plants were individually assessed for plant weight, main shoot grain yield, head number, final grain yield and plant height. Experiments 2 and 3 handled similarly except that the individual seed weights at sowing were not recorded.

4. It was found that rapidity of emergence was not determined by seed size but there was some tendency for the bigger seeds to give higher yielding plants. In the three experiments the earlier emerging plants had higher yields at maturity. This effect was marked; plants emerging on the first day on average had yields 1.4 times those emerging on day 4.

5. The effects of competition between a plant and its neighbours were studied using serial correlations. Some correlations were negative and some were positive. Serial correlations did not reveal the influence of a plant on its neighbours for all characters observed.

6. Environmental effects were large in relation to genotypic effects. Significant genotype-replicate interactions were obtained. Plant weight, head number and final grain yield were similarly affected

by the environment. There was a strong correlation between final grain yield and plant weight. It also was found that except for plant height there were no significant differences among genotypes.

7. The F_2 mean values varied considerably between replicates in their relation to the parental mean values. The range of the F_2 values covered the combined range of the parental values and transgressive segregation was found in some instances in the F_2.

8. The variance values of the F_2 were not significantly greater than the variances of the parents P_1 and P_2 and only plant height showed clear evidence of segregation, with F_2 variances in some crosses larger than the parental variances. It appeared that the main shoot grain yield was less influenced by microenvironmental variability.

9. The frequency distributions of all characters were skewed to the right except for plant height which was skewed to the left.

10. Three trials involving the F_7 generation were conducted in 3 years but at two sites. The F_7 lines were derived from lines selected or taken at random from an F_5 population. There 30 selected lines and 19 randomly chosen lines. The trials were laid out at as randomized blocks with 2 replicates. The number of plots in each trial was 825, including the check plots. The plot size was 0.60 m X 2.50 m and grain yield was the character measured.

11. Of the three correlations across years and sites only one was significant. It was the correlation of trial results at Charlick over 2 years. It was suggested that the correlation was due to differences among lines in their resistance to nematodes. Only few lines, however, were consistent over three years and two sites.

12. Selection within families at the F_5 generation resulted in relatively better F_7 lines than those taken at random. It was showed that the parents of a cross contributed the stability of lines in the F_7 generation.

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I will always remember the staff and post graduate students in the Department of Agronomy who gave me congenial surroundings during my study.

DEDICATION

To my wife, Sri Pratiwi, and my sons, Arundi Kriptanto, Boni Jianto and Christian Sarnanto who encouraged and helped me during my study.

INTRODUCTION

This thesis is concerned with selection of single plants in the early generations following a cross of two parents of wheat. It is also concerned with the testing of plots of F_7's lines over different sites and years.

In the breeding of self-pollinated crops the breeder faces the difficulty of making an accurate phenotypic assessment of single plants and the selection of desirable homozygous genotypes. Most of the characters of interest to him such as yield and quality are quantitative. These characters are under the control of many genes each with small effect on the phenotype. The expression in single plants of quantitative characters is also influenced by the microenvironment which tends to blur the genetic differences between the plants. Microenvironmental variation always occurs even in the small area occupied by a selection block and increases the variability amongst plants making it more difficult to assess them individually.

The microenvironment affects the growth of a plant from the moment germination occurs. Soetono (1975) found with a cultivar of barley that the earlier emerging seedlings gave bigger plants than those with a later emergence. In view of this finding, the present experiment was concerned with comparing the effects of seedling emergence and growth in an F_2 segregating population with the emergence and growth of its parents. If early emergence was determined by the microenvironment and this resulted in large differences in yield it would mean that it would be difficult to select among F_2 plants on a basis of yield and achieve a genetic improvement.

In the pedigree method of breeding, selection may begin on single plants in the F_2 and be continued until the genotypes of the desirable plants are homozygous. It would be advantageous if an accurate assessment could be made in an early generation analysis of hybrids and some knowledge gained of the relative importance of heredity and environment in determining the expression of characters. Theoretically the phenotypic variance of a segregating population of plants should be much larger than among individuals of the homozygous parents. However, it often happens in a breeding programme with wheat that the variances of the F_2 and parents are not statistically different (Knight, personal communication).

Selection on a single plant basis may be practised if the plants are at a wide spacing or at a crop density. At wide spacing every plant can grow and show maximal expression of its characters. The plants are more easily handled and provide more seed for testing in the next generation. A low density, however, implies that the selection block will occupy a larger area and have greater soil heterogeneity and microenvironmental variation. Furthermore the expression of a genotype will be different from what it would be under the competitive conditions of normal crop density. The factors limiting growth will be different. At crop density, every plant is subject to strong interplant competition. Only a smaller area is needed and it is possible to select under conditions similar to those in which the crop will be grown. It was considered that the results of the present study would be more meaningful to selection if the plants were grown at a crop density.

Many breeders have stated that selection for yield in the F_2 is not effective. The matter is worthy of study as Shebeski (1967) on theoretical grounds has indicated that the F_2 generation has a higher proportion of genotypes with a favourable combination of genes than in any subsequent generation.

As selection based on yield has not been notably successful some workers have suggested that plant characters related to yield should be considered when undertaking selection. Other characters may be less influenced by heterozygosity, genotype-environment interactions or competition effects than is yield itself. Hence this study of the F_2 and parents at a crop density has considered yield as well as related characters.

In the final stages of the pedigree method, selection moves away from individual plants to selection between plots of each genotype. Furthermore tests are conducted over different sites to enable selection of genotypes with wide adaptation or sometimes specific adaptation. Usually stable high yielding lines are the main interest of such tests. Some statistical analyses of the genotype-environment interactions present in these tests have been suggested, but the validity of the analysis for any test is still debated.

Some aspects of such tests, the prediction of desirable genotypes and the effect of environmental variability, form the background to the second part of this study on F_7 lines of wheat.

CHAPTER 1. LITERATURE REVIEW

1.1 Selection in self pollinated crops

According to the genetic theory of quantitative characters in a segregating population there may be many different individuals or genotypes. The ability to select between these individuals and detect desirable plants with a high yield potential remains an important question for plant breeders. The main problem is to know whether the observed variability is genetic or environmental as only the heritable differences are important in selection.

The main breeding procedures used for self pollinated crops are the pedigree, bulk, back cross and single seed descent methods. Selection of single plants in an early generation is an aspect of the pedigree method. Shebeski (1967) surveyed the procedures of wheat breeders in many countries and found that most breeders still use the pedigree method when selecting plants for yield and quality. Single plant selection is often commenced in the F_2 generation and is continued in each successive segregating generation. The relationship between progenies and their parents or among families is recorded in the pedigree. By the F_3 and F_4 generations family characteristics may have appeared, so that selection may be conducted for the best families. Homozygosity at most loci is expected by the F_5 onwards. Many commercial varieties have resulted from the single plant selection method which commenced in an early generation.

Usually by the F_4 or F_5 when segregation of self pollination have resulted in many different lines but a reduced variation within a line, selection may be practised between plots (lines).

1.2 Genetic Considerations of F_2 populations

The number of genotypes in a segregating population depends on the number of loci by which the parents differ. The complexity of the genetic situation increases exponentially with increase in the number of segregating gene pairs. For 10 allelic pairs, for instance, the number of genotypes possible in an F_2 are 3^{10} or 59,049. It is evident that for characters such as yield which are controlled by many genes, a breeder should work with large numbers of plants to ensure the presence of the best possible genotypes. Shebeski (1967) gave an example of a cross between two parents having 50 alleles affecting yield and showed that it is not feasible to grow all the possible genotypes. Furthermore the proportion of homozygous genotypes in the F_2 is also dependent on the number of gene pairs.

If two parents differ in a character, theoretically the variability of the F_2 population must be greater than the parental and F_1 generation. Environmental effects may increase or reduce the variability of any generation. Therefore it is possible that the phenotypic variability of the F_2 may not be much different from that of the parents or F_1.

Although many studies have concluded that selection for yield in the F_2 generation is not effective, ideally selection should be commenced in that generation. The reasons are

1) genotypes with the desirable genes occur at a greater frequency than in any subsequent generation (Shebeski, 1967),
2) the F_2 offers the best chance of preserving the genes responsible for high yield and so that they are not lost in later generations (McGinnis and Shebeski, 1968) and
3) selection during an early generation means that that effort is not wasted on poor material (Weiss *et al.*. 1947).

Beside this, selection in the F_2 is efficient for those characters having a high heritability, such as disease resistance, height, maturity and straw strength. Eliminating individuals with low potential will improve the frequency of superior material in later generations. Because of these matters, some breeders have attempted to find methods for early generation selection. One possible method of selecting for yield is to reduce in some way the environmental variation in the selection block.

1.3 Heterosis and selection of single plants

Several workers have found that heterozygosity can cause a plant to be more vigorous than both its parents as a result of overdominance or heterosis. Shull (1948) stated "heterosis is not a unitary phenomenon, but a complex series of phenomena for which no single cause or mechanism can be properly assumed to apply to all cases". Heterosis confounds the evaluation of genotypes in selection when the objective is to produce a homozygous variety. The expression of heterosis in any plant character has been investigated in many studies. One of them was conducted by Zeven (1972) who found with wheat that heterosis was only evident in the number of ears and 1000-grain weight. The expression of heterosis is greatly influenced by the environment and agronomic treatment, such as time of sowing, depth of sowing and spacing.

In self pollinated plants the proportion of heterozygotes falls dramatically with each generation. By the F_6 generation, for instance, the proportion is only 3.125%. For this reason many breeders prefer to delay selection until the F_4 by which time the proportion that are homozygous is much larger than in the F_2.

Another genetic factor affecting the efficiency of selection is dominance. Liang and Walter (1968) found that dominance effects in sorghum were important for inheritance in grain yield, head weight, kernel weight, kernel number, plant height, stalk diameter and germination percentage. In rice, Li (1970) observed that dominance and additive effects were important in determining all the characters except yield. When dominance has an effect, it can obscure an evaluation when the ultimate objective is a homozygous genotype. The present study is concerned with parents and their F_2 populations and it was of interest to determine if heterosis was evident in the F_2 under crop density conditions.

1.4 The environment in which selection is practised. Spaced plant or crop density

Frequently, breeders undertake selection on F_2 plants grown at a wide spacing. This is done to facilitate visual evaluation rather than for precise measurements (Allard, 1960). At wide spacing the plants are easier to handle and their morphological characters can be readily assessed. For example, dwarf plants will have a chance to grow as well as the tall plants whereas this would not occur in a competitive situation. The effects of competition on plant height in wheat were shown by Jensen and Federer (1965) where competition enchanced the yield of taller plants and depressed the yield of shorter plants. A weakness of selection at wide spacing is that larger selection plots are needed and there will be greater microenvironmental variation. McGinnis and Shebeski (1968) suggested the use of control plants grown between two rows of segregating plants as a means of estimating microenvironmental variation. The results showed that the method was successful in identifying high yielding F_2 plants. But again this method needs larger areas than conventional methods, and a more variable environment is encountered. It is only efficient if the control plants can be used satisfactorily to measure variation.

1.5 Plant establishment under competitive condition

Plants grown under crop density must share resources and if the supply is limited, individual plants compete with each other (Donald, 1958). Competition increases with plant density and depresses the expression of characters of individual plants (Puckridge and Donald, 1967). If a population of plants is measured, the distribution of plant weights changes with time from approximately a normal curve to an L-shaped curve having the mode to the left of the mean (Koyama and Kira, 1956). The smaller the distance between neighbours the earlier does competition start and the more severe it becomes. The effect of neighbours of each plant is basically believed to be a function of distance and size of neighbouring plants. In a population consisting of different genotypes, there may be cooperation or competition (Mather, 1969).

A breeder who undertakes selection in a competitive situation hopes there will be no change in yielding ability when the selection is grown in pure stand under crop density, because it will have been selected for performance in a stress situation. However it is still a question whether a genotype with a high competitive ability in mixture will have a high yielding ability in pure stand.

The competitive ability of a genotype is normally estimated as the ratio of its yield in mixture to its yield in pure stand or as the difference between these values. Varying results have been obtained in different studies. Jennings and Aquino (1968) and Donald (1963) reported a negative relationship between competitive ability and yield in pure stand. In contrast, Johnston (1972) concluded from study with barley that yield in a heterogenous populations was positively associated with yield potential in a pure stand.

It is not easy to define the morphological characters that determine the ability to compete (Joshua, 1960; Jennings and Aquino, 1968). Until competition is more fully understood it will continue to affect the efficiency of breeding. However recent studies have idnicated the effect of early seedling emergence on competition.

1.6 Factors affecting seed emergence

The effect of rapidity of seed emergence on competition and final yield has been referred to by Soetono and Donald (1980) who found that there were significant regressions between the time of seedling emergence and grain number per plant. Their study was conducted at different plant densities. All regressions were negative and decreased as the density increased. They gave the example that the number of grain will be 43% less on plants with a delay of 3 days in emergence. Accordingly they stated that selection based on grain yield in a segregating population will be affected by variation in the date of emergence.

Factors affecting seedling emergence are often thought to be seed size, depth of sowing and other microenvironmental factors including soil structure. The seed of a monocotyldeon is partly the embryo and partly the endosperm. If the large seed is associated with greater embryo size, it is understandable that large seeds may produce larger shoots and have more vigor to emerge. This will result in relatively higher dry weights in early plant growth as found by Rogler (1954) for wheatgrass and Goydani and Singh (1971) for wheat.

Deep sowing is considered to provide an environment more suitable for germination as the moisture status is better. In general, however, the rapidity of emergence decreases with increase in sowing depth (Whan, 1976; Hadas and Stibbe, 1977; Lindstrom, 1979). In wheat, the ability of the coleoptile to emerge is largely dependent on seedling vigor, coleoptile length, crust thickness and presence of cracks (Whan, 1976). The deeper the seeds are placed the longer it takes for the coleoptile to reach the soil surface.

The length of coleoptile in wheat varies between plant varieties. Varieties having long coleoptiles emerge more rapidly than those with short ones (Sunderman, 1964; Inouye and Tanakamaru, 1977). Poor emergence was due mainly to a failure of the coleoptile to reach the soil surface. Once the coleoptile had reached its maximum length, the first leaves could not break through to the soil surface (Burleigh *et al.* 1965).

1.7 Yield and other characters

Because yield is the outcome of many processes such as photosynthesis, respiration and mineral uptake it is very difficult to analyse and many people have suggested that it might be easier to select for other characters that have a significant genotypic correlation with yield. Selection for these characters in early generations might improve the efficiency of breeding for grain yield (Hinson and Hanson, 1962; Hsu and Walton, 1971; Nass, 1973; Sidwell *et al.*, 1976). Early growth may be such a character. McGinnis and Shebeski (1968) selected well-tillered vigorous F_2 plants resulting in an increased yielding capacity in the F_3 lines. Characters like ear length, leaf sheath length, flag leaf area, ear numbers influenced yield and its components significantly (Hsu and Walton, 1971). Hinson and Hanson (1962) suggested selecting for a certain combination of characters to obtain more progress than from selection for yield. It is therefore important to have information on the factors affecting development, especially for plants grown under competition.

A character suggested by some to be closely related to yield is harvest index which is the ratio of yield to total plant weight (Donald, 1962; Syme, 1972; Fischer and Kertesz, 1976). Syme (1972) found a remarkably high correlation (r = .85) between single plant harvest index of 49 varieties grown in a glass house and the mean yield of the same varieties when grown in 63 sites. In contrast grain weight of single plants showed no relation with mean yield (r = .10). Fischer and Kertesz (1976) using spaced plants and microplots came to the conclusion that harvest index in one environment was a good prediction of yield in other environments.

Donald (1968) took the concept further of breeding for characters related to yield when he introduced the idea of the ideotype. This is a biological model based on physiological considerations. For cereals, he suggested plants should have strong stems, a few small erect leaves, a large and erect ear and a single culm. These characters are expected to reduce the risk of lodging, to provide a greater surface of leaves to incident radiation, to allow deeper light penetration, less mutual competition and to avoid the production of low yielding tillers. For this ideotype concept to be feasible single plant selection must be practised.

1.8 Genotypic and environmental variability

In most breeding programmes selection of genotypes is practised in one site and season, but the genotypes selected as varieties are to be grown in many sites and seasons. The interaction of genotypes or varieties with the environment affects the efficiency of selection (Horner and Frey, 1957; Allard and Bradshaw, 1964). The variety-season interactions is more difficult to accommodate than the variety-site interaction, because season to season fluctuations cannot be predicted (Allard and Bradhsaw, 1964).

When selecting on a single plant basis microenvironmental variation within the selection block may confound the assessment of genotypes. Knight (1971) mentioned three possible approaches to the problem, namely, by using a moving mean, response surfaces or the use of a grid of one or more genotypes as controls among the segregating plants. Fazoulas and Tsaftaris (1975) proposed a honey-comb method of selection in which plants are grown at the centre of hexagon of the other plants. The value of all these various approaches needs further investigations. Hamblin (1971) was unable to show that the use of response surfaces or moving means among single plants was effective. At low density the estimates of microenvironmental variation were not precise and if the density was increased, competition became very important. Townley-Smith and Hurd (1973), however, found with plots that the use of a moving mean of adjacent plots to adjust yields was better than use of frequently repeated control plots in reducing error variances. The value of control plots or plants has been questioned by Knight (1971); the occurrence of genotype-environment interactions may cause the controls in the grid to respond differently from the genotypes under test.

To estimate variety-season or variety-site interactions Finlay and Wilkinson (1963) and Eberhart and Russel (1966) used the regressions of the cultivar values on the mean values for all the cultivars, in each site and season. They concluded that in most cases the genotypic-environment interactions were linearly related to environment effects.

Knight (1970), however, critized this conclusion on the basis of known responses to limiting factors and suggested the evaluation of cultivars was only useful when there were many varieties tested in the trial.

1.9 Conclusion from literature review

The studies reviewed dealing with breeding for yield in cereals have suggested that although in theory it is best to select in early generations, which implies selection of single plants, many breeders have concluded that selection of single plants is ineffective. The factors causing the inefficiency are often competition, microenvironmental variation, genotype-environment interactions and heterozygosity.

If it is difficult to select on a basis of yield there may be other characters that are related to yield and which show less environmental variation. They may provide a means of improving the effectiveness of selection in early generations.

Recent studies have suggested that the time of emergence of plants of a cultivar had a strong effect on early plant development and ultimate yield. If this is confirmed it would have relevance to selection in a segregating population.

Selection under conditions of high density will minimize variability arising from soil heterogeneity and also should provide genotypes adapted to crop density. However the effects of competition may be great and hinder accurate assessment of genotypes.

Estimates of variety-season or variety-site interaction are very important in breeding programmes and part of this study will be concerned with such interactions.

CHAPTER 2. EXPERIMENTAL OUTLINE

2.1 Introduction

A study was undertaken with wheat of the relationship between yield and other characters of plants of the F_2 generation and their parents when grown at crop density. Three field experiments designated 1, 2 and 3 were undertaken at the same site. Different crosses and sowing arrangements were used in each experiment.

A fourth experiment with a different objective was carried out at several sites. A comparison was made of F_7's lines derived from lines selected, or taken at random, from an F_5. The experiment was undertaken in three successive years. The purpose was to study the influence of the different sites and years on a set of lines.

2.2 F_2 generation experiments (Experiment 1, 2 and 3)

a. Experiment 1

This experiment was conducted during the 1978 growing season from June to December. The site was the Waite Agricultural Research Institute which experiences a mediterranean type of climate with cool wet winters and hot dry summers. The monthly rainfall is shown in Table 2.1. The soil type is a red brown earth.

The Material

The F_2 generation and the parents in the following three crosses were studied:

cross 1 -	(WW*Halb)/9/9	*	RAC-311
cross 2 -	(WW*Halb)/9/9	*	(G*P)/45/4/10
cross 3 -	(G*P)/45/4/10	*	(Gaines*Waite-6)/7/8

Table 2.1. Monthly rainfall for 1978 and 1979 and the long term averages at the Waite Research Institute.

	1978		1979		1925-1978
	No. of days	mm	No. of days	mm	mean mm
January	4	1.8	3	41.2	23.7
February	5	8.2	7	13.8	27.7
March	5	4.2	6	16.6	21.5
April	8	42.0	15	51.6	55.6
May	15	65.9	15	74.4	80.0
June	20	97.6	14	24.6	73.5
July	20	116.6	17	71.0	85.2
August	14	76.4	22	122.0	72.5
September	19	93.6	18	172.2	61.3
October	6	31.4	9	69.4	53.9
November	9	49.8	10	40.2	38.6
December	6	28.4	6	35.6	29.9
Total	131	615.9	142	732.6	623.4

Some of these crosses have a parent in common. The parents were high yielding lines from a current wheat breeding programme and are believed to be homozygous and uniform.

Sowing

Before sowing all the seeds were individually weighed so that the plants that developed could be related to their weights. For sowing, large boards with holes drilled at a spacing of 3.5 cm x 17.5 cm were used. After covering the holes on one side of the board with strips of paper a weighed seed was placed in each hole. Then the second side of the board was covered with paper.

Another board with holes drilled at 3.5 cm x 17.5 cm spacing was used as a base at sowing. This board was placed on the ground. A dibber board with pegs at the same spacing was placed on the top of the base board and pressed down to create holes of equal depth in the soil. After removing the dibber board, the board holding the seeds was placed on top of the base board and the dibber board was then used to press the seeds into the soil. The seeds were covered with soil. The seeds were sown on June 15, 1978. The spacing of 3.5 cm within a row and 17.5 cm between rows is representative of commercial density in this environment. Two rows around each plot were used as borders. On the sixteenth day after sowing, where plants were missing, seedlings of the parents were transplanted to maintain the stand. These plants are not included in the analyses. Because there were a different number of plants for the various entries some of the comparisons are based on percentages.

Layout and method of experiment

The crosses were grown separately in a randomized block with three replicates (Figure 2.1). The reason for the separate arrangement was that the main interest was in the comparison of the P_1, P_2 and F_2 populations within a cross. A plot consisted of 120 plants sown in three rows. Hence, each population was represented by 360 plants and the whole experiment consisted of 3240 plants.

The area has been fertilized annually with superphosphate at the rate of 125 kg/ha and planted with pasture frequently. No fertilizer was applied for this experiment to avoid variability due to fertilizer application. Plots were sprayed 14 days after sowing with a mixture of 5 g. DDT and 2.5 g. malathion in 1 litre water to protect against cut worm species. Hand weeding was carried out 46 days after sowing. Weeds were not a problem.

In the central area of the experiment, the plants did not grow as well possibly due to some aspect of soil variability. The area was occupied by cross 2. No lodging occurred and visible disease incidence was negligible.

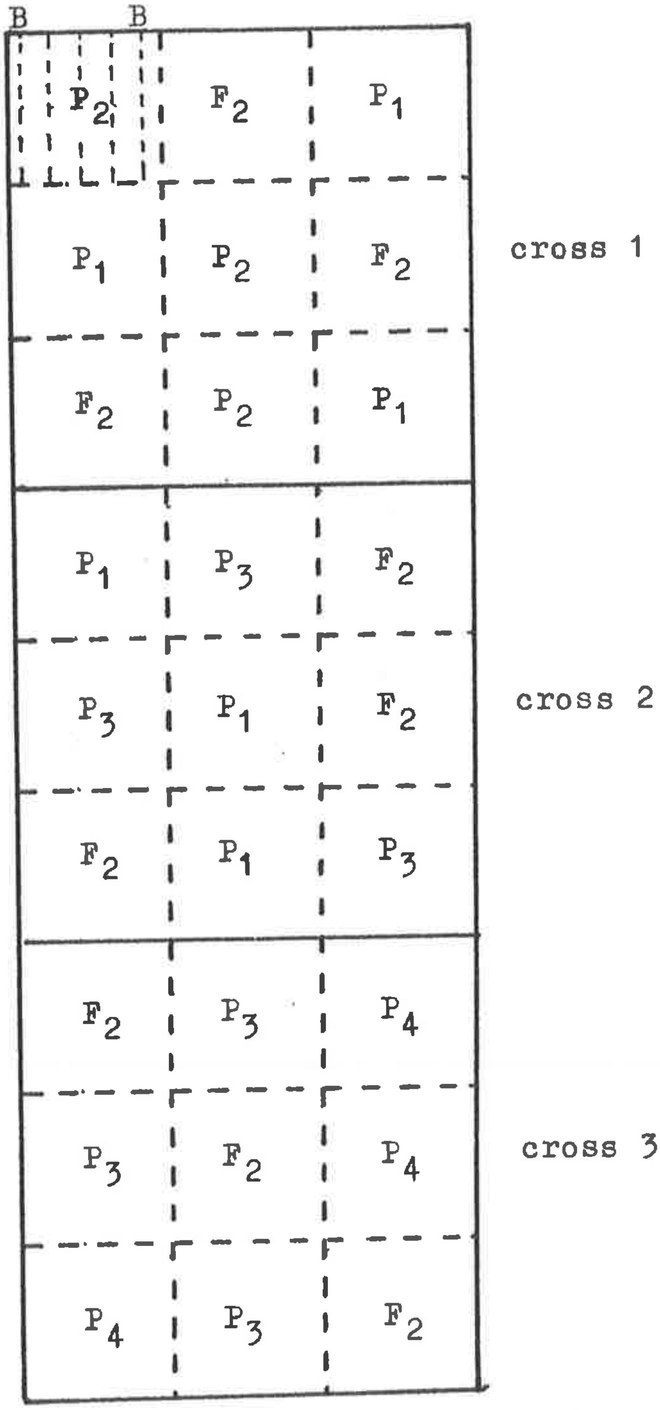
After discarding the borders, single plants were harvested by cutting the shoot immediately above the ground. Each plant was then put in a labelled bag.

Characters observed

Reference has been made already to the fact that the seeds sown were individually weighed.

Seedling emergence was recorded twice a day at 9.00 a.m. and 4.00 p.m. It began on the 8^{th} day and continued for ten days. The criterion

Figure 2.1. Lay out of experiment 1.



B = borders row

P_1 - (WW15*Halb)/9/9

P_2 - RAC-311

P_3 - (G*P)/45/4/10

P_4 - (Gaines*Waite-6)/7/8

of emergence used was the appearance of the coleoptile above the ground.

Plant height was measured before cutting of the plants. Each plant was weighed to obtain plant weight and the head number was counted. The weight of grain on the main head was obtained and then final grain yield per plant.

Serial correlations were computed to determine the relation between a plant's value and the mean value of its two neighbouring plants in a row. This should provide an indication of the influence of neighbours on a plant.

Data analysis

The results were analysed using FORTRAN IV and the University of Adelaide CDC 6400 computer.

b. Experiment 2

This experiment was conducted in 1979 from July to December. It was undertaken with the same objectives as Experiment 1 that is to compare F_2 and parental population but with a different pattern of seed placement of the P_1, P_2 and F_2. They were sown in a repeating sequence within a row. With this pattern it was hoped that information would be obtained on the effect on a plant of neighbouring plants of a different genotype.

The material

Three crosses were used:

cross 1 - (PIT*Fest)/41/W/4 * RAC-266
cross 2 - (PIT*Fest)/41/W/4 * Oxley
cross 3 - (PIT*Fest)/41/W/4 * Warigal

One parent was common to the three crosses which again represent promising material in a current wheat breeding programme. By using a common parent it was hoped to obtain an assessment of microenvironmental variation, by comparing the variance values of this parent over the three crosses.

Planting preparation and seeding emergence

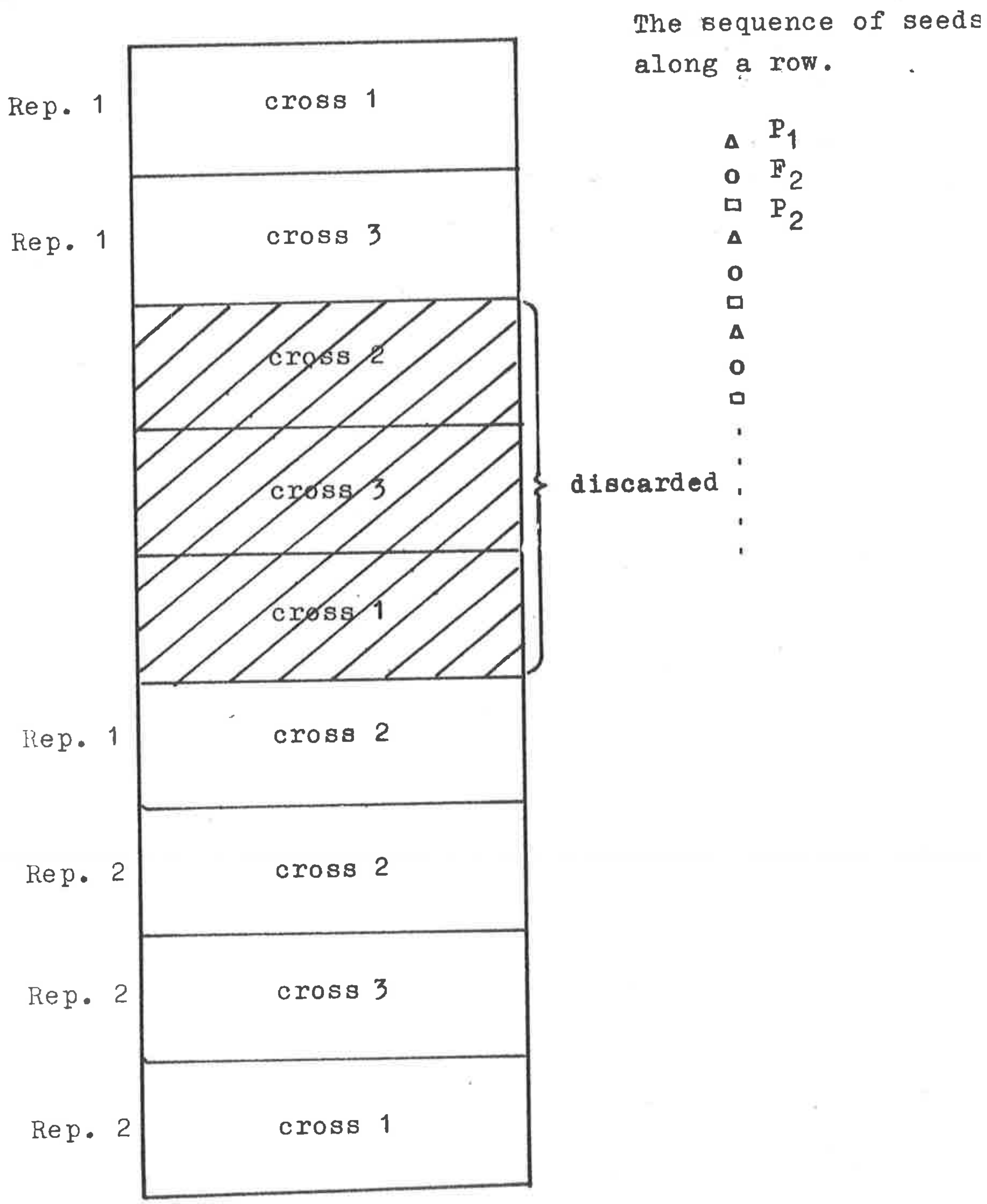
Seed were sown with the equipment used in experiment 1, but the seeds were not individually weighed. The seeds were sown on July 11. One seed was placed in each hole for replicate 1 and 2, while in replicate 3 two seeds per hole were sown and the seedlings were thinned later. A commercial density was established with 15 rows in each plot. Two rows on the long sides of the experiment and 5 plants at the end of rows were used as borders. Transplanting to fill any gaps was undertaken 17 days after sowing. On the fourteenth day plants in the third replicate were thinned to give one plant per hole.

Seedling emergence commenced 6 days after sowing. It was recorded at 9.00 a.m. and 3. p.m. for 10 days.

Layout

The layout is shown in Figure 2.2. The experiment was planned as a randomized block with three replicates, but because many seeds in three plots did not germinate, these plots were discarded to give two replicates (Figure 2.2). Also illustrated in Figure 2.2 is the arrangement for sowing seeds in a repeating sequence of parent 1, F_2 and parent 2. In each plot there were 15 rows with 40 plants per row. Because 40 is not a multiple of the 3 genotypes, there was not an equal number of genotypes in a plot. The number of plants in each plot was 600, consisting of 210 parent 1, 195 of the F_2 and 195 of parent 2.

Figure 2.2. Layout of experiment 2.



cross 1 - (PIT*Fest)/41/W/4 * RAC-266

cross 2 - (PIT*Fest)/41/W/4 * Oxley

cross 3 - (PIT*Fest)/41/W/4 * Warigal

c. Experiment 3

This experiment was also conducted in 1979 with the same objectives as Experiment 2. It was sown when it became evident that emergence was poor in Experiment 2.

The material

The crosses used:

cross 1 - (PIT*Fest)/41/W/4 * Halberd
cross 2 - (PIT*Fest)/41/W/4 * (MKR)/11/8S/8
cross 3 - WQ*(Opal*PIT)/34/W/3 * (WMK*Halb)/30/W/2

These crosses are not the same as in Experiment 2 as there was insufficient seed to repeat exactly that experiment.

Planting preparation and seedling emergence

The seeds were not sown using boards as in experiments 1 and 2. After raking the surface, the soil was removed to a constant depth and placed in a container. The seeds were sown in the same order as experiment 2 and then the soil was replaced. This was done one plot at a time. The sowing date was August 7 and the spacing was 3.5 cm x 17.5 cm as in the previous experiments. Borders plants were grown as in Experiment 2.

Transplanting was undertaken 20 days after sowing. A sowing on August 7 represents a relatively late sowing in this environment.

Seedlings started to emerge 7 days after sowing.

Layout

The P_1, P_2 and F_2 of each cross occupied one plot and there were three plots (Figure 2.3). There were 15 rows in each plot and 120 plants in a row consisting of 40 of parent 1, 40 of the F_2, and 40 of parent 2. The number of plants in each plot was 1800.

2.3 Experiment 4

This experiment was conducted at Saddleworth in 1977 and at the Charlick Experiment Station (Strathalbyn) in 1978 and 1979. Saddleworth is about 100 km north, and Charlick about 50 km south east, of Adelaide.

Climate and soil

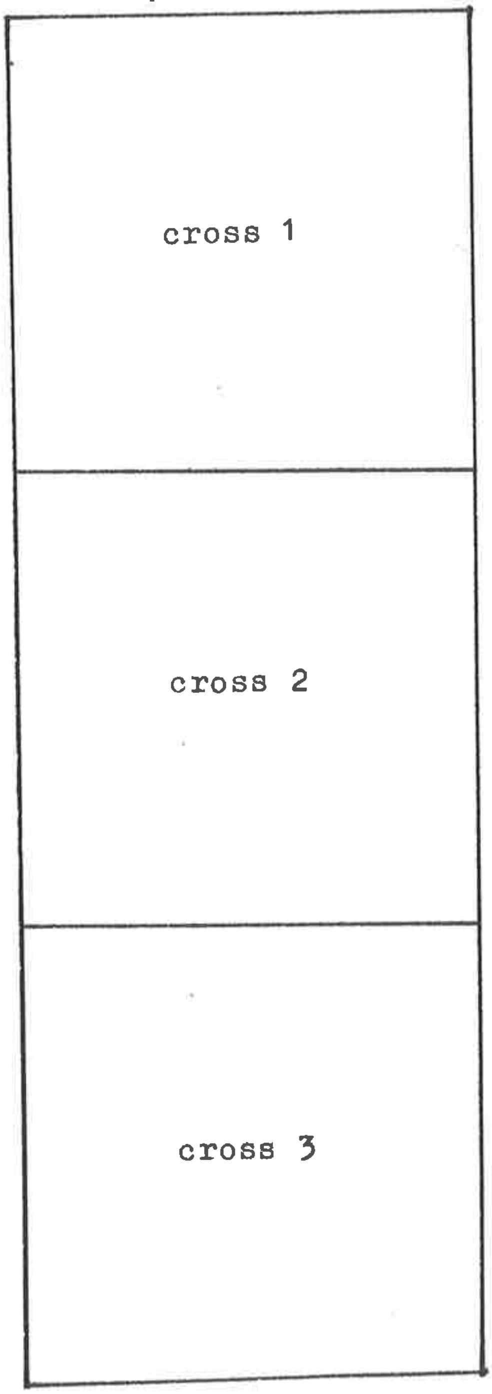
Both sites have a mediterranean type of climate. Values for rainfall were obtained from the stations nearest to these sites; for Saddleworth it was obtained from Mintaro and for Charlick from Strathalbyn (Table 2.2 and 2.3).

Saddleworth has a sandy red-brown earth and the soil at Charlick is transitional between a red-brown earth and a solonized brown soil.

The material

Two groups of lines were used. One group consisting of 30 lines was derived from selection in the F_5 (Table 2.4) while the second of 19 lines was taken at random from the same population (Table 2.5). When tested both groups were at the F_7 generation in a pedigree breeding programme at the Waite Agricultural Research Institute. Selection had been commenced in the F_4 generation when selection was within families. Selection was not strong as three-quarters of the lines were retained. Selection was on a visual basis, with several heads being taken from any line. Grain of selected plants were sown in plots at 4 sites with one replicate. From the F_5 generation there was visual selection within lines

Figure 2.3. Layout of experiment 3.



cross 1 - (PIT*Fest)/41/W/4 * Halberd

cross 2 - (PIT*Fest)/41/W/4 * (MKR)111/8S/8

cross 3 - (PIT*Fest)/41/W/4 * (WMK*Halb)30/W/2

Table 2.2. Long term average rainfall (mm) and rainfall in 1977 at Mintaro (mm).

Month	85 year average	1977
January	21	31
February	24	30
March	22	28
April	39	18
May	72	69
June	76	55
July	79	46
August	84	41
September	69	62
October	55	34
November	34	61
December	28	15
Total	603	410

Table 2.3. Long term average rainfall (mm) and rainfall in 1978 and 1979 at Strathalbyn (mm).

Month	30 year average	1978	1979
January	21	13	26
February	22	3	55
March	24	21	23
April	39	42	57
May	56	55	39
June	59	77	13
July	63	78	58
August	60	87	71
September	53	76	66
October	44	29	54
November	29	39	40
December	25	8	16
Total	495	528	518

Table 2.4. F_7's lines selected from F_5 generation.

	Lines	Number of lines Rep. 1	Rep. 2
1.	(M*M)*CM)/21)*Warimek)/41S	6	6
2.	(Wariquam * Warimek)/1S	10	10
3.	(Wariquam * Warimek)/5S	13	13
4.	(Wariquam * Warimek)/12S	13	13
5.	(M*M)/68/1)*(M*M)*CM)/21)/29S	13	13
6.	(M*M)/68/1)*(M*M)*CM)/21)/38S	13	13
7.	(M*M)/68/1)*(M*M)*CM)/21)/47S	13	13
8.	(M*M)/68/1)*(M*M)*CM)/21)/49S	13	13
9.	(M*M)/68/1)*(M*M)*CM)/21)/57S	13	13
10.	(GB*PT)/45/15)*(M*M)*CM)/21)W/17S	7	8
11.	(GB*PT)/45/15)*(Wariquam)W/5S	12	12
12.	(GB*PT)/45/15(*(Wariquam)W/9S	12	12
13.	(WW-15*RVN)*(Champ*PIT)/8)/12S	13	13
14.	(WW-15*RVN)*(Champ*PIT)/8)/15S	11	11
15.	(M*M)/75/1)*(M*M*GB)/37)/4S	13	13
16.	(M*M)/75/1)*(M*M*GB)/37)/7S	11	11
17.	(M*M)/75/1)*(M*M*GB)/37)/14S	13	13
18.	(M*M)/75/1)*(Oly*8156)/13)7S	12	12
19.	(M*M)*CM)/21)*T-64-2-W)30S	12	12
20.	(M*M)/75/1)*Hazera-2152)/27S	13	13
21.	(M*M)*CM)/21)*Hazera-2152)/33S	10	10
22.	(WW-15*RVN)/24)*Hazera-2152)/16S	9	9
23.	(M*QD)*CM)/91)*Wariquam)/4S	11	11
24.	(M*QD)*CM)/91)*Wariquam)/9S	11	11
25.	(M*QD)*CM)/91)*Wariquam)/11S	11	11
26.	(M*M)*CM)/21)*(M*M)*CM)/73)/6S	13	13
27.	(Vardenik*(M*M)/68/1)2)/29S	12	12
28.	(M*M)*GB)/5/9)*Wariquam)/3S	10	10
29.	(M*M)*GB)/5/9)*Wariquam)/4S	12	12
30.	(M*M)*GB)/5/9)*(M*M*CM)/26/4)/12S	13	13

Table 2.5. F_7's lines taken at random from F_5 generation

	Lines	Number of lines Rep. 1	Rep. 2
31.	(M*Q)*C)/91)*(WW-15*RVN)/24)/22S	14	14
32.	(M*M)75/1)*(M*M)*CM)/73)/17S	15	15
33.	(Wariquam * Warimex)/2S	8	8
34.	((M*KD)/114/30)*(M*M)*CM)/21)/48S	12	12
35.	(M*MK)114/30)*Wariquam)/9S	13	13
36.	(M*KD)/10.9)*(M*M)*CM)/21)/14S	14	14
37.	(Wariquam*(HER*MYO)/45/6)8S	12	12
38.	(M*M)*CM)/21)*(T-64-2-W)35S	11	11
39.	(WW-15*RVN)/24)*T-64-2-W)/15S	14	14
40.	(M*M)*CM)/21)*Manitiou)/3S	13	13
41.	(Amur-74*(M*M)/68/1)2)/29S	7	7
42.	(Pitic * Gaines)/13S	13	13
43.	(Vardenik * (Wariquam)2)/2S	12	12
44.	(Kzyl-Cas * (Warimek)2)/3S	11	11
45.	(Amur * (M*M)/68/1)2)/17S	13	13
46.	(M*M*C)/73/27)*(M*M*C)/26/4)/10S	14	14
47.	(SON*ISRL-38)/34/3)*Wariquam)/4S	14	14
48.	(M*M*GBO)/5/9)*(M*M*C)/26/4)/1S	13	13
49.	(M*M*GBO)/5/9)*(M*M*C)/26/4)/25S	13	12

and also single heads were taken at random of each plot from each site.

The trial contained 2 replicates of the selected and random group. Also included were single plots of Oxley, RAC-266, Kite and Condor and 90 plots of Warimba as checks in each replicate. In addition, to enable a comparison across generations, there were 3 plots of 49 lines of the F_6.

Sowing

Seeds were sown by machine at a rate of 20 g. per plot in four rows, 2.5 m long (equivalent to 133 kg/ha), on July 5 in 1977, July 19 in 1978 and June 21 in 1979. The distance between rows was 15 cm and between plots 30 cm.

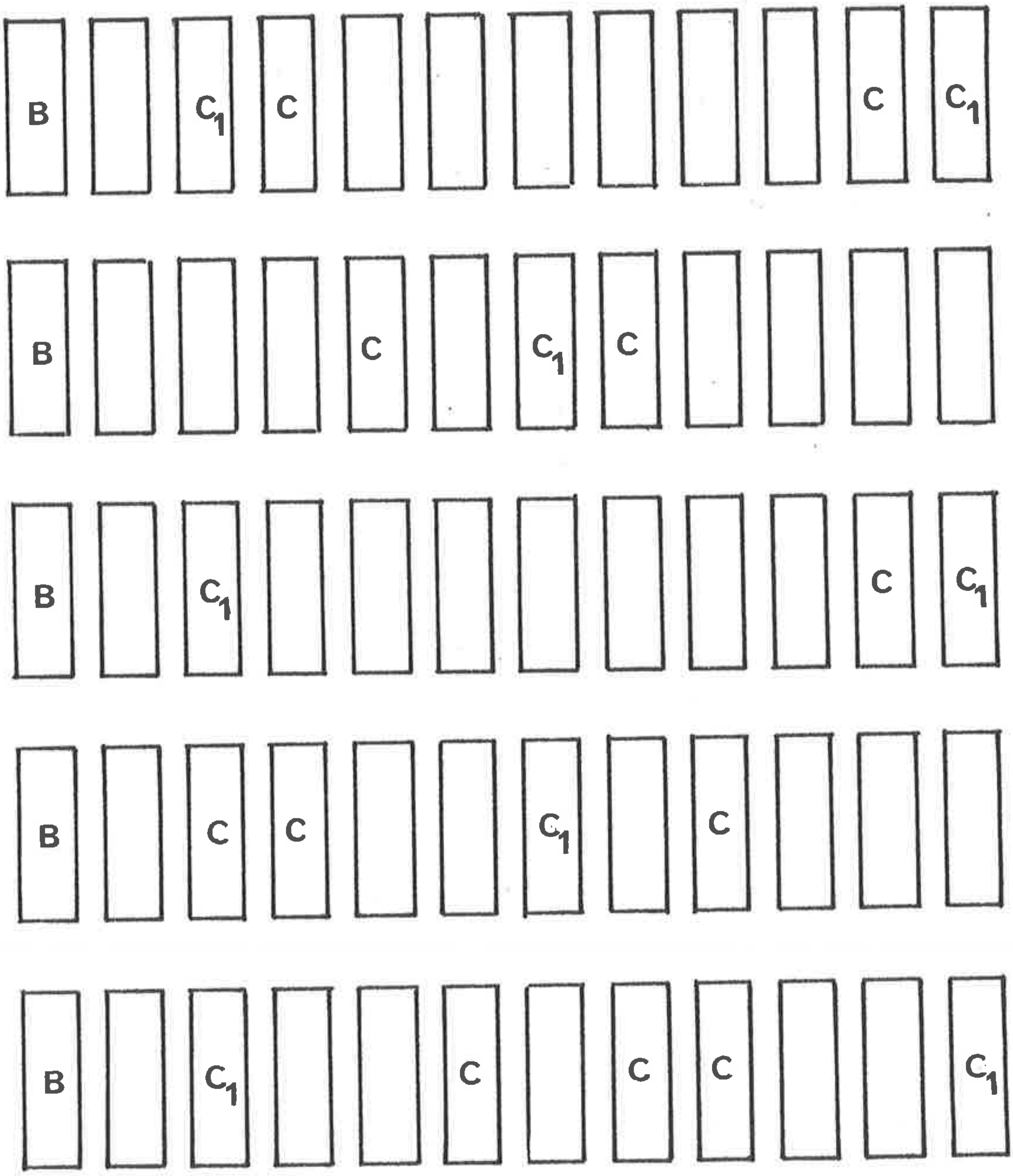
Field layout

The design was a randomized block with 2 replicates. The layout of a block is illustrated in Figure 2.4. The checks of Warimba were one in every nine plots and other checks were placed at random. The number of plots in a replicate was 825.

Harvesting

Harvesting was done using a stripper harvester on December 17 and 18 in 1977, January 3 and 4 in 1979 and January 15 and 16 in 1980.

Figure 2.4. Part of the field plot layout of experiment 4.



B = border plot

C_1 = Warimba plot

C = other checks plot

CHAPTER 3. RESULTS

3.1 Result of experiment 1

3.1.1 Introduction

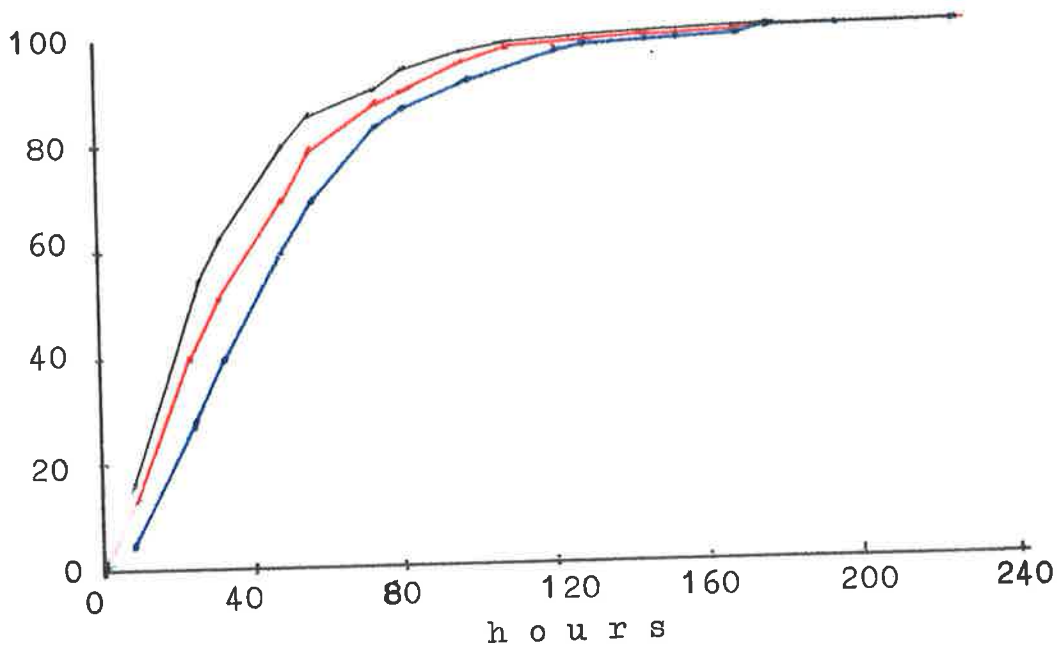
Analyses of variance were undertaken to evaluate statistical differences between genotypes and replicates (Appendix 1). Many of the characters when illustrated as histograms showed a positive skew. Logarithmic transformations were made of the results to make these distributions more symmetrical. For all the characters observed except plant height, there were ~~statistical~~ significant differences across replicates, so the comparison between the F_2 and parental values were considered for each replicate in each cross. When the results are similar, only some examples are presented.

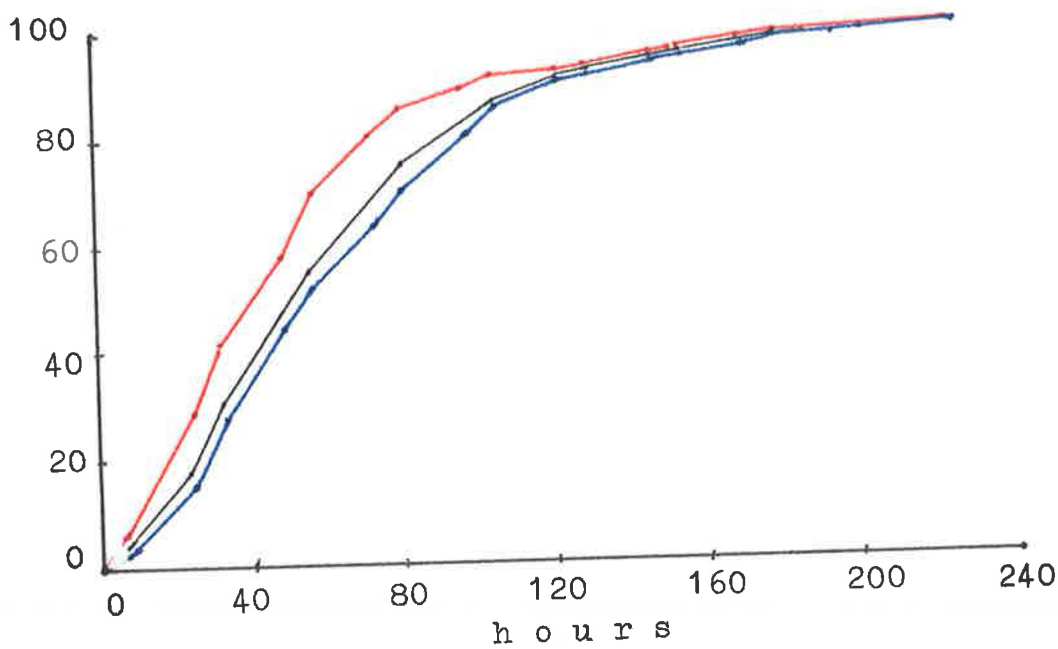
3.1.2 Seed weight and seedling emergence time

The seed weight values were normally distributed (Appendix 2) and ranged from 25 - 70 mg per seed. Seeds began emerging 8 days after sowing and most emergence occurred in a four day period commencing on the 9^{th} day. The cumulative percentage distributions are shown in Figure 3.1. The forms of the distributions were similar, however, the F_2's distributions of cross 1 and 3 were between the parental distributions, but in cross 2 the emergence of the F_2's were relatively faster than the parents. There was no consistent evidence that the populations with a larger mean weight of seed emerged earlier than populations with small seeds.

The distributions of seedling emergence time and the distribution for grain yield at maturity were positively skewed. It is not strictly correct therefore to analyse the regression of these characters on the

Figure 3.1. Cumulative percentage of seedling emergence time. The X axis is time from first emergence of a seedling and the Y axis the percentage cumulative of emergence. The blue curve is parent 1, the black is parent 2 and the red is the F_2. P_1 is the same genotype in cross 1 and 2 and P_2 of cross 2 (black) is the same as P_1 of cross 3 (blue).


100
80
60
40
20
0
0
40
80
120
160
200
240
h o u r s


100
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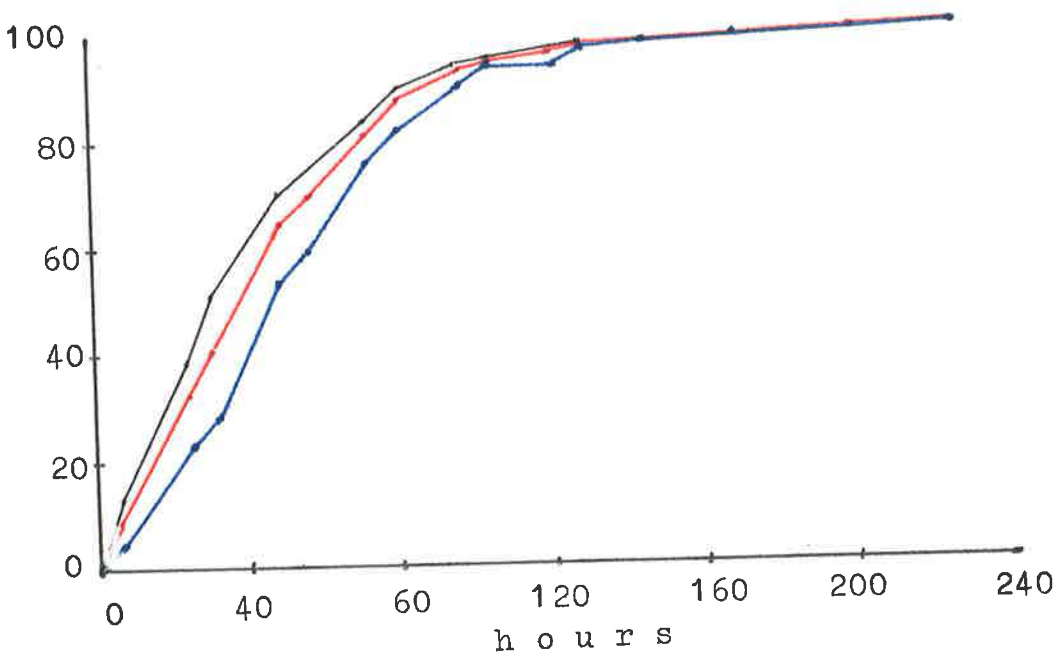
h o u r s


100
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120
160
200
240
h o u r s

weights of seeds sown. However for illustrative purposes these regressions are presented.

The regression of emergence time on seed weight showed that for only 7 of the 27 plots were the regressions significant (Table 3.1 and examples in Figure 3.2). Although there were relatively few significant regressions, very many of the coefficients were negative and it appears there was some tendency for the bigger seeds to result in seedlings that emerged earlier.

Figure 3.3 depicts the regression of final grain yield per plant on emergence time. Regression analysis showed that 22 of the 27 plots were significant (Table 3.2). It indicates that earlier emergence often resulted in higher grain yields. However other factors influenced the relationship, so that there was considerable variation in yield for any one emergence time.

There were some significant regressions of final grain yield per plant on the weight of seeds sown (Table 3.3) and heavier seeds tended to result in plants with higher yields. This effect was not as strong as that of seedling emergence time. Examples of the regression between these characters are illustrated in Figure 3.4.

Table 3.1. Linear regression coefficients (b) and coefficients of determination (R^2) for the regression of seedling emergence time on seed weight.

Cross	Rep.	P_1 b	P_1 R^2	F_2 b	F_2 R^2	P_2 b	P_2 R^2
1	1	-1.001±0.426*	0.05	-0.841±0.273**	0.08	-0.051±0.193	0.00
	2	-0.232±0.443	0.00	-0.430±0.261	0.02	-0.326±0.340	0.01
	3	-1.285±0.450**	0.07	-0.686±0.392	0.03	-1.140±0.398**	0.08
2	1	-1.115±0.890	0.02	0.147±0.345	0.00	-0.469±0.481	0.01
	2	0.083±0.507	0.00	-0.955±0.880	0.02	0.038±1.026	0.00
	3	0.321±0.487	0.00	-0.179±0.379	0.00	-3.468±1.004***	0.18
3	1	-1.048±0.643	0.03	-0.718±0.426	0.03	-1.193±0.487*	0.07
	2	0.311±0.500	0.01	-0.142±0.556	0.00	-0.485±0.518	0.01
	3	-1.374±0.844	0.03	-1.116±0.698	0.03	-1.337±0.664*	0.05

*, **, *** these denote significance at the 5%, 1% and 0.1% levels respectively.

Table 3.2. Linear regression coefficients (b) and coefficients of determination (R^2) for the regression of final grain yield on seedling emergence time.

Cross	Rep.	P_1 b	P_1 R^2	F_2 b	F_2 R^2	P_2 b	P_2 R^2
1	1	-0.032±0.008***	0.13	-0.030±0.011**	0.07	-0.060±0.017***	0.11
	2	-0.011±0.005**	0.04	-0.040±0.010***	0.12	-0.030±0.009**	0.09
	3	-0.032±0.007***	0.15	-0.023±0.008**	0.08	-0.025±0.008**	0.09
2	1	-0.013±0.004**	0.12	-0.008±0.008	0.01	-0.007±0.005	0.02
	2	-0.003±0.006	0.00	-0.016±0.006**	0.09	-0.010±0.004**	0.09
	3	-0.012±0.004**	0.07	-0.018±0.005***	0.10	-0.017±0.008*	0.10
3	1	-0.020±0.006**	0.09	-0.012±0.008	0.02	-0.012±0.006	0.04
	2	-0.025±0.007***	0.13	-0.028±0.007***	0.14	-0.023±0.008**	0.10
	3	-0.021±0.006***	0.15	-0.020±0.007**	0.10	-0.015±0.006**	0.10

*, **, *** these denote significance at the 5%, 1% and 0.1% levels respectively.

Table 3.3. Linear regression coefficients (b) and coefficients of determination (R^2) for the regression of final grain yield on seed (i.e. the seed sown).

Cross	Rep.	P_1		F_2		P_2	
		b	R^2	b	R^2	b	R^2
1	1	0.077±0.035*	0.04	0.129±0.029***	0.15	0.056±0.035	0.02
	2	0.042±0.025	0.02	0.057±0.029	0.03	0.035±0.034	0.01
	3	0.145±0.032***	0.14	0.085±0.033**	0.06	0.067±0.035	0.04
2	1	0.052±0.032	0.04	0.062±0.028*	0.05	0.027±0.023	0.01
	2	0.026±0.031	0.01	0.120±0.047*	0.09	0.032±0.035	0.01
	3	0.027±0.023	0.01	0.071±0.021***	0.10	0.119±0.057*	0.07
3	1	0.110±0.041**	0.07	0.089±0.035*	0.06	0.116±0.030***	0.15
	2	0.042±0.036	0.02	0.032±0.041	0.01	0.087±0.037*	0.07
	3	0.032±0.046	0.01	0.115±0.045*	0.08	0.043±0.034	0.02

*, **, *** these denote significance at the 5%, 1% and 0.1% levels respectively.

Figure 3.2. The relationship between the seed weight in mg (X axis) and the time of seedling emergence in hours (Y axis), in single plots

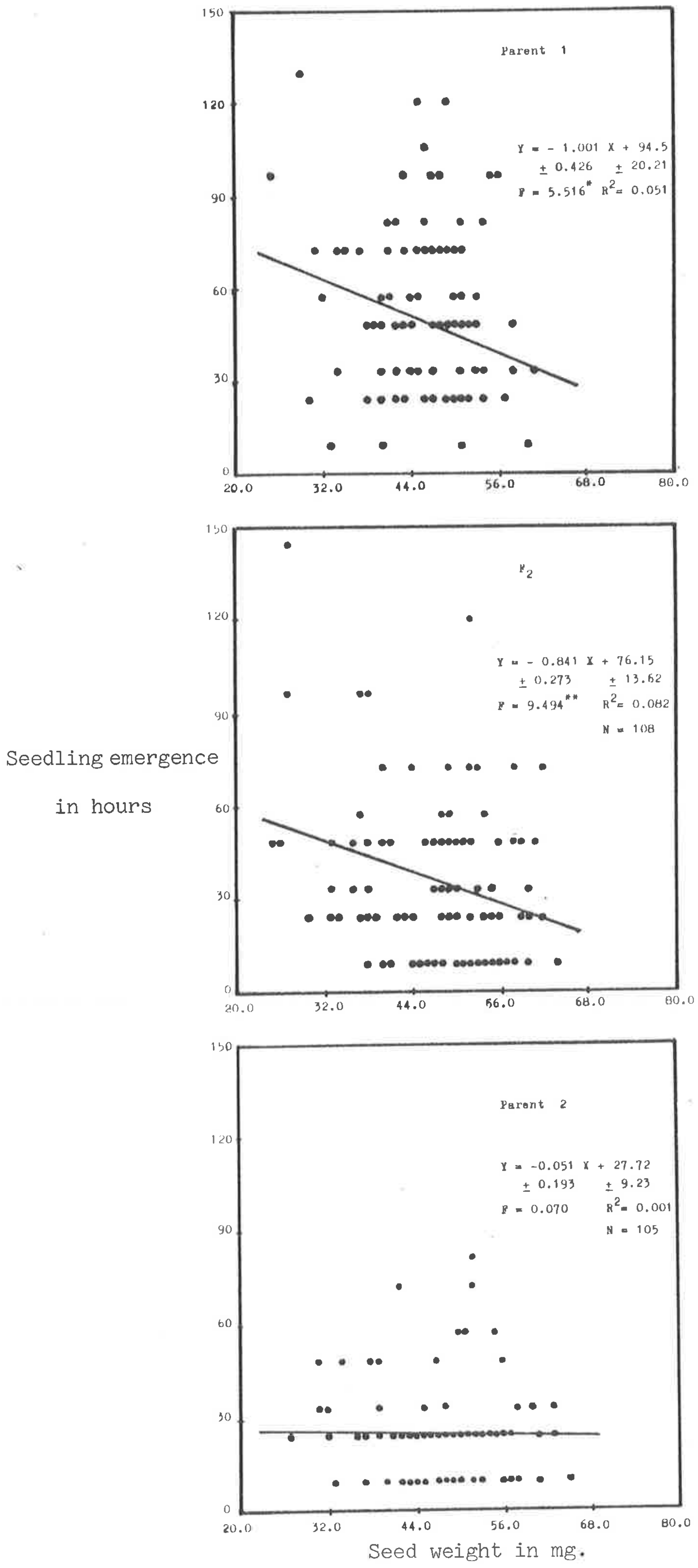
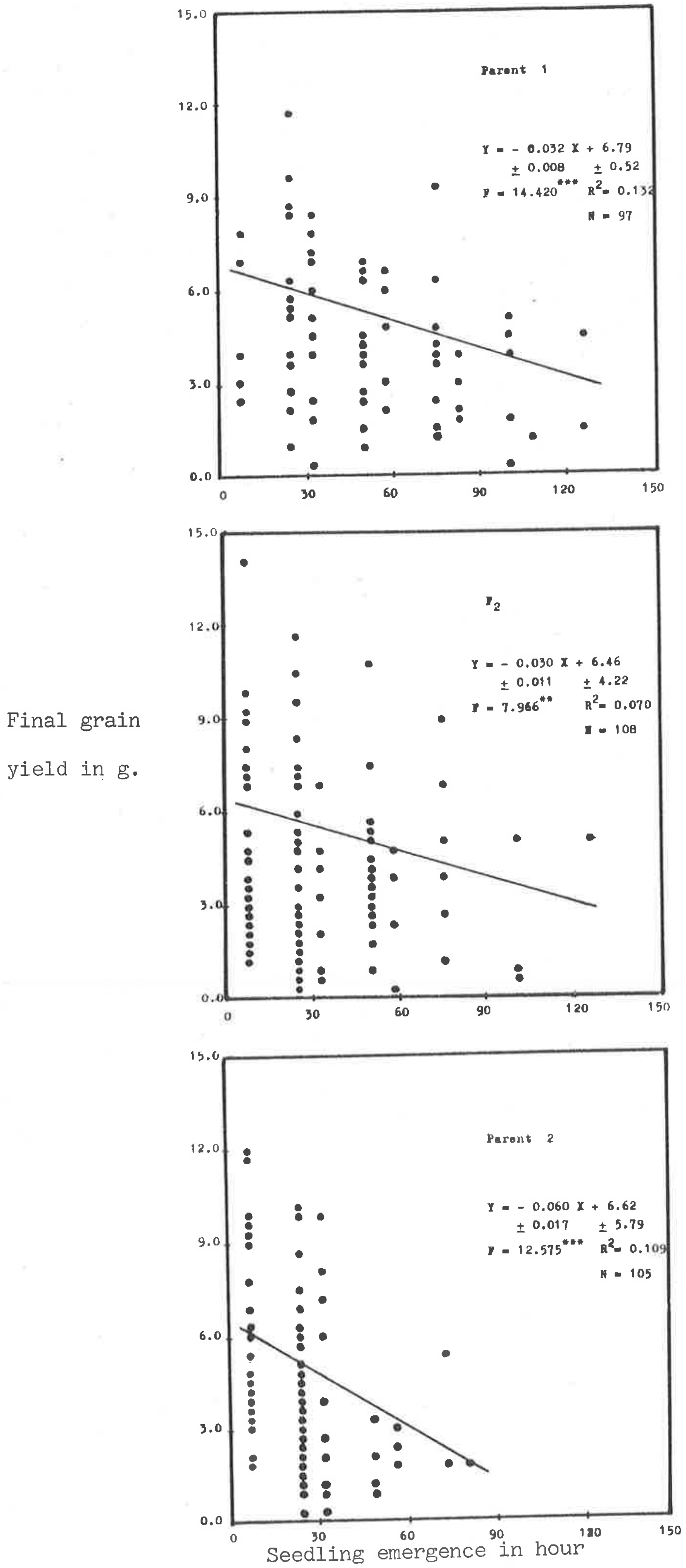
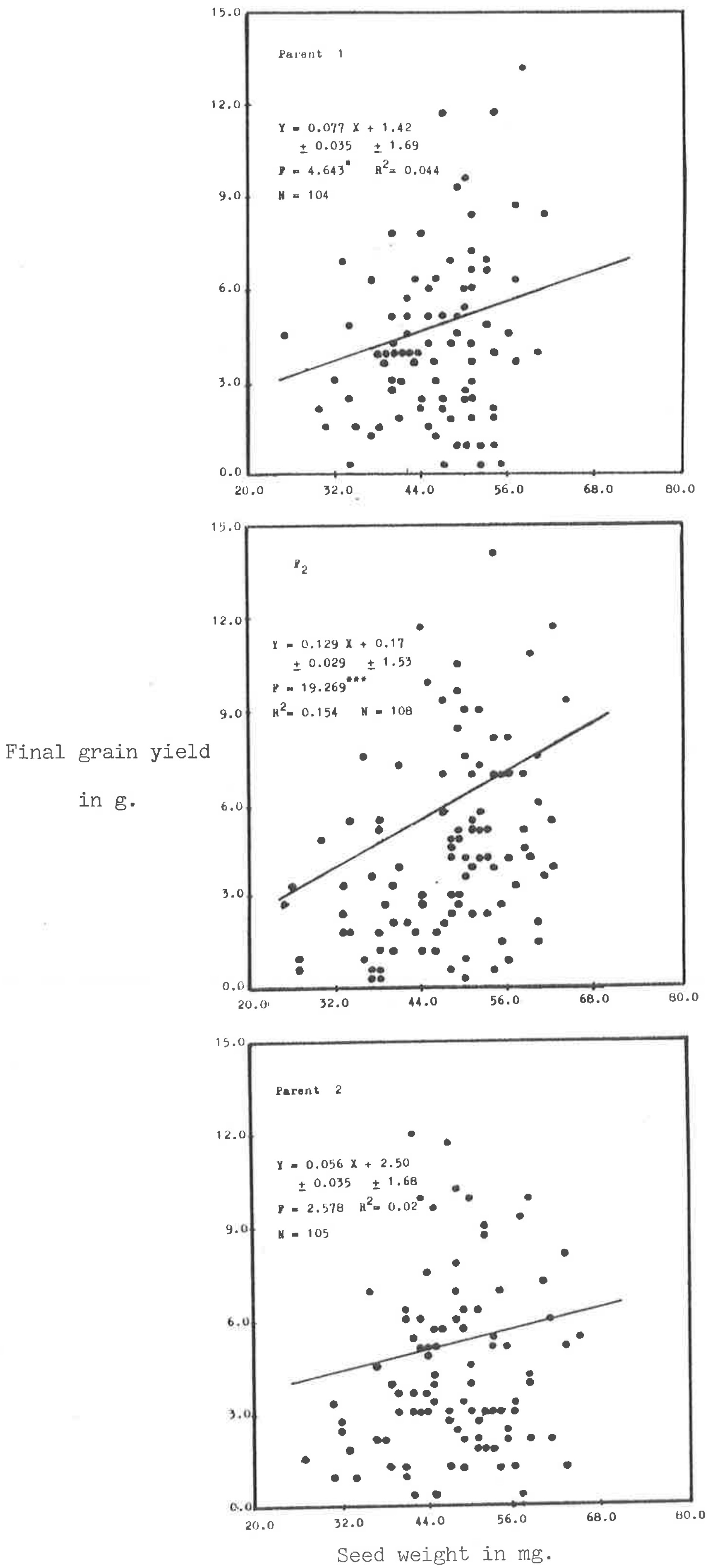

Parent 1
Y = - 1.001 X + 94.5
± 0.426 ± 20.21
F = 5.516* R2= 0.051
F2
Y = - 0.841 X + 76.15
± 0.273 ± 13.62
F = 9.494** R2= 0.082
N = 108
Parent 2
Y = -0.051 X + 27.72
± 0.193 ± 9.23
F = 0.070 R2= 0.001
N = 105
Seedling emergence
in hours
Seed weight in mg.
0
30
60
90
120
150
20.0
32.0
44.0
56.0
68.0
80.0

Figure 3.3. The relationship between the time of seedling emergence in hours (X axis) and final grain yield in g. (Y axis).



Final grain yield in g.
Parent 1
Y = - 0.032 X + 6.79
± 0.008 ± 0.52
F = 14.420*** R2= 0.132
N = 97
F2
Y = - 0.030 X + 6.46
± 0.011 ± 4.22
F = 7.966** R2= 0.070
N = 108
Parent 2
Y = - 0.060 X + 6.62
± 0.017 ± 5.79
F = 12.575*** R2= 0.109
N = 105
Seedling emergence in hour

Figure 3.4. The relationship between the weight of seed sown (X axis) and grain yield of the resulting plant in g. (Y axis).


Parent 1
Y = 0.077 X + 1.42
± 0.035 ± 1.69
F = 4.643* R2= 0.044
N = 104
F2
Y = 0.129 X + 0.17
± 0.029 ± 1.53
F = 19.269***
R2= 0.154 N = 108
Parent 2
Y = 0.056 X + 2.50
± 0.035 ± 1.68
F = 2.578 R2= 0.02
N = 105
0.0
3.0
6.0
9.0
12.0
15.0
20.0
32.0
44.0
56.0
68.0
80.0
Final grain yield in g.
Seed weight in mg.

3.1.3 Plant weight

There were highly significant genotype x replicate interactions for the three crosses (Appendix 1) and the mean values varied considerably with the replicates (Table 3.4). This is indicative of the microenvironmental effects on plant weight. The variances were variable and there was no consistent evidence that the F_2 plants had higher variances.

The strong positive skews of the frequency distributions are evident from Figure 3.5. These skews are characteristic of distributions for the weight of plants grown at crop density. The shapes of the F_2 distributions were similar to those of one or both of the parental distributions. In all crosses there were some F_2 plants with values exceeding that of both parents, indicating transgressive segregation.

From the serial correlation analysis no clear information was obtained of the influence of a plant on its neighbours (Table 3.5). However there were more significant negative coefficients than positive coefficients, indicating perhaps the effects of competition.

Table 3.4. Means and variances of plants weights (in g.)

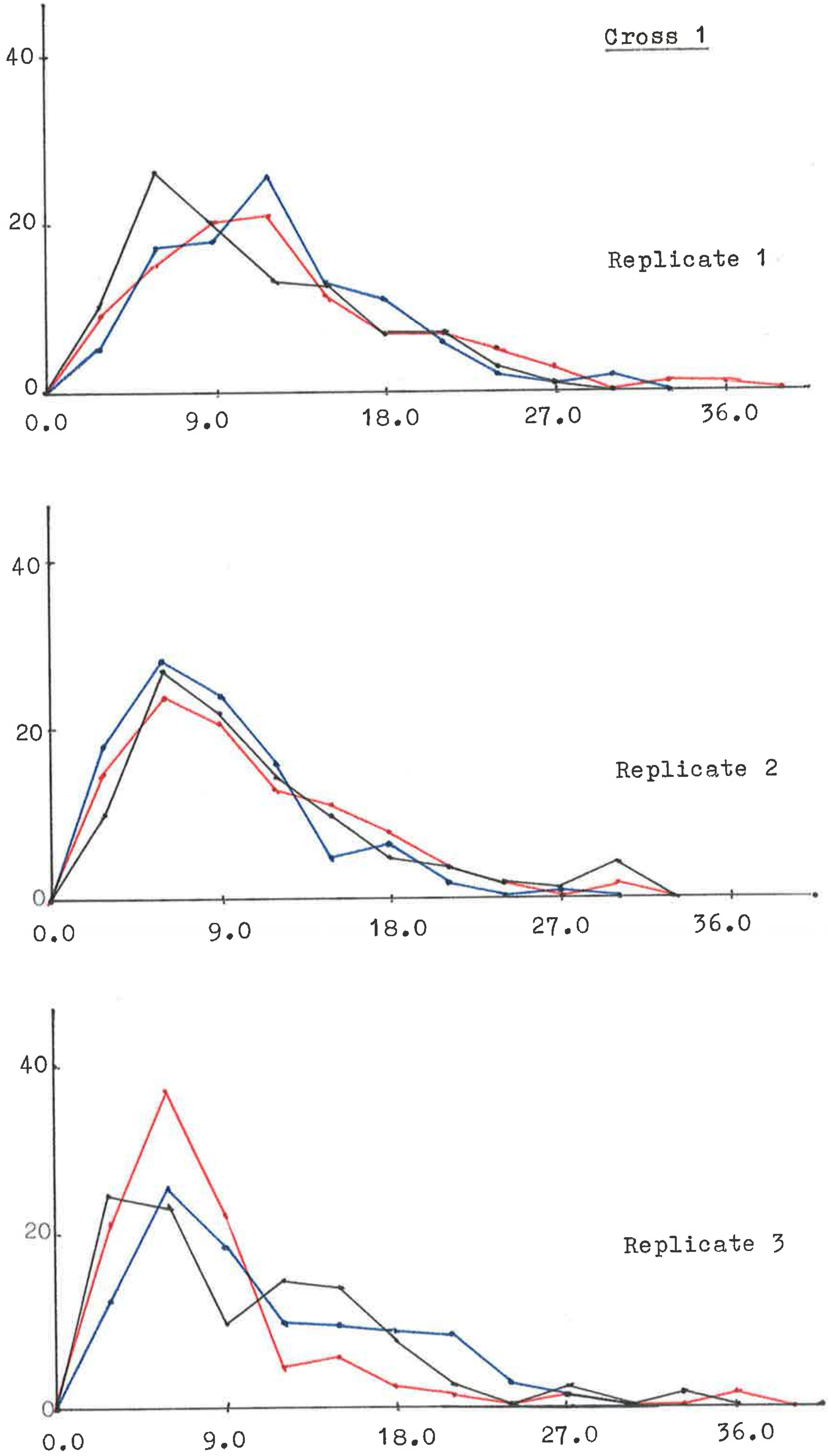
Cross	Rep.	Mean			Variance		
		P_1	F_2	P_2	P_1	F_2	P_2
1	1	10.92	11.28	9.53	33.66	47.01	33.55
	2	7.46	8.92	9.51	22.16	34.59	42.47
	3	9.68	6.57	8.15	40.38	26.89	36.48
2	1	6.09	7.71	5.15	19.39	34.86	10.58
	2	7.08	9.62	5.72	26.10	61.18	16.63
	3	5.43	5.57	9.11	13.23	19.80	43.04
3	1	7.18	7.96	6.57	29.06	29.08	24.29
	2	7.30	9.43	10.45	25.68	33.91	28.90
	3	6.88	10.13	7.24	32.53	43.49	19.44

Table 3.5. Serial correlations of plants with their neighbours.

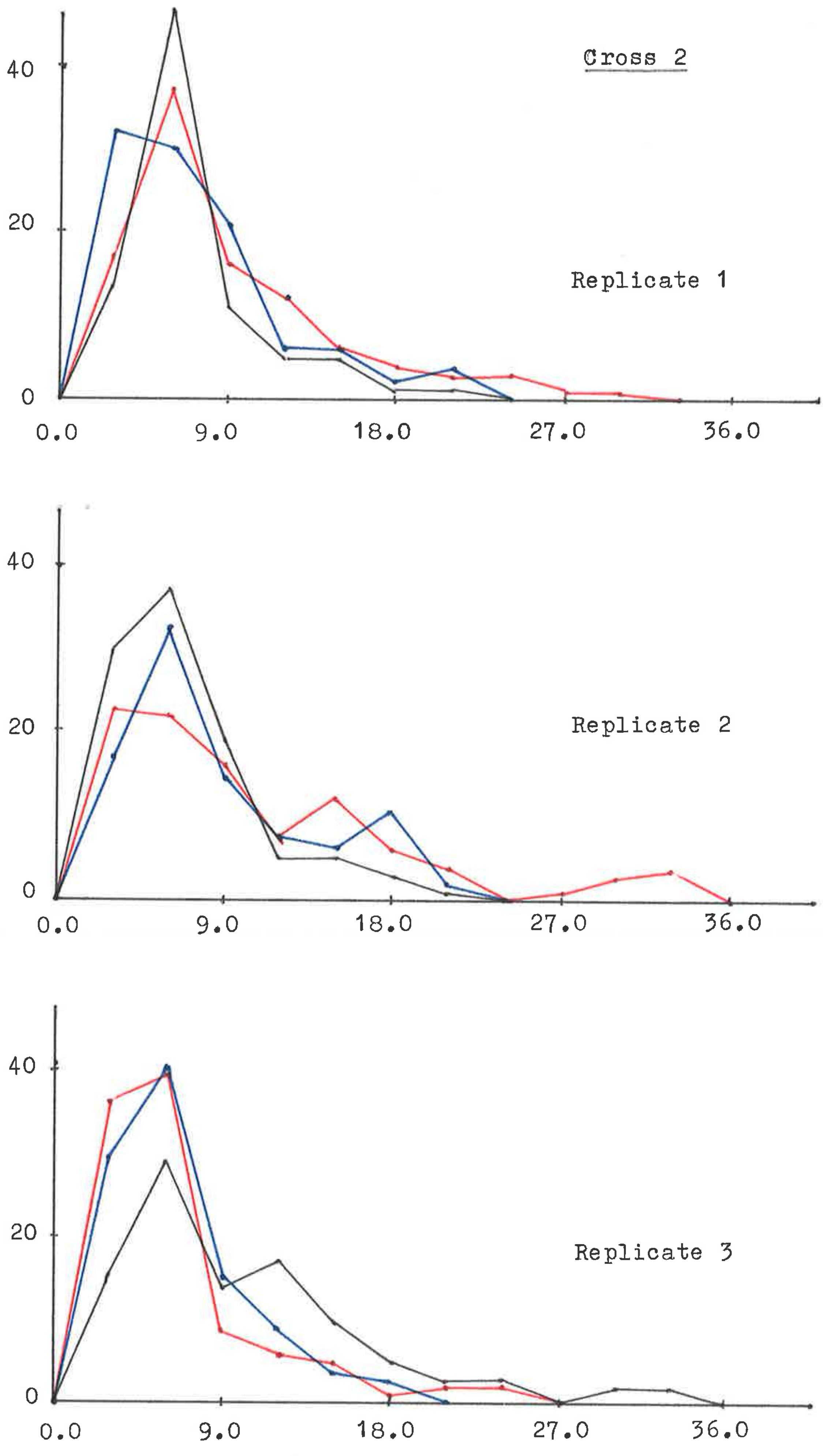
Cross		Rep. 1			Rep. 2			Rep. 3		
		row								
		1	2	3	1	2	3	1	2	3
1	P_1	0.2	-.17	-.17	.25	-.04	.15	-.33*	-.22	-.08
	F_2	0.3	-.22	-.19	-.06	.21	.19	-.31*	-.19	-.14
	P_2	-.44**	-.18	-.38**	.06	.01	.01	-.15	-.25	.10
2	P_1	-.02	.17	.41**	.09	.41	.13	.11	-.45**	.15
	F_2	-.04	-.23	.17	-.04	-.27	-.35*	.27	.38*	.03
	P_2	-.24	.20	.11	.13	-.38**	.19	.33*	-.38**	-.05
3	P_1	-.16	.00	-.26	.14	-.10	.14	-.19	-.12	-.17
	F_2	-.24	.17	-.21	-.41**	-.17	.12	-.20	.11	-.06
	P_2	-.56***	.02	-.12	.07	-.10	-.05	.25	.11	-.39

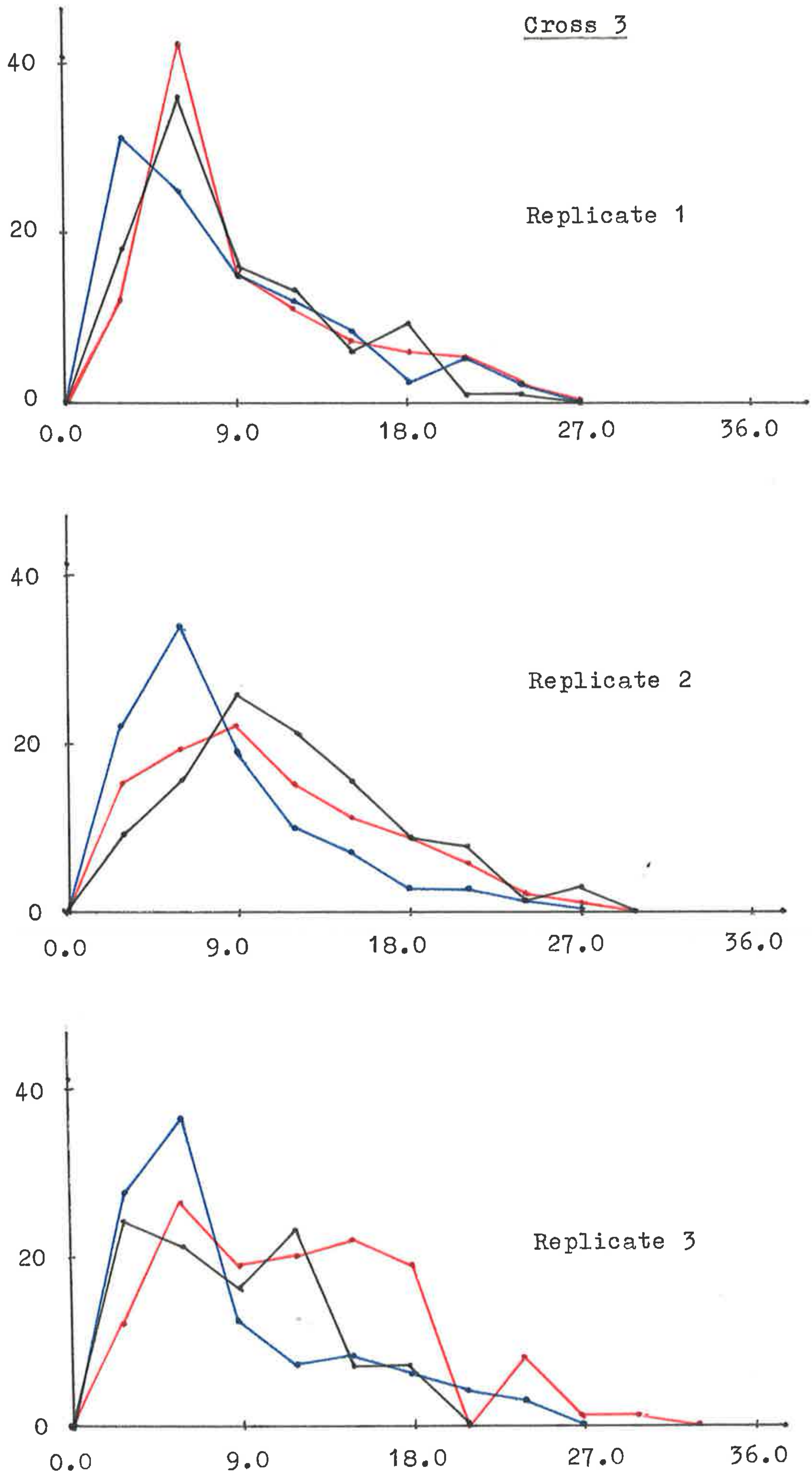
*, **, *** these denote significance at the 5%, 1% and 0.1% levels respectively.

Figure 3.5. Frequency distributions of plant weight. The X axis is the plant weight in g. and the Y axis the percentage frequency. The blue curve is parent 1, the black is parent 2 and the red is the F_2 distribution.



Cross 1
40
20
0
0.0
9.0
18.0
27.0
36.0
Replicate 1
40
20
0
0.0
9.0
18.0
27.0
36.0
Replicate 2
40
20
0
0.0
9.0
18.0
27.0
36.0
Replicate 3


Cross 2
Replicate 1
Replicate 2
Replicate 3
0
20
40
0.0
9.0
18.0
27.0
36.0


Cross 3
40
20
0
0.0
9.0
18.0
27.0
36.0
Replicate 1
40
20
0
0.0
9.0
18.0
27.0
36.0
Replicate 2
40
20
0
0.0
9.0
18.0
27.0
36.0
Replicate 3

3.1.4 Main shoot grain yield

There were no significant differences among genotypes, replicates or their interactions for this character (Appendix 1). The mean values are given in Table 3.6. The variances provides no evidence of segregation in the F_2.

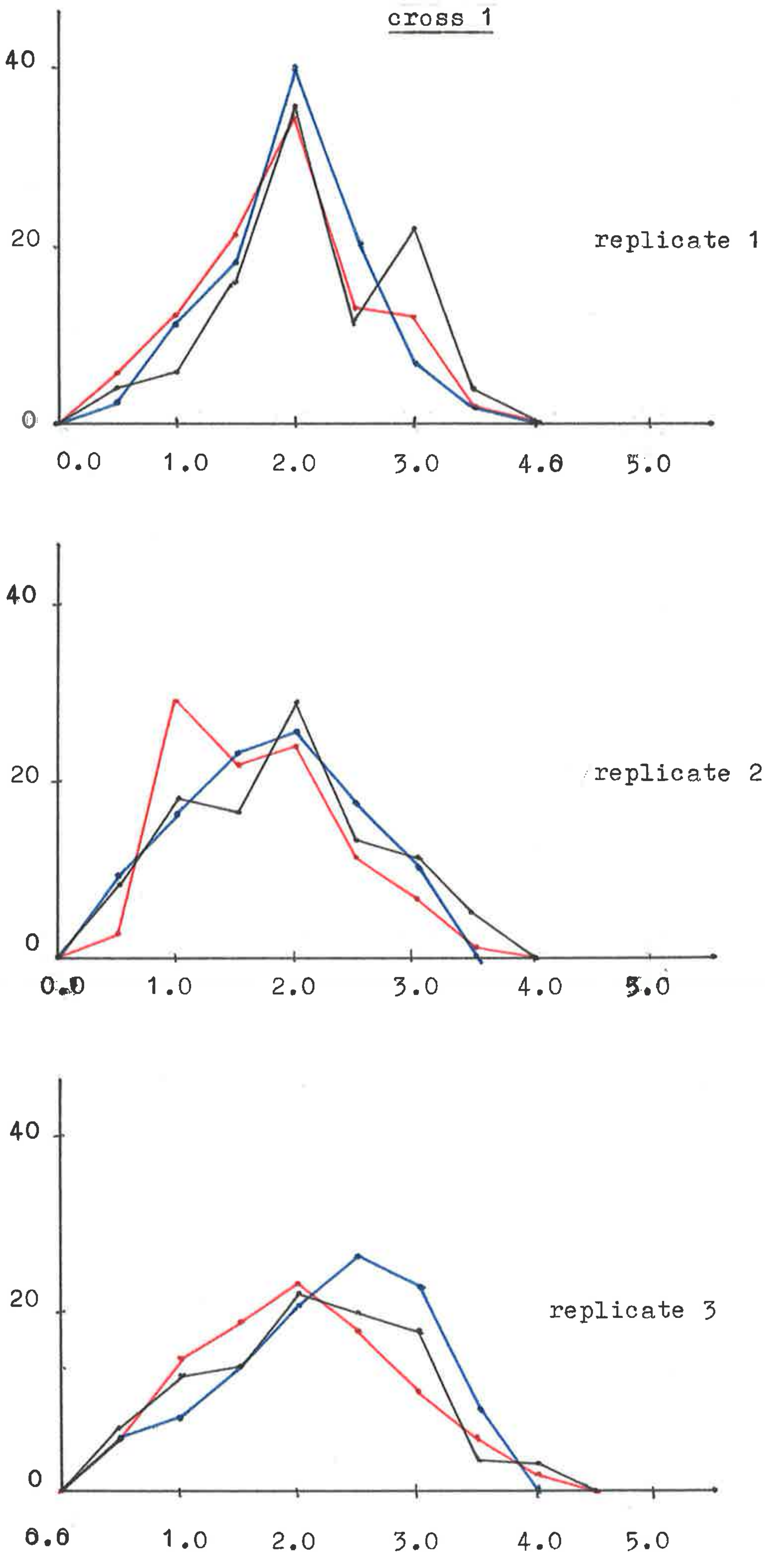
Examples of the frequency distributions shown in Figure 3.6 reflect the analysis above.

The serial correlation analyses are not presented as no trends were evident.

Table 3.6. Means and variances of main shoot grain weight (in g.)

Cross	Rep.	Mean			Variance		
		P_1	F_2	P_2	P_1	F_2	P_2
1	1	1.71	1.77	1.96	4.02	5.51	5.15
	2	1.58	1.56	1.66	5.27	4.82	6.28
	3	2.03	1.80	1.90	5.77	6.84	7.66
2	1	2.11	2.05	1.54	9.11	6.71	4.66
	2	2.02	1.81	1.70	6.94	5.77	5.35
	3	1.92	1.75	1.71	8.10	5.89	4.43
3	1	1.91	2.14	1.88	6.84	6.23	8.21
	2	1.80	1.86	2.09	5.31	5.22	3.74
	3	1.75	2.01	1.79	6.54	5.46	4.15

Figure 3.6. Frequency distributions of main shoot grain yield. The X axis is the main shoot grain weight in g. and the Y axis the percentage frequency. The blue curve is parent 1, the black is parent 2 and the red is the F_2 distribution.


cross 1
40
20
0
0.0
1.0
2.0
3.0
4.0
5.0
replicate 1
40
20
0
0.0
1.0
2.0
3.0
4.0
5.0
replicate 2
40
20
0
0.0
1.0
2.0
3.0
4.0
5.0
replicate 3

3.1.5 Head number

There were highly significant genotype x replicate interactions for all the crosses (Appendix 1). The mean values and variances are given in Table 3.7. The number of heads per plant was very low as a result of the competition at crop density. Most of the F_2 variances were slightly higher than the mean of both parents, however few were greater than that of both parents

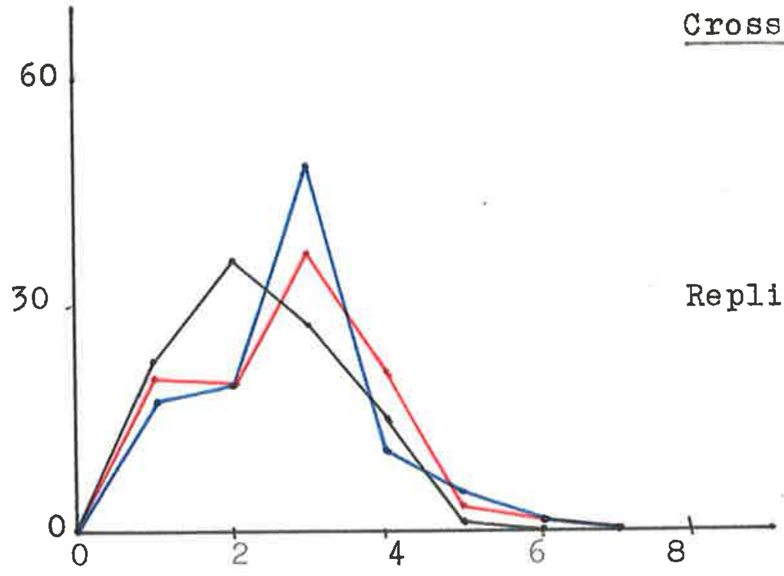
Example of the frequency distributions are presented in Figure 3.7. There were all positively skewed.

Table 3.7. Means and variances of head number.

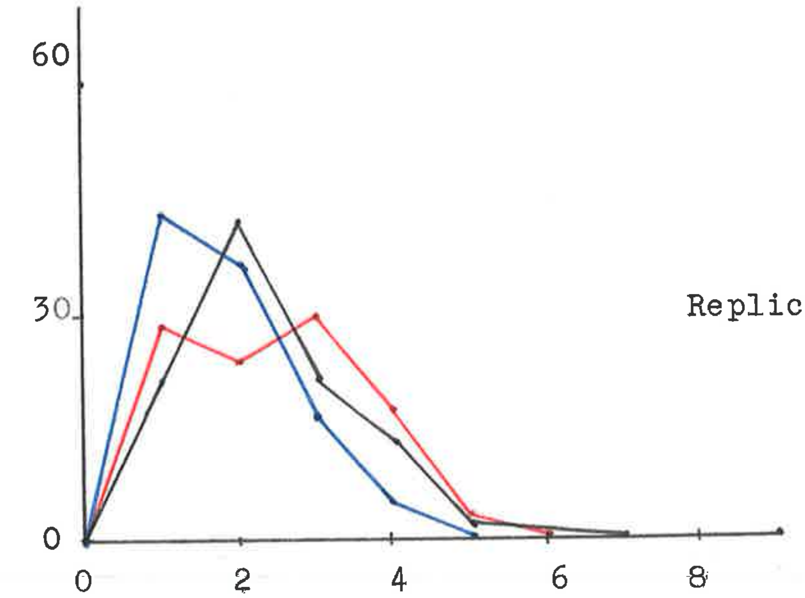
Cross	Rep.	Mean			Variance		
		P_1	F_2	P_2	P_1	F_2	P_2
1	1	2.71	2.70	2.36	1.21	1.34	1.06
	2	1.82	2.43	2.34	0.76	1.32	1.16
	3	2.19	1.59	1.91	1.35	0.80	0.93
2	1	1.38	1.79	1.31	0.43	1.11	0.41
	2	1.67	2.26	1.54	0.73	1.75	0.59
	3	1.27	1.34	1.98	0.55	0.47	1.28
3	1	1.76	1.85	1.60	1.01	1.06	0.70
	2	1.78	2.21	2.43	0.05	1.30	0.89
	3	1.69	2.13	1.78	0.97	1.18	0.70

Figure 3.7. Frequency distributions of head number. The X axis is the head number and the Y axis the percentage frequency. The blue curve is parent 1, the black is parent 2 and the red is the F_2 distribution.

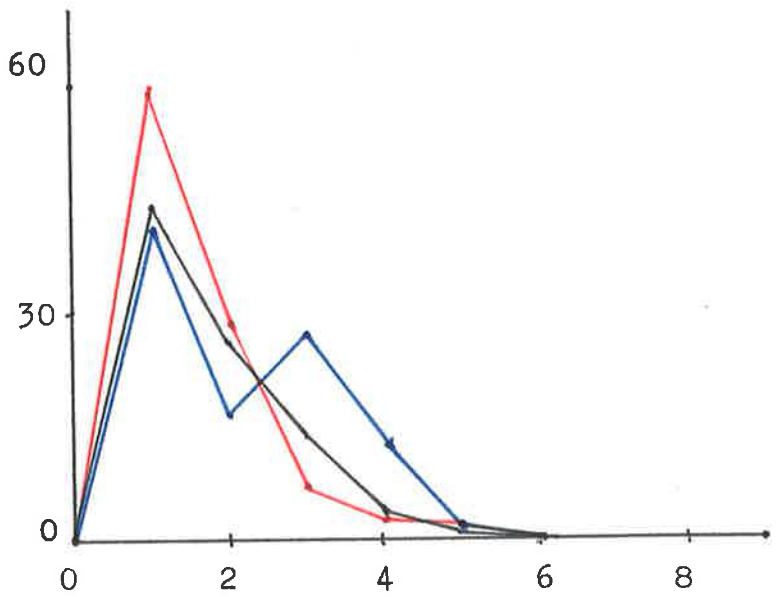
Cross 1



Replicate 1



Replicate 2



3.1.6 Final grain yield

Significant differences were found only for the genotype x replicate interactions (Appendix 1). These differences were not as big as for plant weight or head number. The means and variances of the F_2's and their parents showed a similar pattern to that of plant weight (Table 3.8).

The frequency distributions show very strong positive skews (Figure 3.8). The F_2 distributions covered the combined range of the parental distributions and transgressive segregation occurred commonly. The patterns of the frequency distributions were similar to those for plant weight.

There was no strong indication from the serial correlation analysis of the effects of competition but as with plant weight many correlations were negative (Table 3.9).

Table 3.8. Means and variances of final grain yield (in g.)

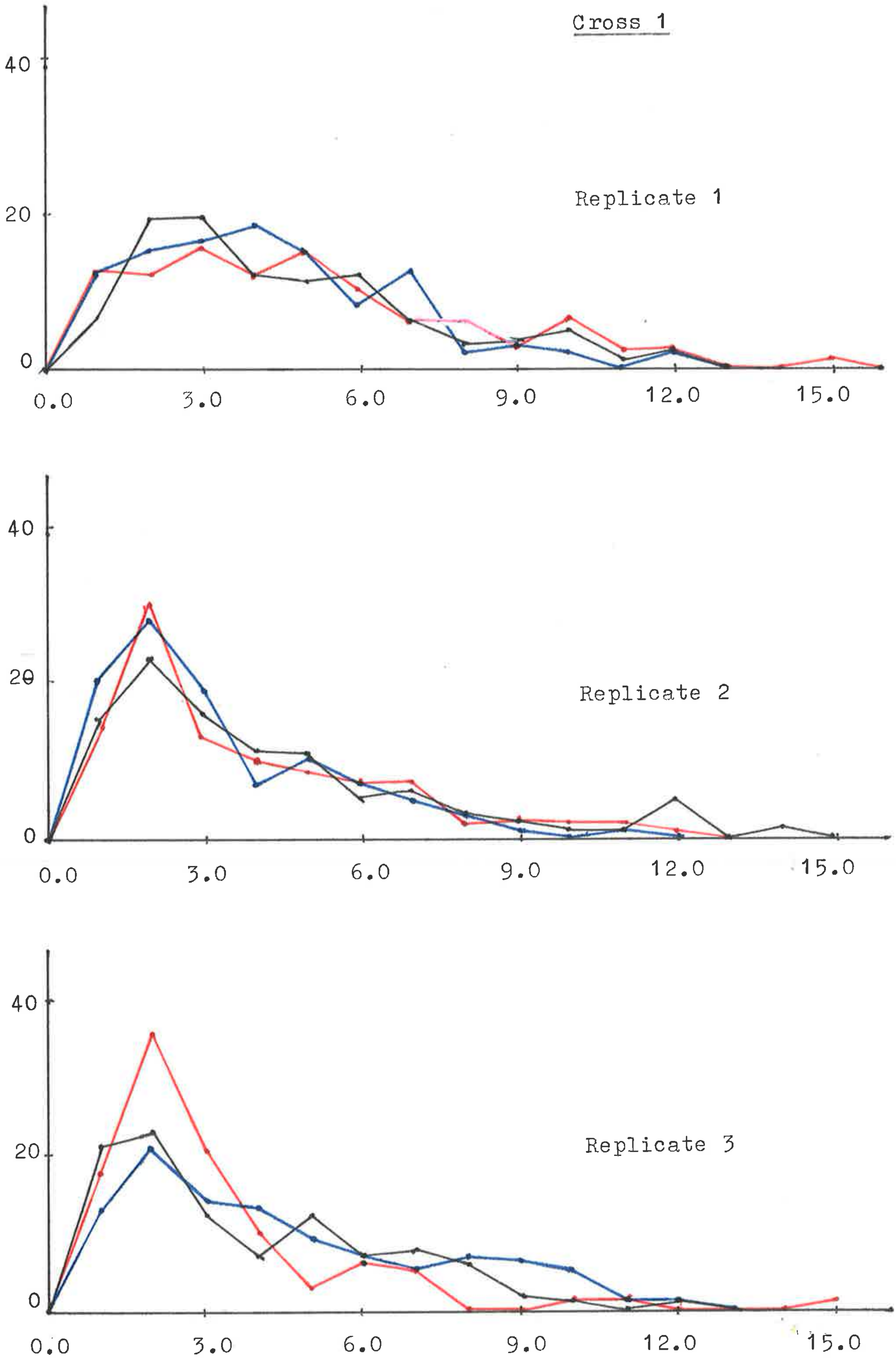
Cross	Rep.	Mean			Variance		
		P_2	F_2	P_2	P_1	F_2	P_2
1	1	3.98	4.41	4.16	7.23	8.69	7.67
	2	2.76	3.49	3.75	4.55	6.75	9.57
	3	3.89	2.92	3.60	8.04	7.87	8.37
2	1	2.66	3.32	1.98	3.71	6.54	2.31
	2	3.15	3.93	2.44	5.07	10.42	3.01
	3	2.32	2.36	3.32	2.85	3.71	6.62
3	1	3.03	3.47	3.24	4.93	5.80	4.84
	2	2.76	3.85	4.58	3.65	6.02	5.85
	3	2.84	4.00	2.92	5.09	7.43	3.39

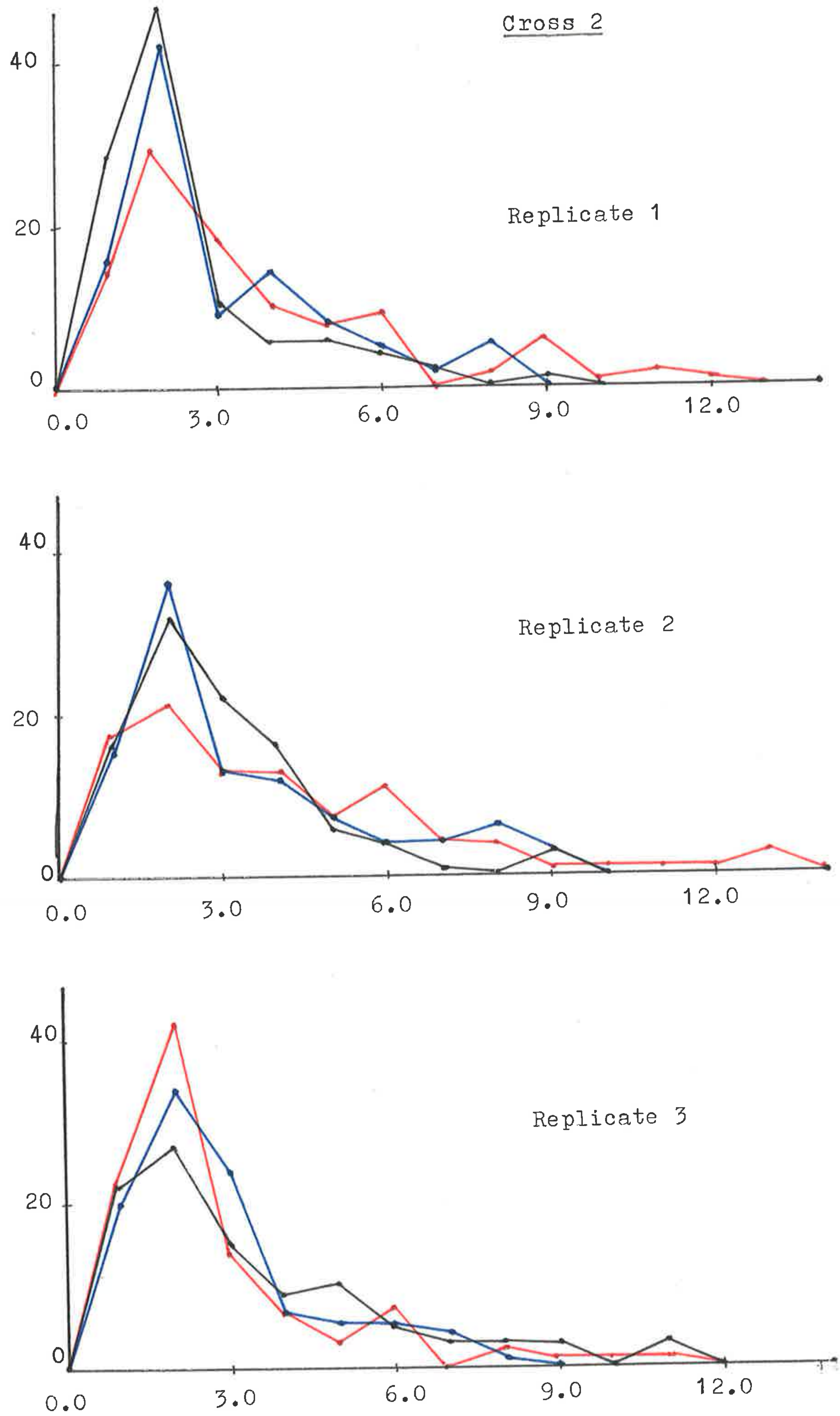
Table 3.9. Serial correlation of plants with their neighbours.

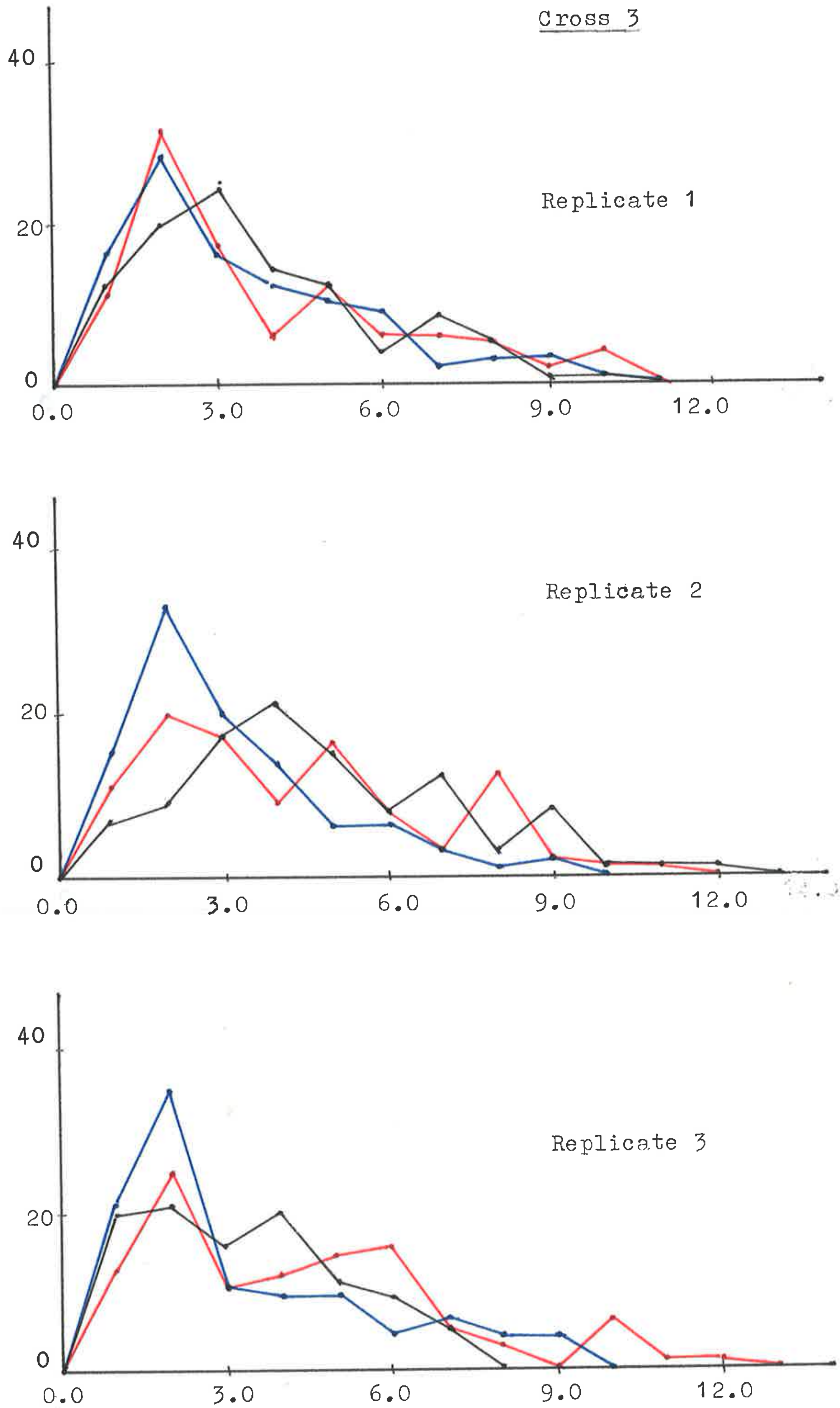
Cross		Rep. 1			Rep. 2			Rep. 3		
		r o w								
		1	2	3	1	2	3	1	2	3
1	P_1	.03	-.18	-.18	.38*	.04	.09	-.24	-.30	-.10
	F_2	.10	-.22	-.20	.05	.15	.13	-.19	-.19	-.12
	P_2	-.42**	-.15	-.14	-.01	.08	.11	-.23	-.10	.03
2	P_1	.06	.14	.37*	.05	.31*	.09	-.03	-.38*	.37*
	F_2	-.09	-.18	.16	-.13	-.27	-.33*	.13	.39**	.02
	P_2	-.22	.25	.05	.20	-.35*	.09	.31*	-.44**	-.02
3	P_1	-.14	-.09	-.32*	-.15	-.19	.09	-.15	-.18	-.17
	F_2	-.22	.05	-.17	-.32	-.15	.04	-.23	.14	-.01
	P_2	-.50***	.03	-.20	.09	-.19	.04	.22	.13	-.38*

*, **, *** these denote significance at the 5%, 1% and 0.1% levels respectively.

Figure 3.8. Frequency distributions of final grain yield per plant. The X axis if the final grain yield in g. and the Y axis the percentage frequency. The blue curve is parent 1, the black is parent 2 and the red is the F_2 distribution.


Cross 1
Replicate 1
40
20
0
0.0
3.0
6.0
9.0
12.0
15.0
Replicate 2
40
20
0
0.0
3.0
6.0
9.0
12.0
15.0
Replicate 3
40
20
0
0.0
3.0
6.0
9.0
12.0
15.0


Cross 2
Replicate 1
40
20
0
0.0
3.0
6.0
9.0
12.0
Replicate 2
40
20
0
0.0
3.0
6.0
9.0
12.0
Replicate 3
40
20
0
0.0
3.0
6.0
9.0
12.0


Cross 3
Replicate 1
40
20
0
0.0
3.0
6.0
9.0
12.0
Replicate 2
40
20
0
0.0
3.0
6.0
9.0
12.0
Replicate 3
40
20
0
0.0
3.0
6.0
9.0
12.0

3.1.7 Plant height

There were statistical differences between genotypes for plant height in crosses 1 and 2 (Appendix 1) with the F_2 means intermediate between the parental means. The F_2 variances were significantly larger than the parental variances indicating segregation (Table 3.10).

The frequency distributions (Figure 3.9) show clearly the greater variances of the F_2s. In cross 3 the F_2 distribution resembled one of the parental distribution.

There were consistent negative correlations between seedling emergence time and plant height (Table 3.12). Also there were highly significance correlations between plant height and final grain yield (Table 3.13). These correlations, however, were not greater among the F_2s than the parents even though the former had larger variances for height as a result of segregation. The relationship between time of seedling emergence, height and grain yield is of great significance for its effect on the efficiency of selection for yield by breeders of this crop.

The serial correlations between neighbours for height were variable being significantly positive or negative (Table 3.11) however that 12 of the correlations were positive and two were negative indicates that the response of height to competition was very different from the response of plant weight (Table 3.5) or final grain yield (Table 3.9).

Table 3.10. Mean and variance of plant height (in cm).

Cross	Rep.	Mean			Variance		
		P_1	F_2	P_2	P_1	F_2	P_2
1	1	109.1	105.8	94.3	38.1	164.0	102.8
	2	110.5	103.0	94.3	44.5	137.5	85.8
	3	106.7	100.5	90.6	51.8	163.1	118.6
2	1	95.3	97.8	88.4	71.9	221.0	60.1
	2	102.4	99.7	91.7	64.0	180.5	139.6
	3	97.6	95.3	94.2	91.2	176.9	126.6
3	1	95.1	95.4	87.1	121.5	70.3	189.3
	2	95.8	96.8	95.3	176.1	93.2	53.3
	3	93.6	94.5	85.1	210.9	135.2	101.1

Table 3.11. Serial correlation of plants with their neighbours.

Cross		Rep. 1			Rep. 2			Rep. 3		
		row								
		1	2	3	1	2	3	1	2	3
1	P_1	-.15	-.25	-.08	-.18	.11	.18	.02	.31*	-.16
	F_2	-.11	-.08	-.03	-.06	-.23	.11	-.13	.17	-.12
	P_2	-.02	-.18	.07	-.03	-.03	-.06	.17	-.23	.75***
2	P_1	.16	.52***	-.07	.06	-.30	.37*	.06	.06	-.08
	F_2	-.04	.03	-.12	.01	.12	-.14	.21	-.10	-.07
	P_2	.33*	.07	-.00	.22	.26	.53***	.19	.33*	-.01
3	P_1	.08	.04	-.11	-.50***	.43**	.48**	-.55***	-.07	.41**
	F_2	.35*	-.17	-.15	-.08	-.01	-.20	.22	.27	.31*
	P_2	-.16	-.17	.00	-.03	-.25	-.28	.02	.29	-.25

*, **, *** these denote significance at the 5%, 1% and 0.1% levels respectively.

Table 3.12. Correlation between seedling emergence time and plant height.

Cross	Rep.	P_1	F_2	P_2
1	1	-0.34***	-0.28**	-0.10
	2	-0.32***	-0.22*	-0.37***
	3	-0.25**	-0.17	-0.41***
2	1	-0.08	-0.17	-0.27**
	2	0.03	-0.29**	-0.24*
	3	-0.32***	-0.23**	-0.28*
3	1	-0.36***	-0.13	-0.08
	2	-0.40***	-0.41***	-0.45***
	3	-0.26**	-0.38***	-0.26

*, **, *** these denote significance at the 5%, 1% and 0.1% level respectively.

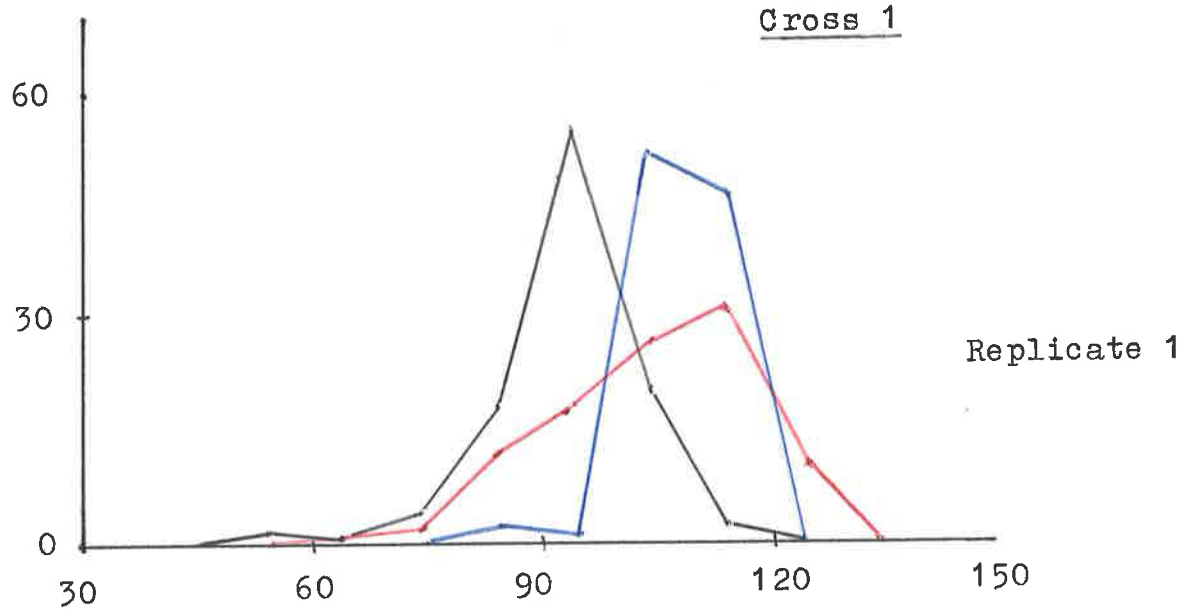
Table 3.13. Correlation between plant height and final grain yield.

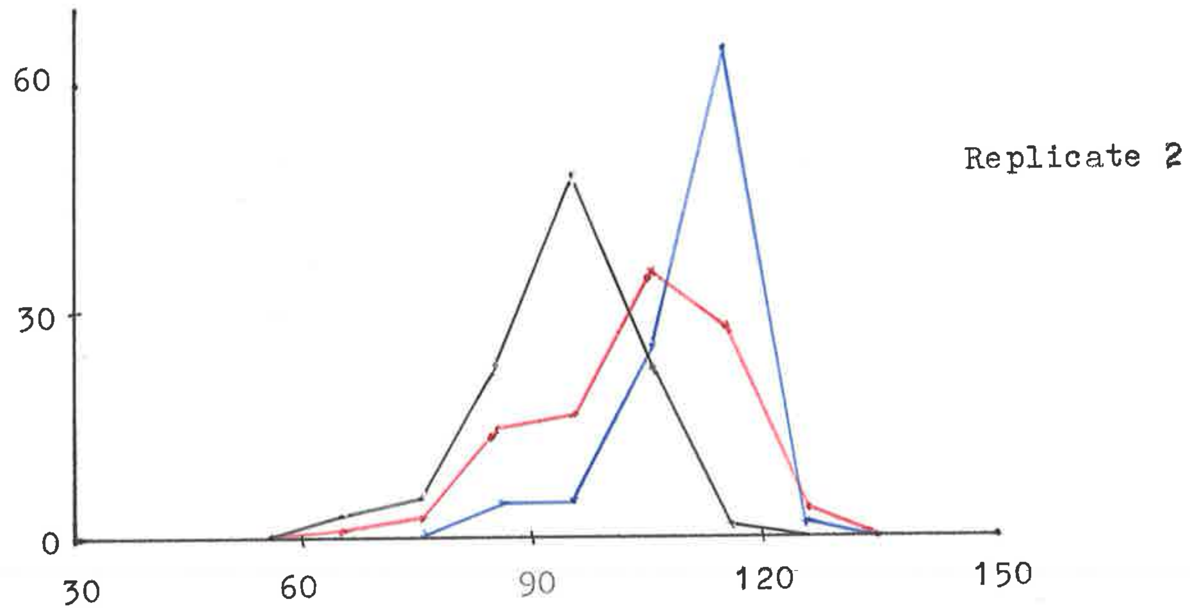
Cross	Rep.	P_1	F_2	P_2
1	1	0.48***	0.46***	0.53***
	2	0.39***	0.36***	0.68***
	3	0.60***	0.33***	0.61***
2	1	0.66***	0.59***	0.62***
	2	0.56***	0.62***	0.64***
	3	0.58***	0.49***	0.56***
3	1	0.59***	0.62***	0.43***
	2	0.65***	0.50***	0.68***
	3	0.64***	0.64***	0.67***

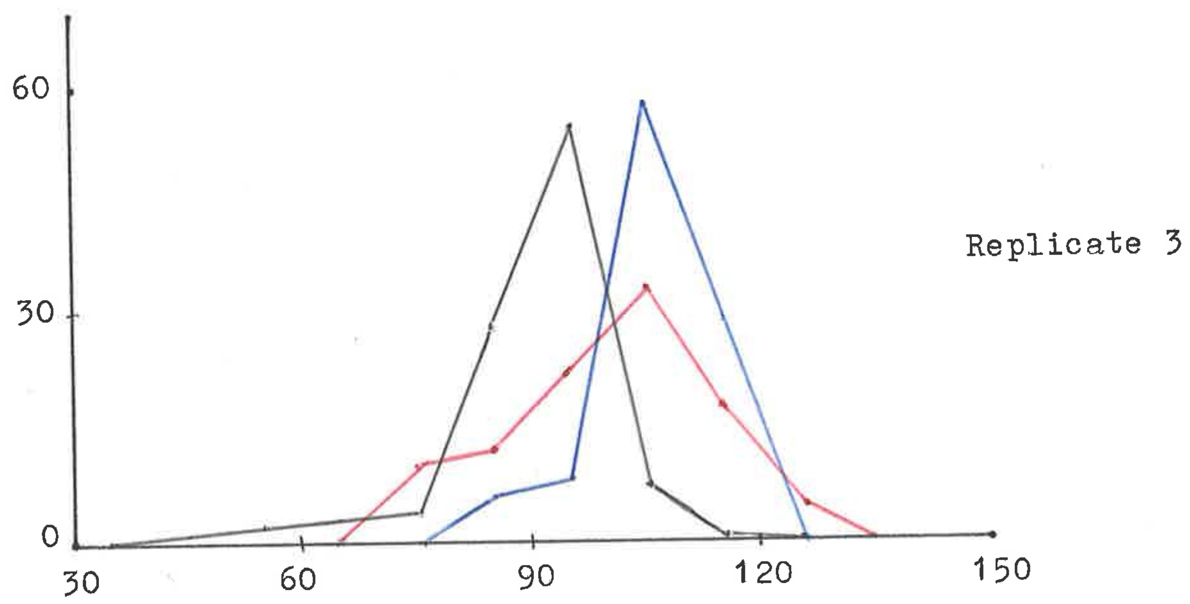
*** this denotes significance at the 0.1% level.

Figure 3.9. Frequency distributions of plant height. The X axis is the plant height in cm. and and the Y axis the percentage frequency. The blue curve is parent 1, the black is parent 2 and the red is the F_2 distribution.

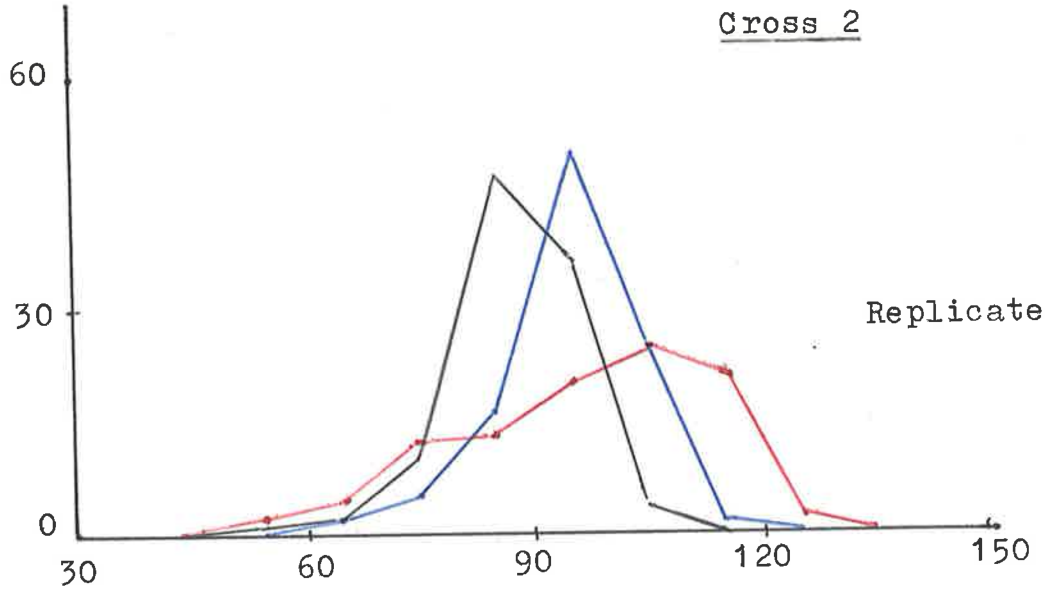
Cross 1


60
30
0
30
60
90
120
150
Replicate 1

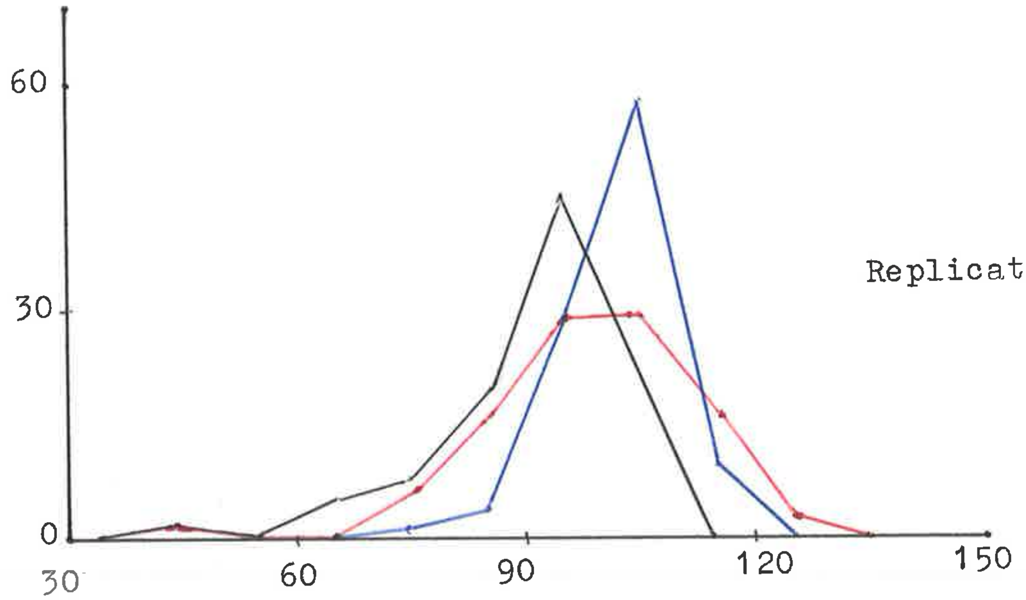

60
30
0
30
60
90
120
150
Replicate 2


60
30
0
30
60
90
120
150
Replicate 3

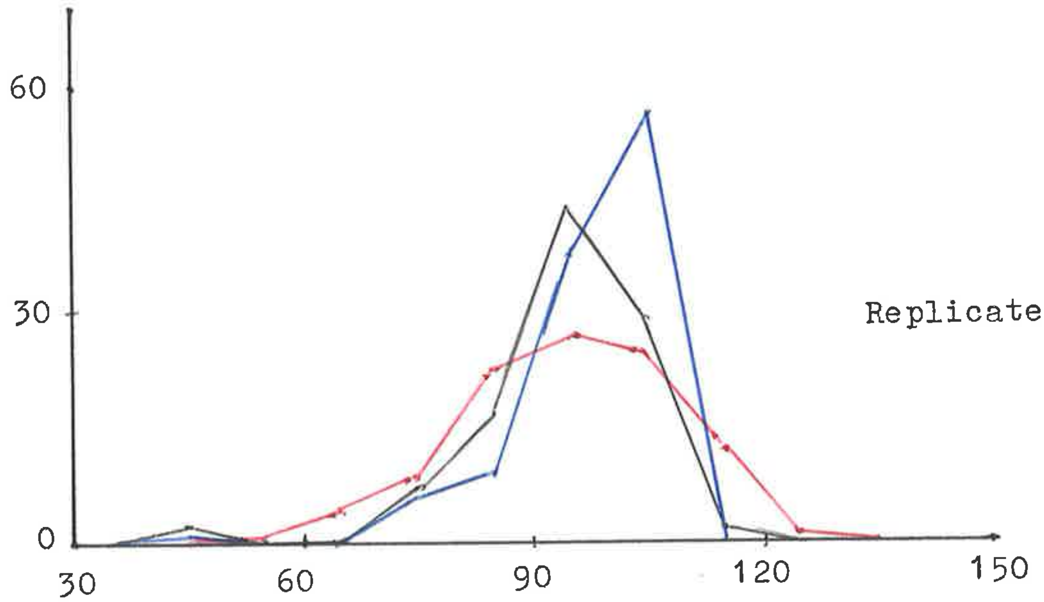
Cross 2



Replicate 1

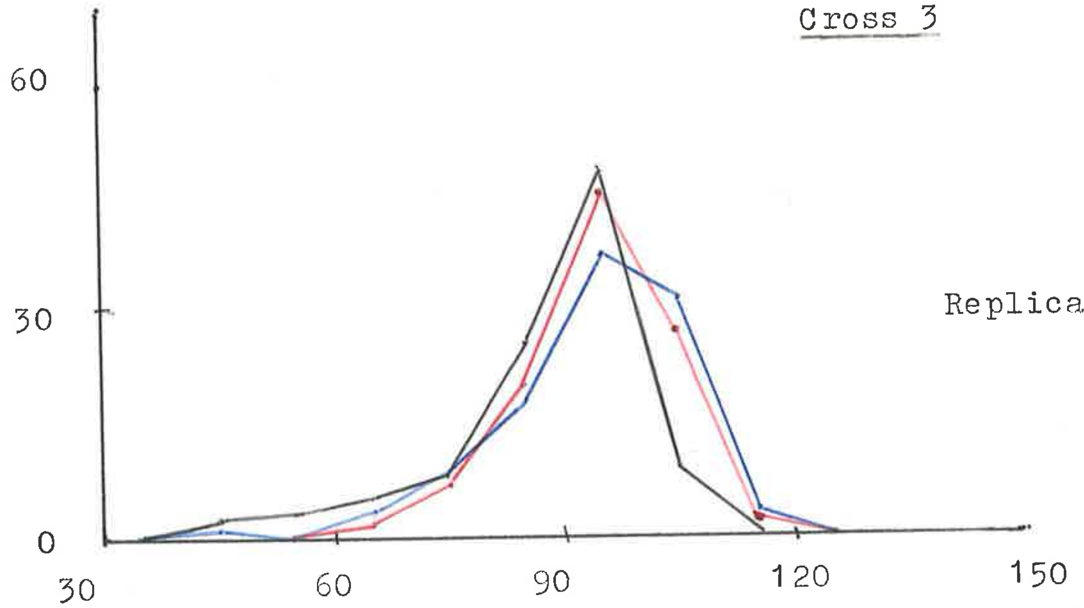


Replicate 2

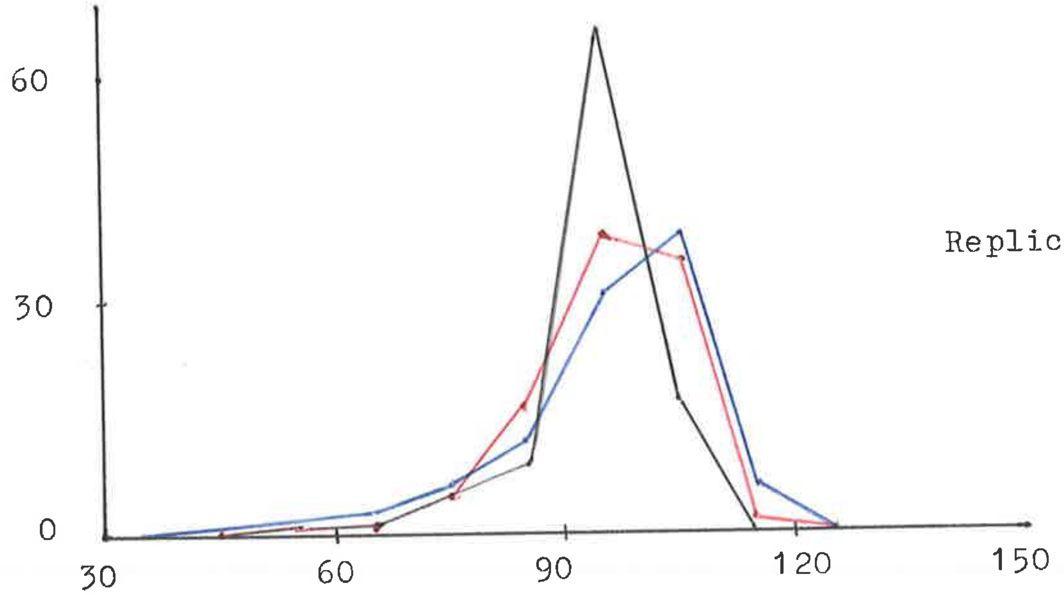


Replicate 3

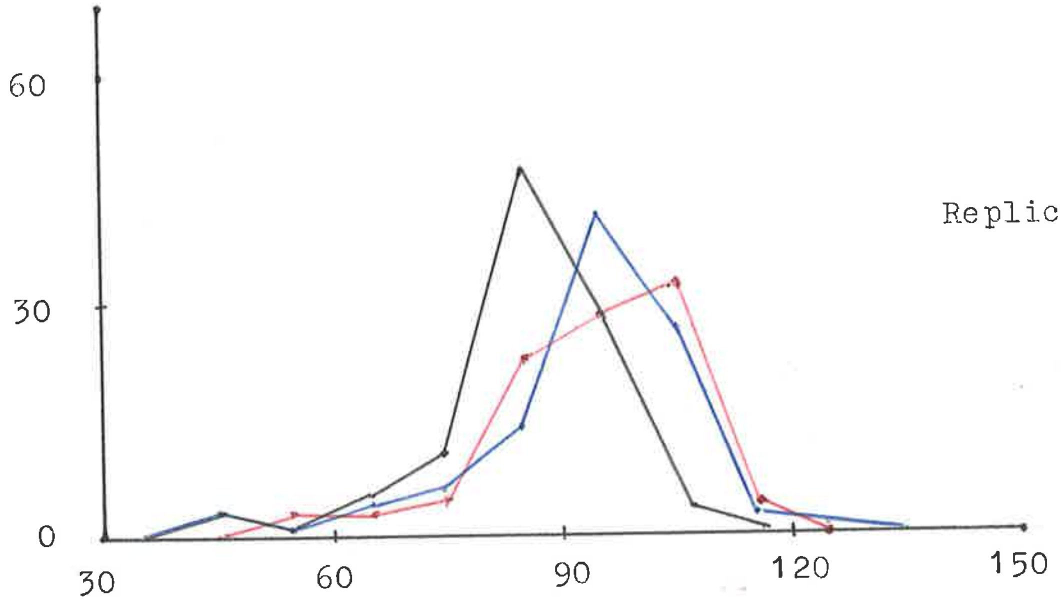
Cross 3



Replicate 1



Replicate 2



Replicate 3

3.1.8 Summary of results from experiment 1

1. The distributions of seed weight values were nearly normal. There were highly significant differences between parents and their F_2s for seed weight.

2. The seedlings emerged without discontinuities during a ten day period beginning 7 days after seeding. The emergence times of the F_2 seedling were intermediate between the parental distribution for crosses 1 and 3 but in cross 2 they were relatively faster than both parents.

3a. There was not a strong relation between seed weight and seedling emergence time.

b. However there was a tendency for the bigger seeds to result in higher yielding plants.

c. There was a marked regression of yield on emergence and the earlier emerging seedlings gave the highest yielding plants. Although the regression had a steep negative slope there was a large variation around the regression.

4. The environmental factors that affected plant weight, head number and final grain yield were similar causing significant genotype x replicate interactions. Except for plant height, no differences among genotypes were found.

5. The mean values varied considerably with the replicates for all characters, except plant height. The variances of characters were variable among genotypes. Only plant height showed evidence of segregation in the F_2. There were correlations between plant height and seedling emergence time and also with final grain yield.

6. The frequency distribution for plant height was skewed slightly to the left, but other characters were skewed to the right. In most instances the F_2's distributions covered the combined range of the parental distributions.

7. The serial correlations did not clearly reveal the influence of neighbours on a plant. Negative coefficients occurred frequently between a plant and its neighbours, except for plant height where many positive coefficients were obtained.

3.2 Results of experiment 2

It will be recalled this experiment was conducted in the following year to experiment 1 and had the same objectives, but that now instead of having P_1, P_2 and the F_2 in adjacent plots, they were mixed within a row. Also the individual seeds were not weighed as seed weight had had only a very inconsistent relationship with yield. The experiment had been planned to have 3 replicates but one was discarded because of poor emergence. Because most of the results and conclusion from this experiment were similar to those of Experiment 1 they will not be presented in detail. Only the exceptional results are emphasized.

3.2.1 Seedling emergence and serial correlation.

Details of emergence are given in Appendix 3. There was a very large effect on emergence of position of a plot in the trial. It is difficult to conclude whether the poor emergence in replicate 1 cross 3 and replicate 1 cross 2 (see Figure 2.2) was due to proximity to the bad area or whether Replicate 2 appears better in emergence simply because 2 seeds were sown in each hole of this replicate and the first seedling to emerge was recorded.

The frequency distributions of the emergence show that except for cross 1, the F_2's distributions were similar to parent-1's distributions.

As in experiment 1, earlier emergence tended to result in plants that finally had higher yields (Figure 3.10) although again there was a lot of variation in final grain yield of the plants emerging on any one day.

The serial correlations between neighbours were inconsistent but most of the significant correlations were negative for many characters. Examples of the serial correlations for final grain yield are given in Table 3.16 for each row. For plant height the significant correlations were frequently positive.

3.2.2 Mean and variance values of the characters

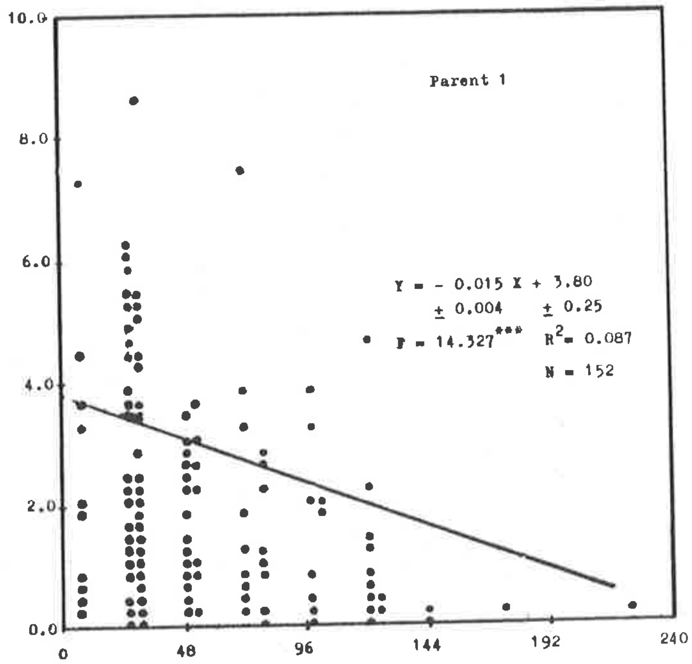
The F_2 mean values (Table 3.14) in some instances were between the parental values for characters final grain yield, plant weight, main shoot grain yield and head number. The environmental effect on genotypic expression is evident in the table when final grain yield was high other characters show high expression. Plant height mean values (Table 3.15) were similar among genotypes of the crosses but the variance values in Table 3.10 and 3.15 indicate that only for plant height was there clear evidence of segregation in the F_2.

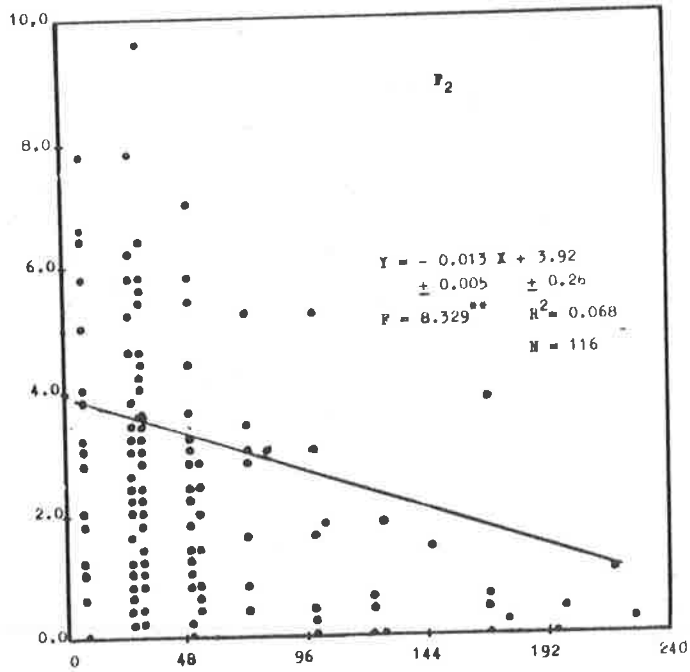
The mean and the variance values were more inconsistent than in experiment 1 for plant weight, main shoot grain yield, final grain yield and plant height, probably as a result of the arrangement of the P_1, P_2 and F_2 in a row. It will be shown in the Discussion that larger coefficients of variation were obtained from Experiment 2. The effect of a neighbouring plants of a different genotypes added to the variation.

3.2.3 Frequency distributions

The skews of distributions were similar to those found in experiment 1. As illustration the distributions of plant weight and final grain yield are given (Figure 3.11 and 3.12). Except for plant height, the F_2 frequency distributions of several characters resembled the parent-1's distributions, especially in cross 3 indicating the possible dominant effect of the parent in common ((PIT*Fest)/41/W/4).

Figure 3.10. The relationship between the time of seedling emergence in hours (X axis) and grain yield of the resulting plant in g (Y axis).


Parent 1
Y = - 0.015 X + 3.80
± 0.004 ± 0.25
F = 14.327*** R2= 0.087
N = 152
10.0
8.0
6.0
4.0
2.0
0.0
0
48
96
144
192
240


F2
Y = - 0.013 X + 3.92
± 0.005 ± 0.26
F = 8.329** R2= 0.068
N = 116
10.0
8.0
6.0
4.0
2.0
0.0
0
48
96
144
192
240

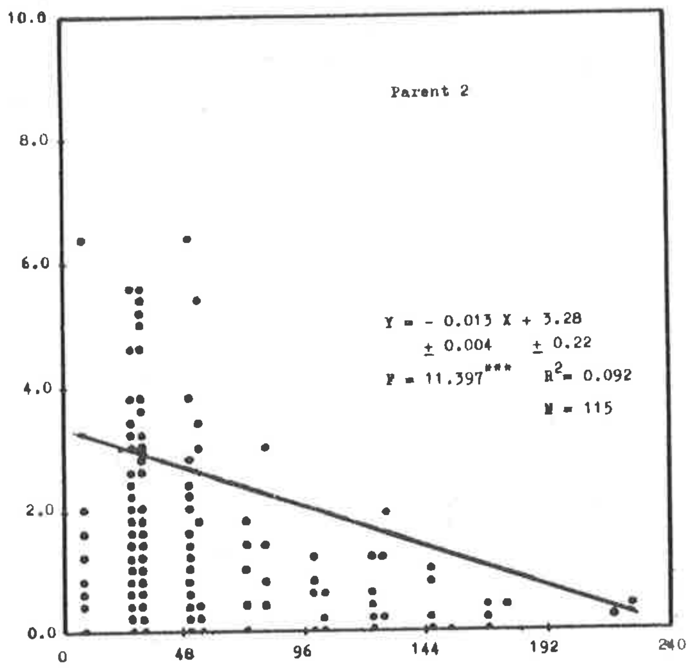

Parent 2
Y = - 0.013 X + 3.28
± 0.004 ± 0.22
F = 11.397*** R2= 0.092
N = 115
10.0
8.0
6.0
4.0
2.0
0.0
0
48
96
144
192
240

Table 3.14. Means and variances of the characters (in g. except head number)

Cross	Rep.	Plant weight P_1	Plant weight F_2	Plant weight P_2	Head number P_1	Head number F_2	Head number P_2	Main shoot grain weight P_1	Main shoot grain weight F_2	Main shoot grain weight P_2	Final grain yield P_1	Final grain yield F_2	Final grain yield P_2
Mean													
1	1	4.36	5.51	3.55	1.73	1.82	1.45	1.08	1.36	1.05	1.77	2.29	1.47
	2	3.81	3.91	5.95	1.53	1.55	1.79	0.83	0.86	1.31	1.44	1.46	2.46
2	1	3.73	4.63	3.67	1.55	1.79	1.52	0.88	1.07	1.04	1.44	1.81	1.51
	2	4.44	4.28	4.15	1.66	1.66	1.61	1.16	1.17	1.23	1.77	1.73	1.76
3	1	4.06	4.93	5.42	1.73	1.92	1.69	1.07	1.19	1.57	1.56	1.95	2.32
	2	4.77	4.69	5.31	1.94	1.97	1.91	1.18	1.16	1.38	1.93	1.90	2.24
Variance													
1	1	16.02	20.55	10.93	0.94	0.80	0.96	0.55	0.56	0.57	3.00	3.71	2.09
	2	19.03	20.45	28.41	1.09	1.49	0.92	0.42	0.43	0.70	2.95	3.17	5.33
2	1	18.13	19.52	10.85	1.39	1.95	1.79	0.44	0.43	0.38	2.93	3.18	2.03
	2	13.99	8.80	8.40	1.12	1.08	0.63	0.39	0.30	0.31	2.55	1.72	1.90
3	1	12.08	17.22	13.92	0.82	0.84	1.01	0.49	0.45	0.40	1.95	2.96	2.79
	2	18.26	12.82	23.62	1.05	1.36	0.76	0.47	0.54	0.40	3.26	3.20	4.05

Table 3.15. Means and variances of plant height (in cm).

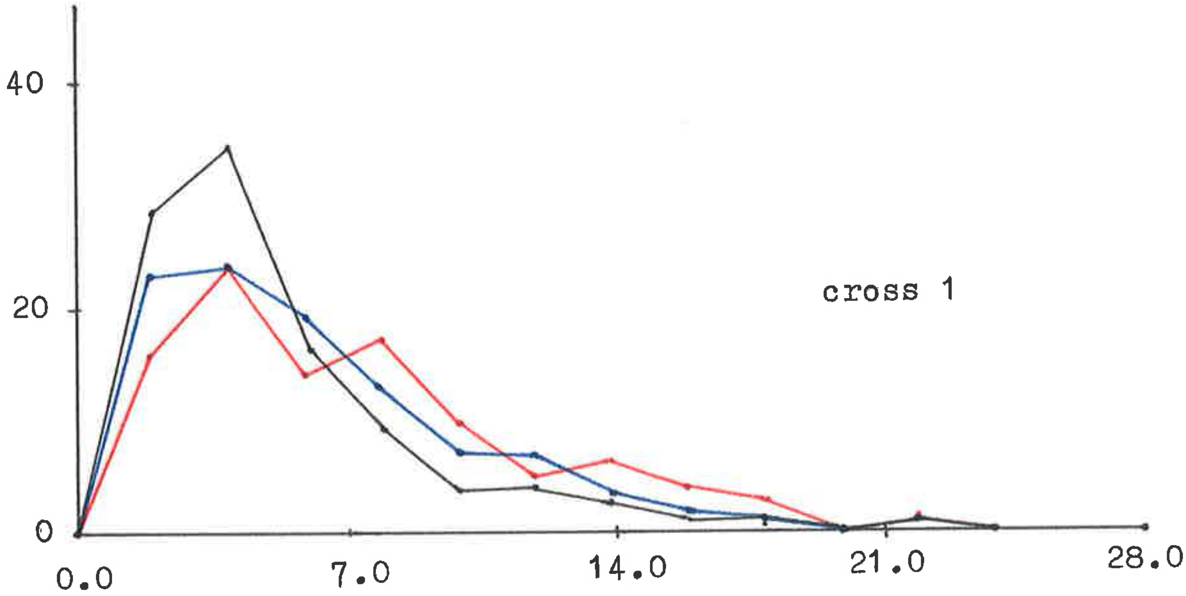
Cross	Rep.	Means			Variances		
		P_1	F_2	P_2	P_1	F_2	P_2
1	1	66.93	71.66	65.42	306.76	266.12	284.27
	2	73.03	72.78	75.51	176.94	242.82	111.98
2	1	64.52	66.29	67.29	233.17	277.24	133.49
	2	72.48	71.10	71.70	156.45	243.99	93.37
3	1	64.40	64.83	63.12	282.72	413.28	130.44
	2	72.14	75.28	68.33	191.87	321.99	76.42

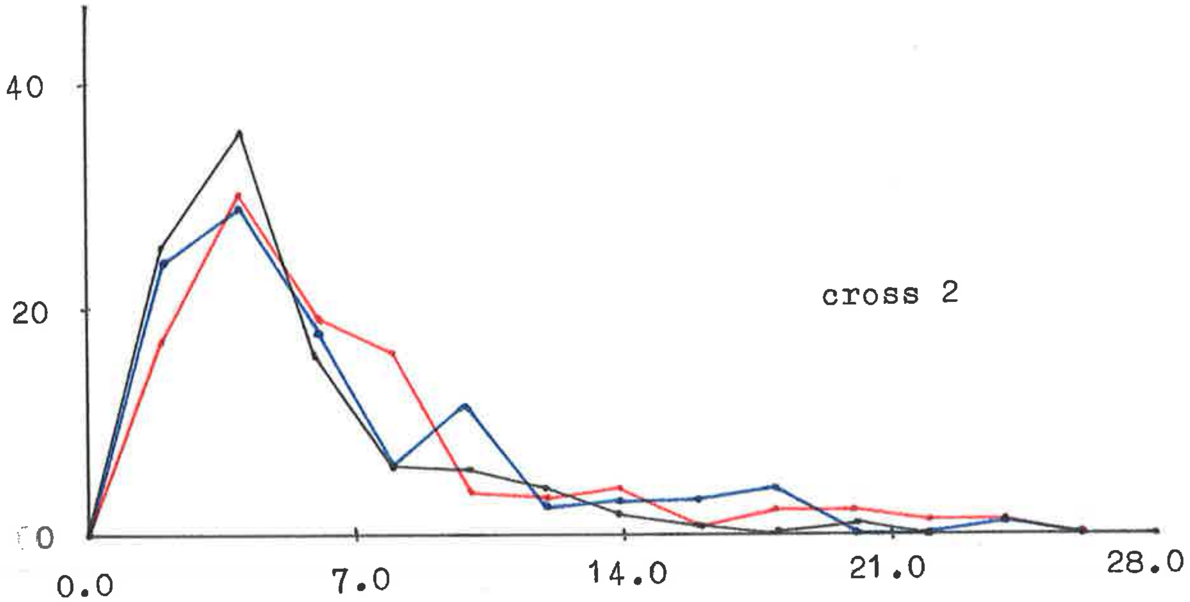
Table 3.16. Serial correlation of plants with their neighbours of final grain yields

Row	cross 1		cross 2		cross 3	
	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2
1	- .30	-0.13	-0.06	-0.05	-0.23	-0.07
2	-0.18	-0.16	-0.10	-0.82	+0.34*	+0.14
3	-0.38*	+0.34*	+0.10	-0.16	-0.30	-0.28
4	-0.31	-0.07	-0.26	-0.21	-0.03	-0.21
5	-0.22	-0.25	-0.18	+0.13	-0.52***	-0.14
6	-0.03	-0.20	-0.32*	-0.21	+0.11	+0.10
7	+0.07	-0.22	+0.01	-0.01	-0.41**	-0.29
8	+0.29	-0.37*	-0.45**	-0.02	-0.35*	+0.22
9	-0.13	+0.12	-0.31	-0.49**	+0.10	-0.09
10	-0.12	-0.18	-0.21	+0.17	-0.19	-0.24
11	+0.47**	-0.09	-0.08	+0.01	-0.42**	-0.43**
12	-0.20	-0.01	+0.23	-0.19	-0.39*	-0.28
13	-0.02	+0.26	-0.20	-0.40	-0.04	-0.05
14	-0.11	-0.32	-0.18	+0.37*	-0.25	-0.15
15	+0.13	-0.14	-0.02	-0.28	-0.03	-0.19

*, **, *** these denote significance at the 5%, 1% and 0.1% levels respectively.

Figure 3.11. Frequency distributions of plant weight. The X axis is the plant weight in g. and the Y axis the percentage frequency. The blue curve is parent 1, the black is parent 2 and the red is the F_2 distribution.


40
20
0
0.0
7.0
14.0
21.0
28.0
cross 1


40
20
0
0.0
7.0
14.0
21.0
28.0
cross 2

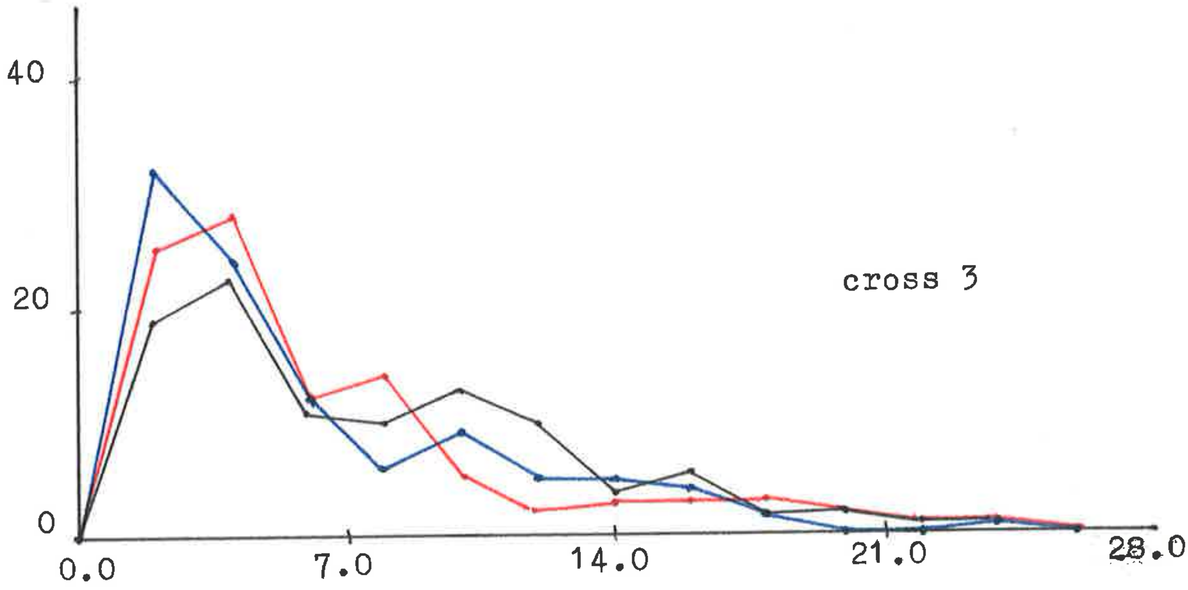
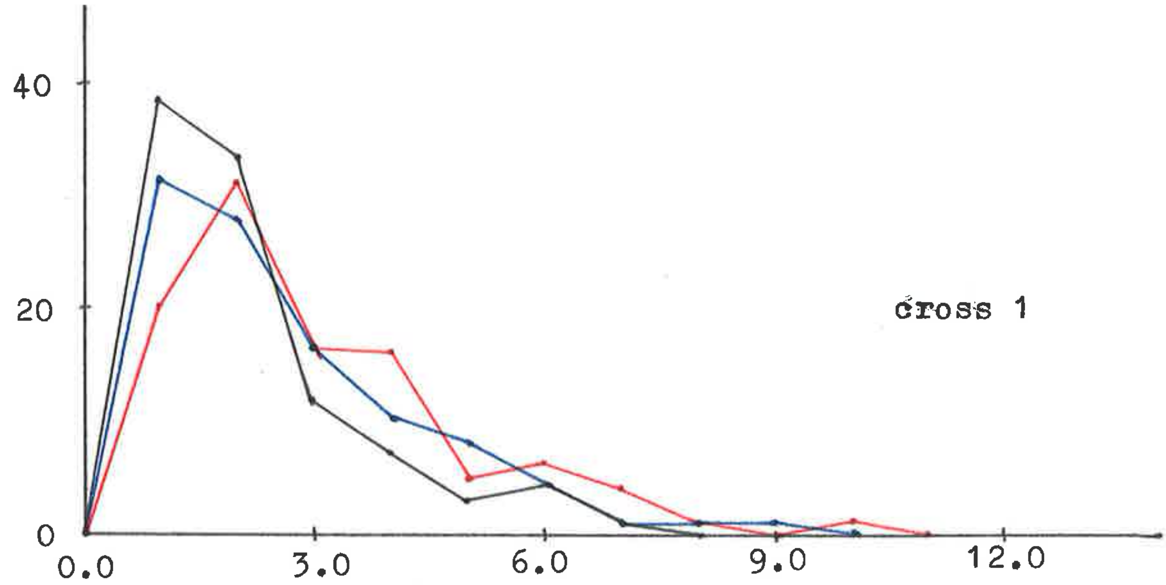
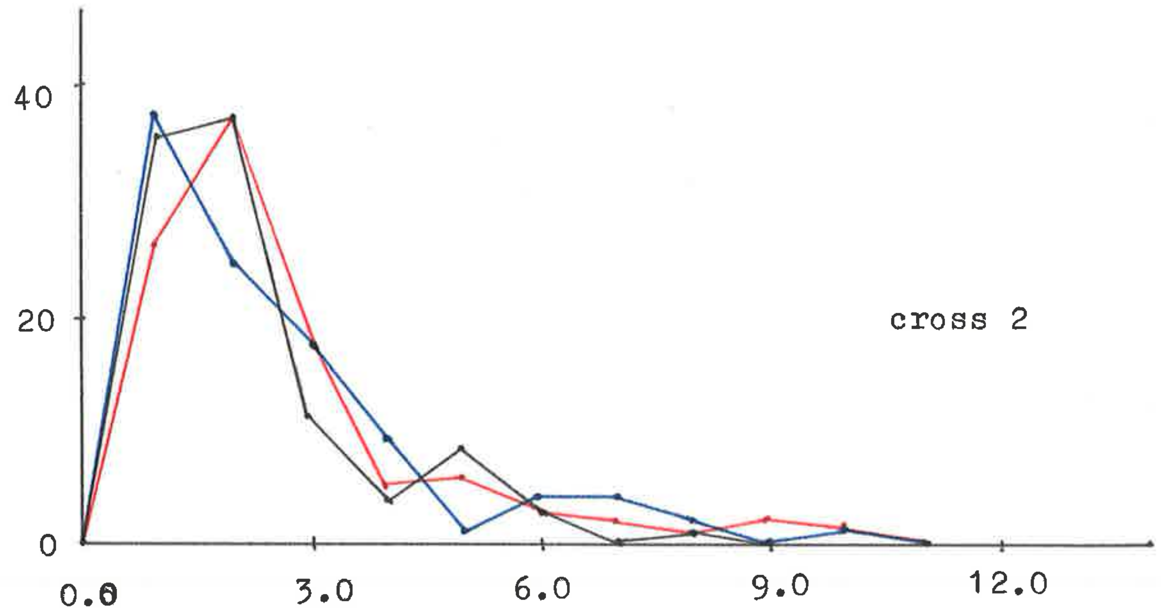
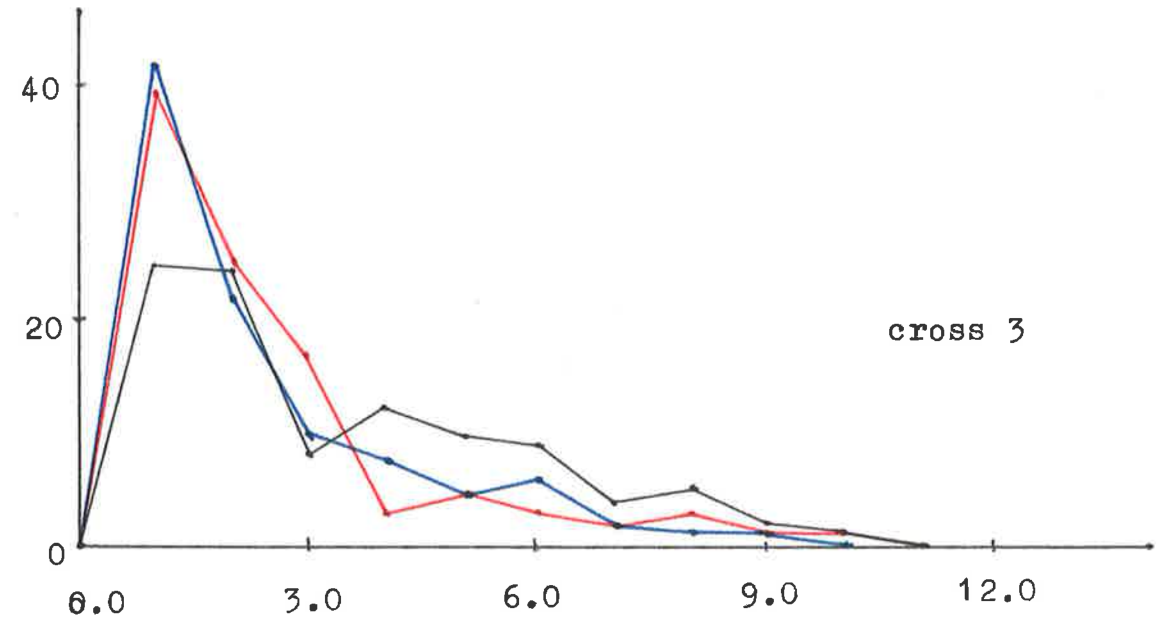

40
20
0
0.0
7.0
14.0
21.0
28.0
cross 3

Figure 3.12. Frequency distributions of final grain yield. The X axis is the final grain yield in g. and the Y axis the percentage frequency. The blue curve is parent 1, the black is parent 2 and the red is the F_2 distribution.


40
20
0
0.0
3.0
6.0
9.0
12.0
cross 1


40
20
0
0.0
3.0
6.0
9.0
12.0
cross 2


40
20
0
0.0
3.0
6.0
9.0
12.0
cross 3

3.2.4 Summary of results from experiment 2

1. Results similar to those of experiment 1 were obtained for rate of seedling emergence and for the relation between seedling emergence time and final grain yield.
2. The mean and variance values were more inconsistent than in experiment 1, probably due to different arrangement of the P_1, P_2 and F_2 in a row. Mean values of the F_2 were intermediate or exceeded. Again the only character which showed evidence of segregation in the F_2 was plant height.
3. Except for plant height, the F_2 frequency distributions of several characters resembled the parent-1's distribution, indicating the possible dominant effect of parent-1 ((PIT*Fest)/41/W/4). Transgressive segregation was found in all crosses.
4. The skews of the distributions were similar to those in experiment 1.

3.3 Results of experiment 3.

Experiment 3 was a repetition of Experiment 2 and was sown in the same season when it became evident emergence was poor in Experiment 2. But as mentioned in the previous chapter the plants did not grow as well possibly due to the late sowing.

The results are not presented as the conclusions from this Experiment relating to emergence and yield, the serial correlations etc. were very similar to those of Experiment 2. Some derived results from Experiment 3 are presented in the Discussion as a reinforcement of results from Experiments 1 and 2.

3.4 Results of experiment 4.

3.4.1 Introduction

The main objective of this experiment was to investigate the stability of yield of F_7's lines when grown in different sites and years. Mean and variance values were calculated for lines derived from the same family. The number of lines within a family varied from 12 to 30 (see Tables 2.4 and 2.5). A correlation of mean values will be used to describe the relation between lines in the different sites and years.

A second objective was to compare the yield obtained from lines selected in the F_5 with the yield of lines taken at random from the same population. This study was undertaken to evaluate selection in the F_5 generation.

3.4.2 Correlation between lines grown at different sites and years

The mean values of the F_7 and F_6 are given in Table 3.17a and b, and the deviation of each mean value from the average of all mean values is given in Table 3.18a and b. Emphasis will be placed on the F_7 results rather than the F_6 because of their greater replication. The correlations between the mean values of the F_7 for lines grown at Saddleworth in 1977 and at Charlick in 1978 and 1979 were not significant (see also Figure 3.13) but a very highly significant correlation was found for the relation between lines grown at the one site (Charlick) in 1978 and 1979 (r = 0.77***). It indicates in this instance that an assessment of lines grown at one site in different years was similar. The correlation occurred despite the fact that the environment was different in the two years and the level of yield was very different.

3.4.3 The stability of yield of each line

It is evident from Tables 3.18a and b that only a few lines of the F_7 were consistent in their yields over the three years. These lines were number 10, 11, 16, 20, 24 (selected lines) and 35, 37, 43, 47 (lines taken at random).

There were highly significant correlations between the means of the F_7's lines and means of their F_6 (means of three plots) in each year, either for selected lines or lines taken at random, except for lines taken at random and grown in 1977. For selected lines the correlations between F_7 and F_6 were 0.89, 0.59 and 0.79 for 1977, 1978 and 1979 respectively (significant at 0.1%). For lines taken at random they were 0.88 and 0.76 for 1978 and 1979 respectively (significant at 0.1). These correlations indicate there were distinct differences between lines and that the relative performance of lines at F_6 or F_7 were consistent across environments.

The variance values are given in Appendix 4. They were used to estimate the heterogeneity of lines within a family over different sites and years. Variable results were obtained over the three years and the two sites. Only a few lines had relatively small variances, but these lines were low yielding. The variance values of lines at Saddleworth 1977 and Charlick 1978 were mostly larger than of Warimba. But the reverse result was obtained for Charlick in 1979.

Table 3.17a. Means within family of selected lines and means of their F_6 lines planted in the same year.

Line No.	Saddleworth 1977		Charlick 1978		Charlick 1979	
	F_7	F_6	F_7	F_6	F_7	F_6
1	623.	611.	800.	772.	378.	424.
2	415.	483.	825.	719.	415.	460.
3	531.	543.	715.	610.	384.	356.
4	478.	506.	854.	924.	445.	440.
5	606.	594.	567.	576.	382.	368.
6	486.	535.	530.	502.	374.	449.
7	566.	557.	576.	500.	376.	361.
8	571.	538.	504.	608.	378.	377.
9	614.	639.	615.	607.	416.	398.
10	621.	541.	673.	617.	411.	422.
11	557.	514.	753.	825.	445.	492.
12	513.	487.	729.	775.	421.	387.
13	442.	622.	870.	858.	469.	488.
14	482.	605.	609.	791.	406.	409.
15	491.	457.	580.	585.	381.	355.
16	545.	487.	643.	704.	413.	386.
17	415.	554.	594.	625.	403.	413.
18	415.	528.	462.	456.	321.	301.
19	481.	472.	479.	449.	304.	318.
20	524.	507.	733.	671.	444.	443.
21	651.	536.	570.	593.	385.	398.
22	505.	455.	673.	675.	392.	398.
23	442.	438.	729.	761.	475.	449.
24	528.	551.	667.	743.	477.	491.
25	532.	518.	539.	648.	358.	376.
26	582.	579.	461.	516.	320.	351.
27	555.	569.	557.	569.	409.	341.
28	552.	522.	542.	470.	352.	314.
29	507.	452.	690.	606.	377.	484.
30	487.	532.	461.	593.	355.	312.
Mean	524.	531.	636.	645.	397.	399.

Table 3.17b. Means within family of lines taken at random and means of their F_6 lines planted in the same year.

Line No.	Saddleworth 1977		Charlick 1978		Charlick 1979	
	F_7	F_6	F_7	F_6	F_7	F_6
31	382.	577.	781.	776.	456.	416.
32	477.	478.	544.	512.	356.	335.
33	429.	537.	830.	708.	478.	483.
34.	450.	469.	718.	672.	397.	381.
35	564.	549.	636.	712.	388.	354.
36	539.	561.	734.	658.	365.	329.
37	499.	457.	694.	760.	402.	371.
38	334.	517.	537.	569.	379.	362.
39	451.	437.	493.	465.	300.	372.
40	483.	454.	397.	424.	318.	336.
41	418.	487.	581.	658.	325.	369.
42	466.	449.	661.	776.	420.	476.
43	581.	558.	666.	734.	443.	411.
44	435.	563.	676.	658.	341.	341.
45	457.	407.	416.	366.	308.	337.
46	593.	469.	467.	404.	345.	394.
47	533.	497.	678.	759.	382.	430.
48	515.	479.	554.	539.	305.	315.
49	472.	403.	530.	557.	322.	263.
Mean	478.	492.	610.	616.	370.	372.

Means of the check varieties

Variety	1977	1978	1979
Warimba	493	584	377
Oxley	307	451	326
RAC-266	575	754	291
Kite	362	540	396
Condor	441	468	237

Table 3.18a. Deviation of each mean value from the average of all mean values of selected lines.

Line No.	Saddleworth 1977		Charlick 1978		Charlick 1979	
	F_7	F_6	F_7	F_6	F_7	F_6
1	+ 99	+ 80	+164	+127	- 19	+ 25
2	-109	- 48	+189	+ 74	+ 18	+ 61
3	+ 7	+ 12	+ 79	- 35	- 13	- 42
4	- 46	- 25	+218	+279	+ 48	+ 41
5	+ 82	+ 63	- 69	- 69	- 15	- 31
6	- 38	+ 4	-106	-143	- 23	+ 50
7	+ 42	- 26	- 60	-145	- 24	- 38
8	+ 47	+ 7	-132	- 37	- 19	- 22
9	+ 90	+108	- 21	- 38	+ 19	- 1
10	+ 97	+ 10	+ 37	- 28	+ 14	+ 23
11	+ 33	- 17	+117	+180	+ 48	+ 93
12	- 11	- 44	+ 93	+ 130	+ 24	- 13
13	- 82	+ 91	+234	+213	+ 72	+ 89
14	- 42	+ 74	- 27	+146	+ 9	+ 10
15	- 33	- 74	- 56	- 60	- 16	- 44
16	+ 21	- 44	+ 7	+ 59	+ 16	- 13
17	-109	+ 23	- 42	- 20	+ 6	+ 14
18	-109	- 3	-174	-189	- 76	- 98
19	- 43	- 59	-157	-196	- 93	- 81
20	0	- 24	+ 97	+ 26	+ 47	+ 44
21	+127	+ 5	- 66	- 52	- 12	- 1
22	- 19	- 76	+ 37	+ 30	- 5	- 1
23	- 82	- 93	+ 93	+116	+ 78	+ 50
24	+ 4	+ 20	+ 31	+ 98	+ 80	+ 92
25	+ 8	- 13	- 97	+ 3	- 39	- 23
26	+ 58	+ 48	-175	-129	- 77	- 48
27	+ 31	+ 38	- 79	- 76	+ 12	- 58
28	+ 28	- 9	- 94	-175	- 45	- 85
29	- 17	- 79	+ 54	- 39	- 20	+ 85
30	- 37	+ 1	- 75	- 52	- 42	- 87

Table 3.18b. Deviation of each mean value from the average of all mean values of lines taken at random.

Line No.	Saddleworth 1977		Charlick 1978		Charlick 1979	
	F_7	F_6	F_7	F_6	F_7	F_6
31	- 96	- 85	+171	+160	+ 86	+ 44
32	- 1	- 14	- 66	-104	- 14	- 37
33	- 49	+ 45	+220	+ 92	+108	+111
34	- 28	- 23	+108	+ 56	27	+ 9
35	+ 86	+ 57	+ 26	+ 96	+ 18	- 18
36	+ 61	+ 69	+124	+ 42	- 5	- 43
37	+ 21	- 35	+ 84	+144	+ 32	- 1
38	-144	+ 25	- 73	- 47	+ 9	- 10
39	- 27	- 55	-117	-151	- 70	0
40	+ 5	- 38	-213	-192	- 52	- 36
41	- 60	- 5	- 29	+ 42	- 45	- 3
42	- 12	- 43	+ 51	-160	+ 50	+104
43	+103	+ 66	+ 56	+118	+ 73	- 39
44	- 43	+ 71	+ 66	+ 42	- 29	- 31
45	- 21	- 85	-194	-250	- 62	- 35
46	+115	- 23	-143	-212	- 25	+ 22
47	+ 55	+ 5	+ 68	+143	+ 12	+ 68
48	+ 37	- 13	- 56	- 77	- 65	- 57
49	- 6	- 89	- 80	- 59	- 48	-109

3.4.4 Selected lines and lines taken at random

A t-test was used to compare the means of the sets of selected lines taken at random. The results are shown in Table 3.19.

Table 3.19. Means, t-value and variances of the mean values.

Years	Rep.	Mean of the means		t-value	Variances of the means	
		selected	at random		selected	at random
1977	1	534.	486.	2.14*	5320.	6743.
	2	514.	470.	2.41*	4246.	3167.
1978	1	606.	556.	1.47	13021.	13869.
	2	667.	665.	0.07	14649.	17056.
1979	1	381.	351.	2.05*	2333.	2816.
	2	413.	390.	1.55	2306.	3256.

* this denotes significance at the 5% level.

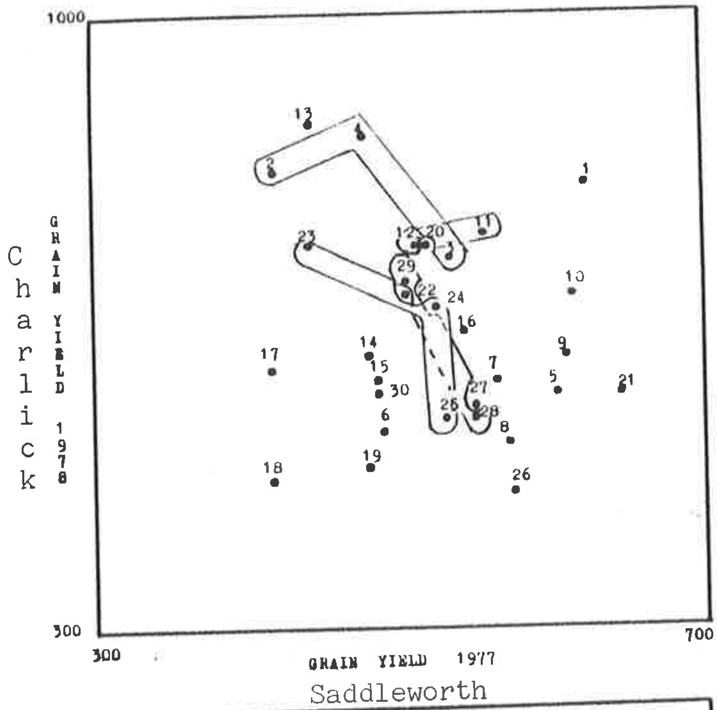
The means of the selected lines tended to be higher than lines taken at random and three of the differences between means were significant at the 5% level. It indicates that selection in the F_5 generation was effective in increasing yield. There were no significant differences between the variances of the selected and random lines, but the variances of the random lines tended to be slightly larger.

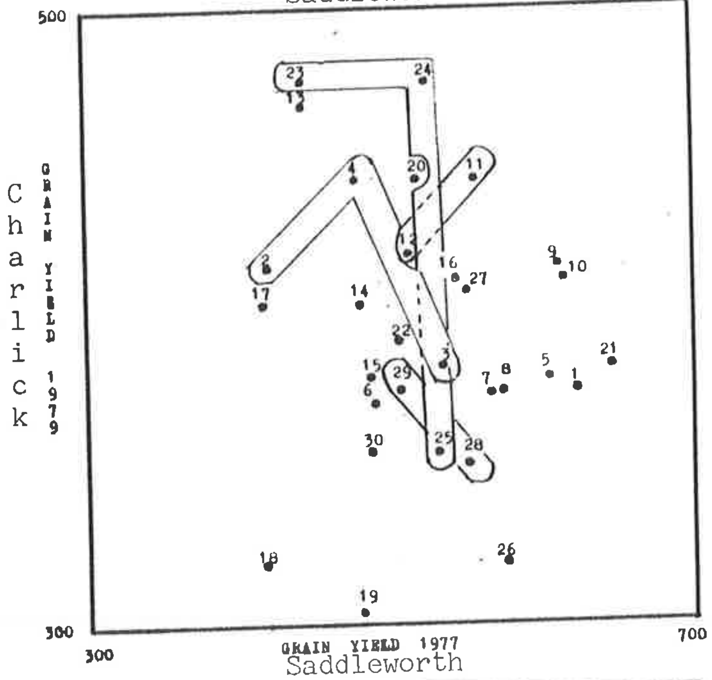
3.4.5 Lines derived from the same parent or parents

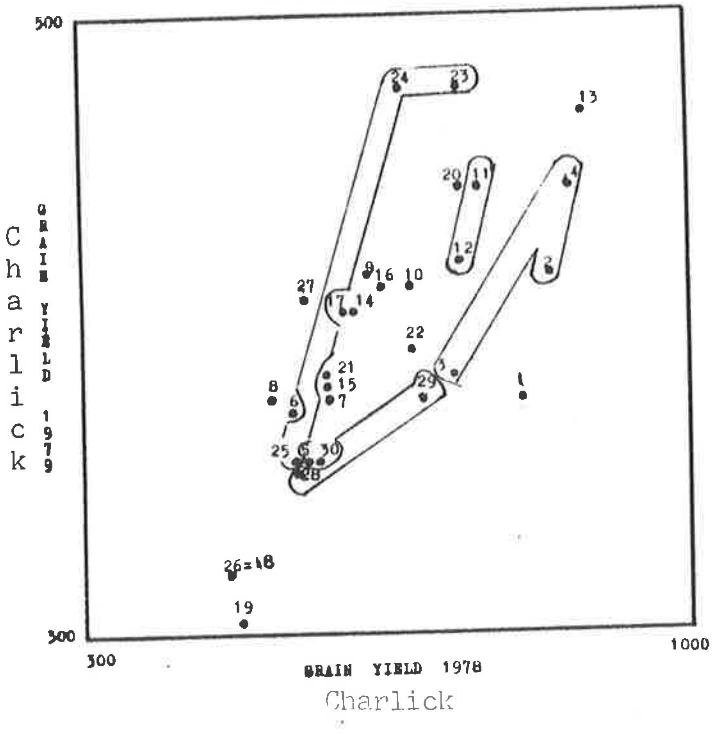
In Figure 3.13 the lines derived from a cross have been enclosed. For crosses with parent Wariquam in common the relationship for one site (Charlick) tended to be positive and for the different sites

Charlick and Saddleworth to be negative. These lines were numbers 2, 3 and 4 (cross Wariquam*Warimek); 11 and 12 (cross (G*PT)*Wariquam); 23, 24 and 25 (cross ((M*CD)*CM)*Wariquam); 28 and 29 (cross ((M*M)* GB)*Wariquam). On the other hand, results were consistent and positive across sites for lines with (M*M)/68/1 in common (line numbers 5, 6, 7, 8 and 9) and with parent (M*M)/75/1 in common (line numbers 15, 16, 17 and 18). It indicates that the relative stability of lines over different sites and years was inherited and differed between crosses. Reference will be made in the Discussion to the possible causes of these differences.

Figure 3.13. The relationship between the mean yields (g./plot) of lines grown at Saddleworth in 1977 and at Charlick in 1978 and 1979. The lines that are enclosed have the same parents (e.g. lines 2, 3 and 4).


1000
300
300
700
GRAIN YIELD 1977
Charlick
GRAIN YIELD 1978
Saddleworth


500
300
300
700
GRAIN YIELD 1977
Charlick
GRAIN YIELD 1979
Saddleworth


500
300
300
1000
GRAIN YIELD 1978
Charlick
GRAIN YIELD 1979
26=18
Charlick

3.4.6 Summary of the results from experiment 4.

1. The F_7 lines when grown in different sites and years showed differences in their yielding ability. When grown at the same site in different years, however, the relative performance of the lines was stable.

2. Only a few lines had high yeilds over the three years and the two sites. These lines came from either selected lines or lines taken at random. The heterogeneity of lines within families varied over different years and sites. Selection in the F_5 had not conferred ~~stability~~ uniformity of yield within families

3. The yields of the F_7's lines were correlated with their F_6 yields in each year, both for selected lines or lines taken at random. This further confirms that within a site and year there was considerable constancy.

4. There were statistically significant differences between the selected lines and lines taken at random for lines grown at Saddleworth in 1977 and at Charlick in 1979 for one replicate. It seems that selection for yield of families at the F_5 generation was efficient in picking out high yielding lines for certain environments.

5. Lines derived from some crosses were positively correlated across some environments but negatively correlated across others. This intersection was inherited being clearly attributable to certain parents.

CHAPTER 4. DISCUSSION

The discussion is concerned with two different subjects the first being the experiments involving single plants of the P_1, P_2 and F_2 populations (Experiment 1, 2 and 3) and the second the F_7 experiment which involved plot yields (Experiment 4).

4.1 Aspects of the results of single plants of P_1, P_2 and F_2

a. Effect of seed weight and seedling emergence on plant growth

It was found that seed weight had little effect on the time of seedling emergence and larger seeds had a negligible advantage. Perhaps of more importance for rapidity of emergence were the environmental factors such as variation in the depth of sowing, soil compaction and soil water availability. Seedling vigor and coleoptile strength, therefore, were not determined by seed size. This result conflicts with that of Kolp *et al.* (1967).

The individual plant yield at maturity was related to seed weight to some degree. About half of the plots showed a statistically significant relation between seed weight and final grain yield per plant. This agrees with previous investigations. It is understandable, as mentioned in the literature review, that seed size would influence the size of the developing plant, especially if the larger seeds have larger embryos.

A more pronounced and consistent effect was the negative association found between the time of seedling emergence and the individual plant yield at maturity. Late seedling emergence reduced drastically plant yield. This result complements that of Soetono and Donald (1980) who when working with one cultivar of barley measured only grain numbers and not yield. The present association between emergence and final yield was found in the P_1, P_2 or F_2 whenever it was measured.

Some of the earlier emerging seedlings did not develop into high yielding plants. Many microenvironmental factors could have been the cause of this result. For example some of the seedlings that emerged earlier from a shallow depth of sowing may have been less able to develop their roots properly. Others might be subject to greater competition from their neighbours.

It was also found that plant height was related to the time of seedling emergence and there were highly significant correlations between plant height and final grain yield. Plant height was less affected by environmental variation and showed clear evidence of segregation in F_2 populations. The relationship between emergence, plant height and final grain yield, therefore, may be meaningful in the prediction and selection of high yielding plants. This relationship was found in parental populations as well as in the F_2 and has therefore a strong environmental component. It would be thought that the relationship would be strengthened when a genotypic component could also be involved, as in the F_2, but this was not evident in the present experiments. The matter warrants further investigation.

b. <u>Effect of neighbours on a plant</u>

One means of assessing microenvironmental effects on a single plant is to compare its yield with the mean of a number of neighbouring plants. In competitive situation, the relation between a plant's yield and its neighbour's yield might indicate its competitive ability.

Some studies have found that the competitive ability of a plant, assessed in various ways, was associated with its yielding ability but others have not. Japanese workers studying competition in maize found a negative correlation for plant weight between a plant and its immediate neighbours within a row (Hozumi *et al.*, 1955).

The results of the serial correlations were not very consistent and therefore there was no direct evidence of neighbouring plants on the yield or plant weight of a plant in any of the three experiments. Many of the correlations were negative and significant but not all of them. This occurred even when the seedling arrangement in a row was P_1, F_2, P_2 and competition should have been most apparent because a genotypic component would have been present. Apparently the yields of plants were not affected in a simple and detectable way by variation in their neighbours a conclusion also arrived at by Johnston (1972) with barley.

The study by Sakai (1957) in which he found a significant effect of surrounding plants was different from the present experiments. In his experiment plants with a known strong competitive ability were grown with weaker plants. In a competitive situation, the reaction of a plant to its neighbours is related to the factors limiting growth. The more vigorous plants will have a greater chance to obtain water, light and nutrients and compete against the weaker plants. However the vigor of a plant may be due to its genotype or the better microenvironment in which it grows.

The present inconsistent results in terms of the serial correlation for yield may be explained by the fact that many of the plants used were not very different genotypically in regard to vigor and that micro-environmental variation especially variation in soil conditions created high and low yielding areas in the trial rather than alternating high and low yielding plants. The idea that competition might cause alternating high and low yielding plants along a row appears to be an oversimplification.

For plant height many of the significant serial correlations were positive. Shoot length of a plant in competitive situations may reduce the intensity of light received by its neighbours. This situation may promote the neighbour plants to etiolate (Yoda *et al.*, 1957) and result in plants with similar height. This would lead to positive serial correlations.

c. Genotype and microenvironment variation

There were no significant differences among F_2's and the parental yield in the three crosses of Experiment 1 for the characters, plant weight, final grain yield, main shoot grain yield and head number. It seemed that the microenvironment and the effects of crop density masked any differences expected from segregation in the F_2. Many characters pertaining to individual plant yield would have been extremely depressed by crop density, causing an inhibition of gene expression including heterosis assuming that these were potentially present in these crosses. Briggle (1963) stated that environmental conditions, such as time of sowing, depth of sowing and spacing greatly influenced the expression of heterosis. In the present study only plant height showed significant differences among genotypes. This is understandable as height has a high heritability and is less influenced by environmental variability. Selection for this character, therefore, could be conducted efficiently in the F_2 generation if it was warranted.

Genotype x replicate interactions were significant for the characters plant weight, final grain yield, head number and plant height in the three crosses of experiment 1. On the other hand, main shoot grain yield seemed to be less influenced by microenvironmental variability. For this reason this character may be more reliable as an indicator when assessing high yielding genotypes on single plants basis in crop density.

d. Mean and variance values of plant characters

In experiment 1, some F_2 means exceeded the parental means for plant weight, final grain yield and head number exhibiting heterosis, but in other F_2 mean values were intermediate between the parents. Such variation in expression was also obvious in plant height where the F_2 mean values were between the parents in cross 1 and 2 but similar to one parent in cross 3. This supports the result of previous studies that plant height is highly hertiable (Fiuzat and Atkins, 1953; Edwards *et al.*, 1976). For main shoot grain yield, P_1, P_2 and F_2 had similar mean values.

The results of experiment 2 and 3 were more inconsistent than for experiment 1 and the coefficients of variations for most characters were larger than from experiment 1 (Tables 4.1, 4.2 and 4.3). This result is attributed to the different arrangement of genotypes in a row. Mixing the F_2 and parents in a row (Experiment 2 and 3) caused a more variable effect from competition and affected the measurement of heterogeneity of segregating plants. It indicates that the pattern of planting used in experiment 1 is more suitable when comparing the F_2's with their parents.

Table 4.1. Coefficient of variations of P_1, F_2 and P_2 of each character from experiment 1.

Cross	Rep.		Plant weight	Main shoot grain yield	Head number	Total grain yield	Plant height
1	1	P_1	0.53	0.37	0.41	0.67	0.06
		F_2	0.61	0.42	0.43	0.67	0.12
		P_2	0.61	0.37	0.44	0.66	0.11
	2	P_1	0.63	0.46	0.48	0.77	0.06
		F_2	0.66	0.45	0.47	0.75	0.11
		P_2	0.69	0.48	0.46	0.82	0.10
	3	P_1	0.66	0.37	0.53	0.73	0.07
		F_2	0.79	0.46	0.56	0.97	0.13
		P_2	0.74	0.46	0.51	0.81	0.12
2	1	P_1	0.73	0.47	0.48	0.71	0.09
		F_2	0.77	0.40	0.59	0.77	0.15
		P_2	0.63	0.44	0.49	0.76	0.09
	2	P_1	0.72	0.41	0.57	0.71	0.08
		F_2	0.81	0.42	0.59	0.83	0.14
		P_2	0.71	0.43	0.50	0.72	0.13
	3	P_1	0.67	0.47	0.47	0.74	0.10
		F_2	0.80	0.44	0.51	0.80	0.14
		P_2	0.72	0.39	0.57	0.76	0.12
3	1	P_1	0.75	0.43	0.57	0.74	0.12
		F_2	0.68	0.37	0.56	0.69	0.09
		P_2	0.75	0.48	0.52	0.68	0.16
	2	P_1	0.69	0.41	0.55	0.69	0.14
		F_2	0.62	0.39	0.52	0.63	0.10
		P_2	0.51	0.29	0.39	0.53	0.08
	3	P_1	0.83	0.46	0.58	0.81	0.16
		F_2	0.65	0.37	0.51	0.68	0.12
		P_2	0.61	0.36	0.47	0.64	0.12

Table 4.2. Coefficient of variations of P_1, F_2 and P_2 of each character from experiment 2.

Cross	Rep.		Plant weight	Main shoot grain yield	Head number	Final grain yield	Plant height
1	1	P_1	0.92	0.69	0.61	0.99	0.26
		F_2	0.82	0.55	0.57	0.84	0.23
		P_2	0.93	0.72	0.55	0.98	0.26
	2	P_1	0.90	0.65	0.66	1.19	0.18
		F_2	0.90	0.56	0.65	0.99	0.21
		P_2	0.92	0.40	0.57	0.94	0.14
2	1	P_1	1.14	0.75	0.58	0.90	0.23
		F_2	0.95	0.61	0.54	0.76	0.25
		P_2	0.90	0.59	0.61	0.78	0.17
	2	P_1	0.84	0.54	0.61	0.90	0.17
		F_2	0.69	0.47	0.71	0.88	0.22
		P_2	0.70	0.45	0.70	0.72	0.14
3	1	P_1	1.15	0.78	0.59	1.19	0.26
		F_2	1.16	0.76	0.59	1.22	0.31
		P_2	0.90	0.64	0.56	0.94	0.18
	2	P_1	0.86	0.58	0.60	0.94	0.19
		F_2	0.84	0.63	0.64	0.94	0.23
		P_2	0.69	0.46	0.57	0.90	0.13

Table 4.3. Coefficient of variations of P_1, F_2 and P_2 of each character from experiment 3.

Cross		Plant weight	Main shoot grain yield	Head number	Final grain yield	Plant height
	P_1	0.73	0.54	0.49	0.79	0.21
1	F_2	0.65	0.46	0.55	0.67	0.18
	P_2	0.62	0.35	0.54	0.65	0.13
	P_1	0.79	0.60	0.52	0.84	0.19
2	F_2	0.67	0.40	0.58	0.69	0.15
	P_2	0.73	0.45	0.56	0.78	0.16
	P_1	0.58	0.42	0.50	0.65	0.14
3	F_2	0.62	0.41	0.49	0.67	0.16
	P_2	0.65	0.42	0.54	0.69	0.16

In most instances the F_2 variance values were not significantly larger than the variance of either parent and sometimes they were smaller for the characters : plant weight, head number and final grain yield. The expectation of segregation and a significantly greater F_2 variance is often not achieved for quantitative characters on plants grown at a crop density and where microenvironmental variation has a large effect. Phung (1976) and Karladee (1980) found that the F_2 and parental variances were similar for yield when measured on single plants. Although segregation may be occurring it does not lead to a very large variance under crop density conditions. The variable expression found in parental populations could be due to a lower stability to microenvironmental factors.

For a character, little influenced by the microenvironment, segregation is more obvious. The classic example is the flower size of tobacco (East, 1916). In the present study it was similarly found for the plant height variances of the F_2. It is seen from the coefficients of variation that final grain yield had the highest coefficient and plant height the lowest.

e. Frequency distribution of characters

The effect of one parent being in common was evident in the frequency distributions. Except for plant height, the characters tended to have frequency distributions similar to one parent especially in experiments 2 and 3. The more obvious effect of dominance, evident in these experiments might have been due to the proximity of the three different genotypes within a row and therefore a lesser effect of microenvironmental variation on their assessment.

In most instances, the F_2's distributions covered the combined range of the parental distributions, indicating segregation. It was most obvious for plant height and least for main shoot grain yield. The distributions of plant weight and final grain yield were similar, indicating a strong relation between these characters. Grain yield was related to head number.

The evidence for transgressive segregation was more obvious in experiment 1 than in 2 or 3. The excess value of the F_2 transgressive plants could be an expression of the accumulation of favourable homozygous dominant genes or to heterozygosity. This will only be advantageous, in pure line breeding of self pollinated crops, if the expression of the transgressive segregants is due to homozygous genes. This could not be determined without growing further generations.

The frequency distributions for final grain yield, plant weight and head number were skewed to the right. Such skews are found commonly in competitive situations (Koyama and Kira, 1956). For plant height, the distributions were skewed slightly to the left. This character tends to maintain a normal distribution under competition as a plant that falls behind in a population elongates by etiolation.

4.2 Aspects of results for the F_7 lines

a. Stability

Only a few lines were stable over the three environments and they were from both selected lines and lines taken at random. There was little evidence therefore that the form of selection used had picked out lines with stability over environments. Stable varieties are often sought in breeding programmes because of their wide adaptation. Of less general value are those varieties that show a high yield in one environment only. A good combination of relative high performance and lower sensitivity to environments one of the main objectives of breeding programmes.

Many of the variance values of lines within a family were variable across locations and years. This diversity of lines within a family was much influenced by environment. Lines within a family were found to be uniform in one area and environment (Charlick), but exhibited great variability of performance between other areas and environments (e.g. between Saddleworth and Charlick). In the result section it was also found that low yielding lines within some families stability in their variance values. With low yielding potentials the diversity was relatively small and remained unchanged over different environments.

b. Value of selection in the F_5 generation

The mean yield of the selected lines was higher than for the random lines. Although as mentioned above selection did not lead to stability across the trial sites it apparently had some effects. The technique used in the F_5 of basing selection on results from several sites seems to have been helpful in picking out the desirable genotypes.

c. Site and year interactions

In view of the large genotype x environment interactions experienced in this region (Finlay and Wilkinson, 1963) the significant correlation of lines grown over two years at the Charlick site was unusual. The high yielding lines at this site may represent a specific adaptation.

The most likely reasons for the stability is the existance of cereal cyst nematodes at this site and the occurrence of resistant and susceptible lines in the trials. A resistant line would have a higher yield than a susceptible line irrespective of good or poor rainfall during the growing season. The lines were stable even though the rainfall in the two years was very different.

d. The effect of the pedigree of the F_7 lines

From Figure 3.13 it is evident that genotype environment interactions were occurring across the different sites and years and that the interactions were related to the pedigree of the lines. Some lines derived from a given parent were stable over Saddleworth and Charlick but others had high yields at Saddleworth and low yields at Charlick. These differences in performance may have been due to segregation within a family into lines resistant or susceptible to nematodes. The more susceptible lines, therefore, were not able to reach their optimal expression at this site. It was segregating.

A positive relationship was also found for some lines with a parent in common grown at different sites and years. The parents used in these crosses appeared to impart stability of lines to environmental change and also resistance to nematodes.

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Appendix 1. Analysis of variance of each character (F test)

	Seed weight	Plant weight	Main shoot grain yield	Head number	Final grain weight	Plant height
Cross 1						
Genotypes	3.29*	.04	.50	.16	.09	42.99**
Replicates	.99	2.40	4.70	2.98	3.47	2.35
Gen.x rep. interact.	-	4.11***	1.32	8.02***	3.09*	1.38
Cross 2						
Genotypes	65.15***	0.29	3.96	.56	1.66	7.86*
Replicates	1.08	.16	.02	.88	.53	3.43
Gen.x rep. interact.	-	10.21***	1.23	13.36***	3.26*	2.53*
Cross 3						
Genotypes	96.30***	3.24	2.23	1.87	4.24	4.54
Replicates	.63	1.76	.73	2.28	.97	2.25
Gen.x rep. interact.	-	3.49**	2.13*	4.15**	1.93*	4.41**

* for significance at 5% level, ** at 1% level and *** at 0.1% level.

Appendix 2. Frequency distributions of seeds weight.

Class (mg.)	Cross 1			Cross 2			Cross 3		
	P_1	F_2	P_2	P_1	F_2	P_2	P_1	F_2	P_2
25-29	11	10	12	3	-	14	5	-	-
30-34	22	32	17	27	25	54	48	12	13
35-39	43	34	49	36	49	65	74	47	33
40-44	62	52	66	69	44	118	122	51	59
45-49	92	84	95	92	68	88	83	96	88
50-54	80	72	61	95	86	19	28	103	91
55-59	35	50	37	29	65	2	-	44	55
60-64	13	22	19	7	22	-	-	7	19
65-79	2	4	4	2	1	-	-	-	2
Total	360	360	360	360	360	360	360	360	360
Mean seed weight	45.8	47.4	46.8	46.7	48.3	41.3	42.1	47.8	49.5

Appendix 3. Cumulative distributions of the emergence rate in percent.

Time of emergence	Cross 1						Cross 2						Cross 3					
	Rep. 1			Rep. 2			Rep. 1			Rep. 2			Rep. 1			Rep. 2		
	P_1	F_2	P_2	P_1	F_2	P_2	P_1	F_2	P_2	P_1	F_2	P_2	P_1	F_2	P_2	P_1	F_2	P_2
1	2	2	5	-	-	-	-	-	1	-	-	-	1	-	1	-	-	-
7	8	15	11	2	1	6	2	1	6	6	2	11	4	-	4	7	5	10
25	31	36	31	13	8	13	3	5	12	13	10	18	12	4	13	16	14	18
31	50	61	53	26	15	31	11	13	21	23	21	41	25	18	32	27	28	34
49	64	74	71	41	23	47	23	26	33	53	50	72	40	28	43	55	52	62
55	70	79	76	59	35	66	36	37	43	66	61	79	43	35	55	65	58	73
73	75	84	79	64	43	73	46	47	55	81	78	86	51	43	61	72	67	83
79	80	85	82	75	52	86	50	54	60	88	89	91	55	49	66	78	75	88
97	84	89	86	80	57	88	58	64	68	89	94	95	62	56	72	80	81	92
103	85	90	87	85	63	89	67	69	74	92	96	96	68	64	76	83	83	93
121	91	92	91	92	69	95	76	79	81	94	97	97	75	71	82	87	86	96
127	93	93	93	93	72	95	83	84	87	95	98	97	79	77	86	88	89	97
145	94	94	95	93	79	97	90	88	91	96	99	98	86	84	90	90	94	98
151	95	94	96	96	84	97	94	93	94	98	100	99	91	90	93	93	97	98
169	96	96	98	97	88	99	96	94	96	99	100	99	94	92	95	97	99	98
175	98	98	98	98	93	99	98	97	97	100	100	100	95	94	96	97	99	98
193	98	98	98	99	98	100	99	98	98	100	100	100	97	95	98	98	100	99
199	98	98	99	100	99	100	99	99	99	100	100	100	98	97	99	99	100	100
217	100	99	99	100	100	100	100	99	99	100	100	100	99	99	99	100	100	100
223	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Appendix 4a. Variances within family of selected lines.

Line no.	1977	1978	1979
1	14521.	18750.	4849.
2	8878.	15043.	4878.
3	9534.	33837.	8569.
4	13227.	21895.	6364.
5	12975.	11305.	5866.
6	6930.	14811.	8755.
7	10804.	19283.	9041.
8	5418.	15035.	3914.
9	9683.	11339.	8299.
10	9232.	16758.	6132.
11	9006.	24179.	6541.
12	5157.	12805.	10050.
13	10681.	22696.	11443.
14	21027.	20915.	6260.
15	13075.	11946.	5325.
16	11394.	13872.	7056.
17	14568.	17075.	7430.
18	14182.	14606.	4316.
19	8778.	13410	5935.
20	11712.	13439.	6024.
21	8514.	28643.	17753.
22	12570.	17337.	8658.
23	5075.	9128.	3296.
24	13426.	46199.	25770.
25	5236.	13242.	6651.
26	11712.	13349.	4832.
27	12838.	17093.	6621.
28	8864.	12546.	5406.
29.	12646.	9331.	9229.
30	13752.	12990.	5834.
Warimba	6135.	12035.	7740.

Appendix 4b. Variances within family of lines taken at random.

Line no.	1977	1978	1979
31	20356.	26180.	5892.
32	11542.	10664.	6997.
33	6610.	15847.	8051.
34	11401.	15805.	6424.
35	8702.	23830.	5758.
36	14297.	16789.	3647.
37	6279.	24775.	7689.
38	7754.	7817.	6969.
39	10550.	18100.	4536.
40	7475.	11057.	7714.
41	7229.	23584.	9030.
42	14031.	18791.	7673.
43	10390.	11586.	10323.
44	10284.	13907.	5388.
45	14642.	12634.	6232.
46	12135.	12769.	6753.
47	7418.	15573.	6329.
48	8629.	15484.	8945.
49	13616.	21082.	4616.