HARVEST INDEX OF F_2 SINGLE PLANTS AS A YIELD POTENTIAL ESTIMATOR IN COMMON WHEAT

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"HARVEST INDEX OF F_2 SINGLE PLANTS AS A YIELD POTENTIAL ESTIMATOR IN COMMON WHEAT"

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A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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ABSTRACT

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Four crosses of spring wheat (*Triticum aestivum* L.) were used in this study.

The objectives were:

a) to assess the effectiveness of F_2 single plant selection, based on harvest index,

b) to study a number of F_2 single plant characters for their possible association with harvest index,

c) to study the relationship between harvest index, grain yield and total productivity of F_2 single plants and the harvest index, grain yield and total productivity of single plants of the derived F_3 families,

d) to study the inheritance of harvest index.

The relationship of harvest index of the 19 selected F_2 single plants per cross and the yield of the derived F_3 and F_4 bulks was assessed. No significant correlations were obtained. The yield of the 19 selected F_2 single plants per cross were also ranked against the plot yields of the derived F_3 and F_4 bulks. And, again no significant correlations were obtained. However, significantly high correlations were obtained between total productivity of F_2 single plants and the bulk yields of the derived F_3 and F_4 generations.

From the analysis of the F_2 single plant characters, it was found that morphological characters, e.g., plant height, total number of tillers, flag leaf length, breadth and sheath length had no associations with harvest index. On the other hand, the numerical components of yield, notably kernels per head and kernel weight had high associations with harvest index. The correlations between harvest index and kernels per head in crosses I, II, III and IV were 0.48, 0.44, 0.41, and 0.47 respectively, and all were significant at the 1% probability level. The correlations between harvest index and kernel weight in crosses I, II, III and IV were 0.47, 0.39, 0.47, and 0.38 respectively, all were significant at the 1% probability level.

In the study to show any relationships between harvest index of F_2 single plants and the harvest index of single plants of the derived F_3 families, significant correlations were obtained in cross I (r_s = 0.54, P = 0.05), cross II (r_s = 0.61, P = 0.01), and cross III (r_s = 0.49, P = 0.05). No significant correlation was obtained in cross IV. Significantly high correlations between total productivity of F_2 single plants and the total productivity of the derived F_3 spaced plants, were obtained in cross II (r_s = 0.59, P = 0.01), cross III (r_s = 0.48, P = 0.05) and cross IV (r_s = 0.70, P = 0.01). No significantly high correlation was found in cross I.

No significantly high correlations were obtained between grain yield of F_3 spaced plants and the F_2 single plants from which they were derived.

The study on the inheritance of harvest index showed that neither the additive nor the dominance gene effects controlled harvest index in the four crosses.

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1. INTRODUCTION

The yields of cereal crops have increased very dramatically from the dawn of agriculture to the present time. For example, in Japan, the yield of brown rice in 900 A.D. was approximately one ton per hectare, in 1885 the yield was two tons per hectare, and by the middle of the 1950's the yield was about four tons per hectare (Ishizuka, 1968). Thus, it took about 1,000 years to double the yield, up to the end of the 19th century, and less than 70 years to redouble it; the latter period being marked by the integration of agricultural sciences, education and extension. The same pattern follows for the other cereals, especially wheat, although not necessarily in the same time scale.

However, in the past few decades cereal yields have not increased appreciably. For example, the rice yields in Japan (Ishizuka, 1968), the oat yields in many parts of the world (Poehlman, 1959) and wheat yields in Oceania, Africa, China, South American (CIGI - Grains and Oilseeds, 1975) have not increased much over the past twenty years. In the rest of the world, the grain yields have also been marked by a progressively slower rate of increase.

It therefore has become very imperative for the research workers to improve the yields of these cereals. The ways to do this are breeding, proper use of the land, efficient use of chemicals and of all these, breeding is the most important because for any crop, the limit to yield is preset by the genetic ceiling.

Breeding for yield has been of considerable interest to cereal breeders, and many alternative breeding strategies have been devised. These include the pedigree and bulk methods, the use of hybrids, recurrent selection, and the use of synthetic varieties (Allard, 1960; Poehlman, 1959). As well, many have been proposed, such as early generation selection (Frey, 1954), plot techniques (Fisher, quoted by Fasoulas, 1976) and the non-replicated honeycomb designs (Fasoulas, 1976); only to mention a few.

For the self-pollinating cereals such as wheat, there is no doubt that for maximum efficiency, selection for yield should be started as early as possible, preferably in the F_2 generation. As the generations advance the frequency of a desired genotype gets progressively lower. Shebeski (1967), and Shebeski and Evans (1973) have outlined in a theoretical consideration the importance of early generation selection for yield. For example, if the two parents in a cross differ by 25 important genes for yield, only $(3/4)^{25}$, or one plant in 1,330, of the F_2 retains the best 25 alleles in either the homozygous or heterozygous condition. If selection is delayed until F_4 as in the bulk method, only one plant in 1.8 million may be expected to contain all of the better alleles.

However, investigators have not all agreed as to the value of predictions based on early generation performance. Immer (1941) working with barley, Harrington (1940) with wheat, and Leffel and Hanson (1961) with soybeans concluded that tests in F_2 and F_3 were useful in identifying crosses from which high yielding segregates might be obtained.

On the other hand, Fowler and Heyne (1955), McGinnis and Shebeski (1968), Knott (1972) and De Pauw and Shebeski (1973) working with wheat, Atkins and Murphy (1949) with oats, and Weis, Weber and Kalton (1947) with soybeans found early generation selection based on F_2 grain yield ineffective.

A selection criterion that is currently drawing the attention of many investigators is plant harvest index, i.e., the ratio of grain yield to the total above ground dry matter yield expressed as a per cent. Wallace and Munger (1966) concluded that the success in breeding higher yielding varieties has arisen in part from the unconscious selection for higher harvest index, particularly when the reproductive organs are the plant fractions of economic interest.

The study reported herein evaluated the feasibility of using harvest index in F_2 as a measure of subsequent generation yield potential. The study also examined a number of plant characters of the F_2 single plants, for their possible association with harvest index and yield. The inheritance of harvest index was also examined.

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 Breeding for Yield

2.1.1 General

Frankel (1947) in his discussion on the theoretical bases of breeding for yield came to the conclusion that improved yields can best be obtained by the elimination of defects, such as disease susceptibility, lodging susceptibility, etc. This, coupled with improved agronomic practices, has ensured relatively high stable yields for many years.

In the past three decades, however, many plant breeders have placed major emphasis on breeding for yield *per se*. Whitehouse *et al.* (1958) tried to accumulate as many genes as possible into one variety using a diallel set of crosses of four spring wheat varieties. Fasoulas (1976) working with corn was successful in improving yield in both inbreeders and outbreeders. The approach he used was based on two principles and two environmental designs: the first principle stated that genotypic evaluation was better accomplished through individual and progeny yielding performance, and the second that maximal genotypic expression and differentiation is obtained under optimal growing conditions, namely, high soil fertility and complete absence of competition. The two environmental designs were the non-replicated screening honeycomb design which evaluated on the basis of individual performance, and the replicated honeycomb design which evaluated on the basis of progeny performance and served three purposes: (a) ranked established cultivars according to yield potential, (b) assessed the breeding value of parent plants, and (c) practiced selection within and between families. He attributed his success to accumulation of favorable genes into progressively fewer cultivars.

Because the heritability of total yield is very low (Johnson *et al.*, 1955; Leng, 1963), the success of breeding depends to a large extent on the efficiency of the selection procedures used. The very low heritability of yield may be due to the fact that yield is conditioned by many genes on many chromosomes (Kuspira and Unrau, 1957), and that individual genes have small effects on the expression of yield (Falconer, 1960). Palmer (1952) suggests that there is even a possibility of gene interaction which may have a negative influence on yield.

2.1.2 Yield Components

Evans and Wardlaw (1976) suggested that one reason for the success of cereals as crops is their capacity for yield component compensation, i.e., for the later-determined components of grain yield to compensate for earlier losses or restriction of development or to take advantage of favorable conditions late in the crop life cycle. The major cereals, however, differ in the extent to which such yield component compensation can occur in the later stages of the life cycle. Matsushima, 1970 (Quoted by Evans and Wardlaw, 1976) observed that kernel size is more restricted by the glume size in rice than in other cereals, with the result that kernel weight in rice is far less variable and unable to accommodate additional carbohydrate when conditions during grain filling favor more rapid or prolonged grain growth.

In wheat and barley, on the other hand, kernel weight displays a substantial range. If grain number per ear is reduced, the remaining grains may grow to a greater size in wheat (Bingham, 1967; Rawson and Evans, 1970). This did not occur in barley (Buttrose and May, 1959) or maize (Duncan and Hatfield, 1964), which suggests that assimilate supply was not limiting grain growth in intact ears.

The increased understanding of the components of yield in the cereals has, therefore, led to deliberate attempts to breed for yield through yield components. Knott and Talukdar (1971) transferred high seed weight from the cultivar Selkirk to Thatcher by backcrossing, and found the backcross lines with high seed weights out-yielded Thatcher. Adams and Grafius (1971) suggest that the major emphasis in breeding for higher yields should be directed towards increasing the flow of environmental resources during the period of greatest need by the individual yield components. Rasmusson (1968) working with barley recommends developing varieties which produce the highest mean yields and yield above average in all environments.

The yield components, however, are affected by the physiological responses of the crop to the environment (Grafius, 1965; Adams, 1967). This makes them particularly difficult to breed for, since the environments are variable. The interaction containing genotype x year terms usually reflects fluctuations in environment which for the most part cannot be predicted in advance (Mather and Jinks, 1949; Allard and Bradshaw, 1964; Johnson *et al.*, 1966). Soil fertility and water supply, and the usual seasonal sequence of conditions, may favor a particular balance among the yield components, as Grafius and Okoli (1974) argue for barley. But there are considerable differences among plant breeders