EFFECT OF THE NUMBER AND POSITION OF INTERCHANGES ON THE FERTILITY OF HYBRIDS INVOLVING NORMAL AND HOMOZYGOUS INTERCHANGE STOCKS OF BARLEY

by

Chang-sheng Shih

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

AND RESEARCH IN PARTIAL FULFILMENT

OF THE DEGREE OF

MASTER OF SCIENCE

THE UNIVERSITY OF MANITOBA

May 1960

ACKNOWLEDGEMENT

The writer wishes to express his sincere appreciation to Professor L. H. Shebeski for his continual guidance and encouragement throughout the course of this study and in the preparation of this manuscript.

Grateful acknowledgement is made to Mrs. B. Chernick and Mr. M. Shaw for their aid in making crosses. Thanks are also extended to Mr. R. Boyd for reading an earlier manuscript and offering suggesttions for its improvement.

The financial assistance for this study by the National Research Council of Canada is acknowledged.

ABSTRACT

Homozygous interchange stocks of barley were intercrossed, and also crossed with the normal stock Montcalm, to produce plants heterozygous for interchanges at different levels of chromosome participation. The fertility of interchange heterozygotes decreased as the number of chromosomes involved in interchanges increased. When the same level of interchange chromosome participation occurred, sterility was dependent on the size of the chromosome ring or rings formed at meiosis. Thus, plants with a ring of eight chromosomes had a higher sterility than plants with two rings of four chromosomes; plants with a ring of ten were more sterile than plants with a ring of six plus a ring of four; the sterility of plants with either two rings of six, or a ring of eight plus a ring of four, was higher than that of plants with three rings of four chromosomes.

Diallel crosses within both (a-b) and (c-f) interchange stocks were made. In six (a-b) interchange stocks, metaphase configurations of seven bivalents were observed in the F_1's from crosses made

among C1343, C1384, C1385, XT8, and Ert7. Both a ring of four configuration and seven bivalents were found in the F_1's from crosses made between these stocks and XT12. In the seven (c-f) interchange stocks, plants from crosses among XT10, Ert1, Ert14, and XT6 as well as crosses among XT4, Ert47, and C1336 formed seven bivalents at meiosis, while crosses between these two groups gave rise to plants in which both ring of four configurations and seven bivalents were observed. A similar degree of sterility was found in plants with and without ring formation.

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX

INTRODUCTION

The "Oenothera" method of establishing homozygous lines from promising hybrids, has been suggested for species which have a relatively low number of chromosomes and where a relatively high degree of fertility can be maintained in plants heterozygous for interchanges (5).

To date, the incorporation of appropriate interchanges in a single stock, which if crossed with a normal stock would produce a complete ring of all chromosomes, has not been achieved. Barley (Hordeum spp.) would appear to be an excellent experimental crop to test the "Oenothera" method of establishing homozygous lines because of the relatively low chromosome number and because at the single interchange level the fertility of interchange heterozygotes appears to be fairly high.

Final synthesis of a stock homozygous for interchanges involving all 14 chromosomes, that will be useful in testing the "Oenothera" method, will depend on the position of interchanges in the stock and the degree of sterility of the heterozygotes produced when it is crossed with normal stocks.

Since very little is known about the fertility of various complex interchange combinations, and how fertility may be affected by the position of interchanges, these phenomena are worthy of study.

A collection of a large number of interchange stocks of barley has been made, and by suitable crossings, it should be possible to build up complex interchanges heterozygotes. For the stocks that involve interchange between the same two pairs of chromosomes, it should be possible to study the positions of the breakage points and how these may affect fertility.

The objectives of this study were designed therefore to investigate:

(1) The fertility of interchange heterozygotes at different levels of chromosome participation.

(2) The effect of the relative positions of the points of interchange on metaphase pairing and fertility in the F_1's resulting from diallel crossing within different (a-b)* and (c-f) stocks.

---

* The seven chromosomes of barley have been assigned the letters a to g by Burnham *et al*. (10). The hyphenated letters indicate the interchange chromosomes involved in homozygous interchange stocks.

LITERATURE REVIEW

Interchanges are the result of exchanges of segments between non-homologous chromosomes. They were first termed "segmental chromosomal interchanges", but are now more simply referred to as interchanges, reciprocal translocations, or translocations (8). The interchanges may arise "spontaneously", may be induced by irradiation or may be produced by treatment with certain chemicals.

According to Burnham (8), the first observation of more than two chromosomes attached, so as to form a ring at meiosis, was reported by Gates in Oenothera rubinervis L. The first account of the breeding behavior of a probable case of interchanged chromosomes was reported by Belling (2). He proposed a two-gene hypothesis to account for the 50 per cent aborted pollen in the F_1 of a velvet bean cross, but he also pointed out that the abnormal behavior of two chromosome pairs may explain the results. That interchanges were responsible was not interpreted until 1925, when he explained this breeding behavior on the basis of "segmental interchange between non-homologues" (3). Since then, the phenomenon of interchanges has been widely studied in a number of plants.

Belling's explanation of chromosomal ring formation at the time of reduction division (4), has been applied to explain ring formations in Oenothera and other genera (13, 14, 15). After Burnham's proposal that the "Oenothera" method may be applied to gamete selection (5), attempts have been made to build a large ring in maize (Zea mays L.), Einkorn wheat (Triticum monococcum L.) and barley, by a series of crosses between, or by cyclic irradiation of, existing interchange stocks. A ring of 10 chromosomes (⊙10) in maize was obtained from cyclic irradiation of an interchange stock (8). This was obtained in successive steps. First, a ring of eight chromosomes (⊙8) was produced by X-irradiation of a stock homozygous for one interchange. Then a stock homozygous for the interchanges involving the four pairs of chromosomes was X-rayed to produce lines which differed from it by one additional interchange. Yamashita (45) developed a ring of 14 chromosomes in T. monococcum L., but both parents of the cross contributed interchanges. Nishimura et al. (34) and Nishimura and Kurakami (33) suggested that a stock in barley which will give a ring of eight plus a ring of six (⊙8+⊙6) or a ring of 10 plus a ring of four (⊙10+⊙4) in crosses may be synthesized in a shorter time then a complete ring of 14 chromosomes.

When a normal stock is crossed with a stock involving one interchange, three possible types of chromosome pairing may occur at meiosis in the F_1 (8). The interchanged chromosomes are usually associated in a ring, if the exchanged segments are long. They appear as a chain if one long segment