A STUDY OF THE RELATIONSHIP AND PERFORMANCE OF PARENTAL RYE LINES, THEIR TOP-CROSSES, AND THEIR TRITICALE AMPHIDIPLOIDS

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Kenneth William May

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TABLE OF CONTENTS

Page

LIST OF TABLES

ABSTRACT

May, Kenneth William. Ph.D., The University of Manitoba, November, 1976. A Study of the Relationship and Performance of Parental Rye Lines, Their Top-Crosses, and Their Triticale Amphidiploids. Major Professor: Dr. E. N. Larter.

Successful plant breeding endeavours are dependent upon a broad genetic base from which superior genotypes may be selected. In the synthesis of triticale (X Triticosecale Wittmack) the production of new amphidiploids is the most common means of combining the genetic variability of the established wheat and rye species. However, the synthesis techniques presently available are not very efficient. One method of overcoming this inefficiency is by concentrating only on those wheat-rye crosses which are the best combiners. The objective of the present study was to investigate the effect of rye upon the plant characteristics in the top-cross rye hybrids and wheat-rye hybrids.

Mainly inbred parental rye lines were selected for this study because of their greater genetic homozygosity than cross pollinated rye lines. The parental rye lines were crossed onto Secale cereale, cultivar 'Prolific,' Tritium durum, cultivar 'Jori,' and Triticum aestivum, cultivar 'Sonora 64.' The crossing produced top-cross rye lines, hexaploid triticale lines, and octoploid triticale lines.

The results of the analyses of variance indicated that there was genetic variability within the inbred rye, top-cross rye, hexaploid triticale, and octoploid triticale. Thus, selection for all of the plant characteristics would be possible. The variation among hexaploid triticale lines occurred both within and between triticale families. The variation between these families was attributed to the difference between parental rye lines. Thus, a definite portion of the variation among the hexaploid triticale arose from the differences between parental rye lines.

The results of the analysis of variance of the field experiment indicated that four rye characteristics (the number of florets per spike, the number of kernels per spike, flag leaf length, and spike fertility) were not affected by the environmental differences occurring between the replications. The results of the correlations between the field and growth cabinet conditions showed that seven rye characteristics (the number of florets per spike, the number of kernels per spike, spike fertility, days to heading, harvest index, kernel weight, and straw protein) maintained consistent rankings, relative to one another. The phenotypic expression of the parental rye lines for six of the seven characters (excluding days to heading) was positively correlated with the expression of that character in top-cross rye. These six rye characteristics were genetically correlated between inbred and top-cross, and environmentally stable enough to be the basis of selection of parental rye lines for hybridization.

The characters measuring grain production on a spike basis (number of kernels per spike and fertility), and harvest index were intercorrelated among the inbred rye, topcross rye, and hexaploid and octoploid triticale. Straw protein was negatively correlated with most of these characters in rye and triticale. An additional negative correlation was obtained between days to heading and the characters measuring grain production in growth cabinet experiment with inbred rye and hexaploid triticale.

There were significant correlations among spike number, plant height, dry weight per plant, and spike length which were environmentally unstable characters among the rye lines. These significant correlations were present in many rye and triticale experiments but were not consistently correlated with the characters measuring grain production. This separation of the plant characteristics into two groups may have been caused by their respective sensitivity to environmental conditions.

There were many other significant correlation coefficients (especially with days to heading) but these did not occur consistently across several or all of the experiments. A few of the plant characteristics were conspicuous by their lack of correlations with other characters. The most notable of these were kernel weight, grain protein, and the number of florets per spike.

The intercorrelations among the characters measuring grain production and plant development means that only one character need be measured to represent each trait. The characters measuring grain production (kernels per spike, fertility, and harvest index) were environmentally stable and contained significant correlation coefficients for the studies between inbred and top-cross rye. The intercorrelated characters measuring plant development (spike number, dry weight per plant, and plant height) were not environmentally stable and were not consistently correlated between inbred and top-cross rye. These characters would not be very reliable as selection indices under the present conditions of experimentation. Kernel weight and the number of florets per spike would each prove to be good selection indices because of their non-significant correlation with other characters, environmental stability, and correlation between inbred and top-cross rye lines. Selection among the present rye lines for one of the characters measuring grain production (kernels per spike, fertility, or harvest index), kernel weight, and florets per spike would produce more desirable triticales than if selection had not been applied. The improvement in the triticales would occur in characters for which selection was practiced.

INTRODUCTION

Triticale (X *Triticosecale* Wittmack) is a recently developed species and consequently still has a narrow genetic base. As this base is broadened due to breeding, selection, and utilization of an increasing array of parental species of wheats and ryes, certain agronomic problems inherent in early triticales are gradually being overcome. Gustafson (1973) outlined techniques being used to increase the variability within the triticale species. These techniques are:

(1) synthesis of new amphidiploids,
(2) 56- X 42-chromosome triticale crosses,
(3) tetraploid wheat X 42-chromosome triticale crosses,
(4) diploid rye X 42- or 56-chromosome triticale crosses,
(5) hexaploid wheat X 42- or 56- chromosome triticale crosses,
(6) 42-chromosome agrotriticum X 42-chromosome triticale crosses,
(7) 42-chromosome triticale X 42-chromosome triticale crosses,
(8) screening composite populations mainly to select specific phenotypes (large seed types).

The synthesis of new amphidiploids is the only technique of the eight listed by Gustafson (1973) which brings an entirely new rye genome into triticale. This technique is the most common method for bringing new genetic variability from rye species into triticale. However, there are a couple of major disadvantages associated with the synthesis of new amphidiploids. It is the most difficult technique because it requires lengthy and involved processes in the laboratory. In contrast, the other techniques can all be accomplished in the field. The second disadvantage is that the new amphidiploids will have more numerous meiotic and/or agronomic abnormalities than the recombinants from the other techniques. This situation exists because the parental triticale material used in the other techniques listed by Gustafson (1973) has already been selected to remove many of the undesirable characters.

The efficiency of the production of desirable raw amphidiploids may be improved considerably if the selection and/or predictive tests suggested by Kaltsikes (1974) and Darvey (1973) could be conducted on the parental rye before synthesis of the new amphidiploids. McDaniel (1973) has suggested the use of mitrochondria complementation test to select the lines of rye and wheat which appear to offer potential for triticale synthesis. The extension of this type of parental testing to plant and grain characteristics has not been reported in the literature. There is a lack of information on rye species concerning the genetics of agronomic characteristics and their contribution to the genetic background of triticale. Heritability studies have been extensive in wheat and limited in rye and triticale. Thus the information from wheat must generally form the basis for the assumptions concerning the genetics of agronomic characteristics in rye and triticale.

Another important question concerning triticale synthesis, is the influence of the parental rye on the resulting triticale. In a study by Quinones *et al.* (1972) it was shown that resistance to wheat leaf rust (*Puccinia recondita*), in the rye parent was not transferred to the resulting triticale. However, Morrison (1975) found that wheat stem rust resistance, *Puccinia graminis tritici*, was transferred from rye to triticale. The need to determine the importance of the rye parent to the agronomic and reproductive characteristics of the triticale formed the basis for the present study.

The objective of the present study was to investigate the effect of rye characteristics upon the respective characteristics in the top-cross rye hybrids and wheat-rye hybrids. Statistical analyses were performed on the data from top-cross rye, hexaploid triticale, octoploid triticale as well as the parental rye lines. Information about individual characters was obtained from rye and triticale by conducting correlations between the data from each pair of plant characteristics and an analysis of variance upon the data for each character in each experiment. Additional information about each character within the rye lines was obtained from correlations between growth cabinet and field conditions as well as between inbred and top-cross lines of rye.

In addition to the main objectives outlined above, the method and effectiveness of amphidiploid synthesis was also evaluated in respect to the triticales produced for this study. Similarly, the inheritance of pericarp colour and grass dwarf hybrids as they related to the rye and triticale in this study, was also studied.

LITERATURE REVIEW

This literature review is presented in the following nine sections: 1. a summary of the factors controlling crossability,

2. a review of the chromosome doubling techniques pertinent to the present study,

3. a short discussion of the relationship of ploidy level as it relates to the agronomic and biological behaviour of triticales,

4. a discussion of meiotic stability and its relationship to grain yield,

5. a review of the studies attempting to explain the cause of seed shrivelling in triticale,

6. a brief summary of the inheritance of grain and plant protein,

7. a review of the literature concerning yield components in small cereals,

8. a summary of the inheritance and correlations among plant characteristics,

9. a review of the studies of general combining ability in relationship to hybrid production and application to triticale synthesis.

Crossability

Crossability of wheat and rye is genetically controlled by two major genes located on chromosome 5A and 5B (Riley and Chapman, 1967). Highly crossable wheats produced approximately 50% seed-set and the low crossable wheats 5% or less (Riley and Chapman, 1967; Kaltsikes, 1974). Riley and Chapman (1967) concluded that tetraploid wheats more readily set seed when crossed with rye than almost all of the hexaploid wheats of Europe that he tested. The crossability indicated by the percent seed-set presented by Kaltsikes (1974) illustrated the great variation among tetraploid and hexaploid wheats in their crossability with rye. The data presented by Krolow (1970) indicated that the majority of the forty-six varieties in six species of tetraploid wheat tested were in the mid and high crossability categories. The very low natural germination of these tetraploid embryos was attributed to abnormalities in embryo and endosperm development. The seed-set of 4.96% given by Krolow (1970) for hexaploid wheat when crossed with rye was lower than his values for tetraploid wheat. However, the germination of the hybrid seed from hexaploid wheat was 61.83% which resulted in a higher percentage of hybrids in comparison to those from tetraploid wheat.

In a series of investigations, Tozu (1966) searched for the physiological stage at which the genetic crossability factors have their effect, and narrowed the phenomena to a period either directly before or after fertilization. The stigmatic receptivity of wheat and the pollen tube growth of rye in the wheat style was not affected by the crossability genes.

The theory has been advanced by Riley and Chapman (1967) that crossability genes could have developed to prevent wheat from naturally crossing with rye and producing its own weeds. Kaltsikes (1974) concluded that the specific genetic factors preventing the crossing between wheat and rye developed gradually. This conclusion was based upon the fact that crossability between tetraploid wheat and primitive rye was higher than with cultivated ryes (Kältsikes, 1974).

Chromosome Doubling Techniques

The alkaloid colchicine is the most commonly used chemical to induce doubling in triticale hybrids. Kaltsikes (1974) briefly reviewed nine methods by which colchicine can be applied and the degree of success experienced with each of the methods. The most effective and commonly used was the capping method proposed by Bell (1950). One or more tillers are cut back to 2-3 cm in length and a vial containing a 0.2 - 0.3% aqueous solution of colchicine is inverted over each cut tiller for seventy two hours. Sanchez-Monge (1958) reported a doubling rate of forty-six percent using the capping method for embryos produced from hexaploid wheat and diploid rye. Using this method he applied colchicine to one to three tillers on plants containing four to eight tillers respectively.

The effectiveness of the colchicine treatment has been increased three to four times by using the surfactant dimethyl sulfoxide (Sanders and Hull, 1970; Subrahmanyan and Kasha, 1975). Sanders and Hull (1970) obtained an increased rate of doubling from the solution of colchicine and dimethyl sulfoxide when applied to germinating seeds of Rubus, but no effect when applied to the apices. The barley haploids used by Subrahmanyan and Kasha (1975) were doubled at the 2- or 3-leaf stage in a culture vial. A 3-4 ml solution, which covered the crown, was poured into the vial and left for five hours before washing the plant and potting it in soil.

Genetic Constitution of Hexaploid versus Octoploid Triticale

Various combinations of the genomes from *Gramineae* have been produced for research purposes in an attempt to produce new and improved species (eg. triticale). Genome interrelationship and combining ability was investigated in relation to its effect on yielding capacity (Shebeski, 1958). The research presented by Shebeski (1958) indicated that the R genome of *Secale cereale* was a better combiner than the D genome of *Aegilops squarrosa L.* with the A and B genomes of tetraploid wheat. Manipulation of whole or parts of genomes may produce a genotypic combination with improved yielding capacity compared to the present species.

The first triticales synthesized by man were between hexaploid wheat and diploid rye (Muntzing, 1939). Emphasis then shifted towards the use of tetraploid wheat parents because of the improvement in seed-set, fertility, and