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# A STUDY OF FACTORS RELATED TO PRODUCTION POTENTIAL OF HYBRID TRITICALE

by

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# INTRODUCTION

Hexaploid triticale became an official crop of commerce in Canada with the licensing of the variety Rosner in 1969 (Larter *et al*. 1970). This has stimulated many researchers and plant breeders to work at this crop more intensively. It is a species in which hybrid seed production could be exploited beneficially because its synthesis involves the combination of a naturally inbreeding species (wheat) with an outcrossing one (rye). Although the inbreeding habit dominates in this amphiploid, triticale nevertheless tends to outcross and with the appropriate selection procedures, the development of a cross-pollinated strain is feasible.

The procedure for commercial hybrid wheat production for example, is dependent upon the development of lines carrying cytoplasmic male sterile and fertility restoring factors. In wheat, cytoplasmic male sterility was obtained by transferring the wheat nucleus into cytoplasm of either *Aegilops caudata* L. (Kihara, 1951, 1967), *Aegilops ovata* L. (Fukasawa, 1953) or *Triticum timopheevi* Zhuk (Wilson and Ross, 1962). Similarly, the fertility restoring mechanism currently used was derived from the nuclear-cytoplasmic interaction involving the same two species, *T. timopheevi* and common wheat. The derivation of both of these mechanisms - male sterility and fertility - requires fairly lengthy and parallel programs of alternate backcrossing and testing.

Triticale, as indicated above, possesses certain traits which make it appear suitable for development as a hybrid seed crop. Before undertaking the development of the genetic mechanisms for hybrid seed production in this species however, fundamentals regarding its potential as a pollen donor should first be investigated. To assess this problem, three main lines of investigation were taken: (1) to compare the pollen productivity of triticale relative to wheat (*T. aestivum* L. em Thell.) and rye (*Secale cereale* L.), (2) to determine the pattern of triticale pollen dissemination through the air, and (3) to determine the longevity of triticale pollen relative to that of wheat and rye pollen. This thesis is devoted to the reporting of the results of these investigations.

# REVIEW OF LITERATURE

## I. Factors affecting pollen dissemination

### (i) Environmental factors

Environment plays an important role in controlling pollen dissemination. Brook and Puri (1963) studied atmospheric conditions as they influence pollen shedding of hops (*Humulus lupulus* L.) and stated that temperature appeared to be the most important factor controlling pollen dissemination. Neither time of day nor relative humidity had a strong influence on shedding of pollen. Cloud cover during the morning seemed to delay pollen shedding while wind velocities from 0 to 5 m.p.h. (0 to 8 km.p.h.) were not considered as an important factor. A similar finding was recorded by Jones and Newell (1946) working with grasses.

### (ii) Morphology of the plant

The morphology of the plant itself also has an influence on pollen production and dissemination. Olson (1966) noticed that wheat varieties that were tall and which possessed lax, awnless heads readily extruded their anthers thereby releasing more pollen into the air. Joppa *et al*. (1968) stated that independent variables such as percent anther extrusion, number of pollen grains per anther, and tillers per plot, accounted for approximately 93% of the variation in pollen production in *T. aestivum* and *T. durum* Desf.

#### (a) Pollen grain size -

Pederson *et al*. (1961 a) concluded that pollen grain size was not a factor in influencing dispersal, thereby the pollen load over a specific area. In his study, the relationship of pollen distribution to fertility as measured in terms of seed-set in rye was not consistently positive. In contrast, Bitzer and Patterson (1967) exposed hand-emasculated wheat spikes to wind-borne pollen and obtained seed-set under conditions of both high and limited pollen dispersal. They concluded that seed-set was directly related to wind-borne pollen load.

Wodehouse (1935) described the structure of wheat pollen grains as irregular but tending to be ovoid with diameters of 48 to 57 $\mu$. The structure of rye pollen grains he described as ellipsoidal with dimensions of 62 X 40 $\mu$. The sizes and shapes of grains are affected by internal environment of the anther and external climatic conditions. These conclusions agree with those of Rajki and Rajki (1966) who described fertile pollen of wheat to be somewhat oval with a diameter ranging from 42.6 to 61.0 $\mu$.

Several workers including Forlani (1953), Petrovskaja-Baranova (1958), Cetl (1960), Aziz (1960), Ukolov (1967), Kozlenko (1968), D'Souza (1970) observed differences in grain size among *Triticum* species. Forlani, Petrovskaja, and Cetl also reported an increase in pollen size with an increase in chromosome number. The average diameter of pollen grains with different ploidy level as found by Forlani were: diploid 45.83 $\mu$, tetraploid 50.44 $\mu$ and hexaploid species, 58.87 $\mu$. The ratio of volume of pollen grain to ploidy level as reported by Petrovskaja-Baranova for *T. monococcum* L. (2n = 14), *T. timopheevi* (2n = 28), and

*T. aestivum* (2n = 42) was 1.00: 1.82: 2.62 respectively. The increase in volume was not directly proportional to increased ploidy. Also Mameli Calvino (1956), after investigating the diameter of pollen grains and chromosome number of some thousand angiosperm species, reported that these two characteristics are positively correlated.

(b) Anther size -

Cahn (1925) reported significant differences in anther length in wheat varieties and concluded that the number of grains per anther is directly related to anther size.

Kherde *et al*. (1967), based on data from 45 wheat strains reported that anther length ranged from 3.19 to 4.41 mm and from 0.59 to 0.96 mm in width. However, he found no correlation between percentage seed-set on male sterile wheats and anther length of the pollinators.

Athwal and Kimber (1970) who studied anther size of wheat-rye addition lines and their parental species, reported the mean length of anthers in wheat and rye to be 3.45 mm and 8.25 mm respectively, while those of six wheat-rye addition lines ranged from 2.82 to 3.83 mm. They concluded that the small size of *T. aestivum* anthers is epistatic to the longer anther of *S. cereale*.

(c) Number of pollen grains per anther -

Cahn (1925) reported a significant difference in the number of grains per anther between varieties of wheat. The number of pollen grains per anther ranged from 856 to 1380 under field conditions and somewhat less in the greenhouse. The length of the anther seems to reflect its pollen holding capacity.

Joppa _et al_. (1968) investigated eleven varieties of hard red spring wheat and three durum wheat varieties and reported that they varied in the number of pollen grains per anther, ranging from approximately 3870 in the variety Rescue to 2690 in Fortune.

D'Souza (1970) reported that in two varieties of triticale, he estimated a total of approximately 6950 and 9270 pollen grains per anther respectively as compared to 21,400 for rye, and from 2230 to 3020 for wheat depending upon genotype.

(d) _Percent anther extrusion_ -

Percent anther extrusion, as related to the frequency of open florets, is an important factor for hybrid seed production and has a direct effect on pollen load (Joppa _et al_. 1968). A wide range in the frequency of open florets has been found among wheat varieties (Turbin and Volodin, 1956). Similarly, environmental conditions affect the degree of floret opening, e.g. moisture level (Rajki, 1960), temperature (Maksimov, 1964), the influence of manuring (Selepov, 1968), and morphology of the flower (Olson, 1966).

The proportion of open florets reached 100% on varieties of _Triticum_ studied by Rajki (1960) who also observed that within species, intervarietal differences in extrusion frequency were smaller than those due to climatic changes. He also demonstrated that the frequency of open flowers was highest in the earliest developing florets of a spike while the late developing florets exhibited a relatively low extrusion frequency.

Varenica *et al*. (1968) from the examination of 26 wheat cultivars found that nine had at least 90% open florets, eight had 80 to 89%, five had 70 to 79% while the remainder exhibited less than 70% open flowers. The lowest frequency found was from 29 to 34%. Similarly Joppa *et al*. (1968) investigating the pollen production of eleven hard red spring and three durum wheat varieties observed that anther extrusion varied from 72% in Thatcher spring wheat to 22% in Lakota durum wheat. They also concluded that percent anther extrusion had a greater direct effect on pollen load than either number of grains per anther or tillers per plant for a given plot area.

D'Souza (1970) working on percent anther extrusion of a number of varieties of wheat, rye, triticale, and *Secalotricum* under field and growth chamber conditions found that intervarietal differences in wheat exist in the field ranging from less than 30% extrusion (cult. Lichti) to over 80% extrusion (cult. "Diamant" and "Frontana Thatcher"). Triticale and *Secalotricum* varieties had a higher frequency of extrusion than wheat, ranging from 70% and 90%. In comparison, rye was found to have over 90% extrusion. From the results of field trials they also observed that the percentage of protruding anthers was influenced by weather and depending upon variety, environmental influence was variable. From growth chamber results however, they concluded that the percent of extruded anthers under standard conditions is constant and specific for one variety.

(iii) Pollen viability

It is known that viability of pollen varies with species, environmental conditions, and time of storage (Abramova, 1967). In general, pollen of the cereal and grass species is short-lived whereas pollen from some of the leguminous species has a long viability period. Hanson (1961) noted that the longevity of alfalfa pollen for example, is equal to the life span of the untripped blossom.

Anthony and Harlan (1920) in their study on germination of barley pollen stated that the period of viability of this species is very short and when left exposed to air for as little as two minutes, severe shrinkage occurred. However, when allowed to remain in a cool, dark room maintained at high humidity, barley pollen remained viable for as long as 24 hours.

Kulbil (1959) as reported by D'Souza (1970), found that wheat pollen remained viable for 5 hours if kept in a desicator above calcium chloride at a low temperature. Rye pollen on the other hand was viable up to 6 days if maintained at 5°C over 25% sulphuric acid. Athwal and Kimber (1970) indicated that rye pollen was still viable after storage under greenhouse conditions for 30 minutes. Pollen of both wheat and wheat-rye derivatives however, was inviable after only 5 minutes.

D'Souza (1970) stored pollen under various temperatures and humidities for different periods of time before pollinating emasculated plants. Based on seed-set percentages, his data indicated that low temperature and high humidity prolonged the viability of rye pollen. Pollen stored for 120 hours at 5°C and 95% humidity still produced a seed-set of 3.8%. Optimum requirements for wheat, triticale and *Secalotricum* pollen were similar, a finding in accord with that recorded by Arp (1967) as reported by Goss (1968).

Very recently, Khan *et al*. (1971) studied the effect of relative humidity on viability and longevity of wheat pollen of the variety Scout. They reported that when pollen grains were stored at 4°C, highest viability at any particular time was obtained for those samples stored at humidity of 80%. In addition, they suggested that the benzidine-hydrogen peroxide technique was reliable for determining pollen viability.

## II. Measured range of pollen dissemination

The dispersal of pollen in relation to distance from the source has been investigated by a large number of workers using either pollen density counts or percent outcrossing as a method of assessment.

### (i) Pollen density count method

Pollen traps consisting of greased microscope slides exposed to the air have been the most commonly used method for evaluating pollen load distribution. Jensen and Bogh (1941), as reported by Griffiths (1950) used this method and found that the quantity of pollen from rye grass (*Lolium perenne* L.), cocksfoot (*Dactylis glomerata* L.), and timothy (*Phleum pratense* L.) decreased most rapidly over the first 400-500 meters from the source. Similar findings were reported by Bateman (1947) working on corn, Hodgson (1949) on Pensacola Bahia grass, (*Paspalum notatum* Flugge), Griffiths (1950) on perennial rye grass, Meinders and Jones (1950) on caster plant (Ricinus communis L.), Pederson et al. (1961 b) on rye, and Zeven (1968) with wheat.

Jones and Newell (1946) working with seven species of cross-pollinating grasses and cereals found that the density of pollen dropped from 100% (as found at plot centres) to approximately 30% at a distance of 12.5 yards (11.4 m) from the centre. At distances of 82.5, 220, and 330 yards (75.4, 201.2 and 301.8 m respectively) pollen densities dropped to 10, 1.2 and 0.8% respectively. Similarly, Meinders and Jones (1950) using the caster plant found that approximately 21% of the pollen was caught 5 rods (25.1 m) from the field centre, while only 1% was trapped at a distance of 60 rods (301.8 m).

(ii) Outcrossing method

Wilson and Ross (1962) found that there was no significant difference in seed-set on male sterile wheat planted at distances up to approximately 8 ft. (2.4 m) from the pollinator. Similarly, Livers (1964) found little or no differences in level of effective pollination up to 22 ft. (6.7 m), Rajki and Rajki (1968) up to 6 m, and Zuzens et al. (1969) up to at least 2 m. A 56% seed-set was recorded by Bitzer and Patterson (1965, 1967) working with hand-emasculated spikes of wheat with a pollinator 25 feet (7.6 m) from the female line. Wilson (1968) noted a reduction in seed-set from about 55% to 10% at distances of 5 m and 30 m respectively, and stated that seed-set depends on the size of the area occupied by the pollen donor and on the degree of synchronization of flowering of the parental lines. Similar results were also reported by Holland (1966).

Long range pollen dissemination was reported by Gorin (1968) who recorded as much as 2.8% seed-set on emasculated wheat plants located 150 m distant from the pollen donor. More recent work was reported by D'Souza (1970) who concluded that wheat pollen can be carried to a distance of about 50 m and reach a height of 0.9 m in comparison to rye pollen which may travel for a distance of 120 m and to a height of 1.3 m.

# MATERIALS AND METHODS

Three genetically diverse strains of triticale (Rosner, 6TA204, and T202) and T. aestivum L. em Thell cultivar Manitou were used throughout this study. In addition, S. cereale L. cultivar Prolific and a line of triticale carrying a dominant marker gene were also employed for specific phases of the investigation. The parentage of these lines are shown in Table I.

## I. Factors affecting pollen dissemination

### (i) Morphology of the plant

#### (a) Pollen grain size -

The diameter of 80 grains was measured in each of the three triticale lines and in Manitou. Samples were obtained from twenty broken anthers which were collected at random from different positions on spikes from each variety.

#### (b) Anther size -

Anther size was determined from anthers randomly collected from approximately 30 heads of the primary tiller from plants of the three triticale lines as well as Manitou. Samples were collected just prior to dehisence of pollen from the primary and secondary florets of the central spikelet and were preserved in Farmer's solution (3 absolute alcohol : 1 glacial acetic acid). The lengths and breadths of 40 anthers from each variety were measured under a binocular microscope fitted with an ocular micrometer.

#### (c) Number of grains per anther -

Just prior to anthesis, spikes were collected randomly from each of the three triticale lines and Manitou from which anthers were extracted and preserved in Farmer's solution. Twenty anthers of each variety were broken singly into a small vial containing one ml of distilled water. A homogeneous solution was made by shaking the vial, after which a drop was pipetted onto a haemocytometer. A total of twenty haemocytometer slides were analysed from each individual vial and five vials (each with twenty anthers) were sampled from each of the four plant lines.

(d) Percent anther extrusion -

In addition to the triticale and wheat varieties used in studies described above, rye cultivar Prolific was also included in the analysis of anther extrusion. About one week after anthesis, fifty spikes of each variety were collected and the number of anthers remaining unextruded in the primary and secondary florets of each spikelet was noted. In conducting this analysis, it was assumed that the pattern of flowering was similar for all plant lines (i.e. the ratio of anthers extruded from the primary and secondary florets to all other fertile florets is the same for all the varieties). Since the numerical value of data exceed the 60% level, arcsine transformation was used before applying analysis to the means.

(e) Pollen load over unit area of crop -

Within a solid-seeded plot of each of the varieites used in this study, six 4' x 2' (1.2 m x 0.6 m) quadrants were marked out and all plants within each quadrant were pulled and counted. In addition, the number of fertile tillers/plant, spikelets/spike, and florets/spikelet were scored from a representative sample of plants from each quadrant. Using these data along with information derived previously pertaining to number of pollen grains/anther and percent anther extrusion, the total number of pollen grains released from a unit area of crop (pollen load) was calculated.

(ii) Pollen viability

Pollen viability tests were conducted using pollen from the three triticale lines previously described together with Manitou wheat and Prolific rye. The central eight spikelets (16 florets) in each of five heads per variety were hand emasculated before anthesis. About two to three days later, emasculated spikes within each strain or variety were pollinated with pollen of that same variety in such a way that time intervals of 1 to 4; 4 to 8; 8 to 12; and 26 to 30 minutes had elapsed between the time pollen was extruded from the pollen plant and the time of application to the stigma. Temperature and relative humidity of the greenhouse at the time of conducting the experiments were approximately $75^{o}F$ ($24^{o}C$) and 40 to 60% relative humidity.

II. Measured range of pollen dissemination

(i) Pollen density count method

For studies on pollen dispersal patterns, three triticale lines and the wheat cultivar Manitou were sown in individually isolated plots, 45' x 45' (13.7 m x 13.7 m). Five pollen traps per plot were erected during anthesis, one located in the centre of the plot and one at each corner at a distance 3 ft. (1 m) from each edge. Two vaseline-coated microscope slides were placed in each trap, one positioned at crop level and the other about 1 ft. (30 cm) above. Slides were set at approximately $75^{o}$ to the horizon and were mounted daily at approximately 8:45 A.M. and retrieved at approximately 7:30 P.M. during the flowering period.

Pollen counts were made with a microscope fitted with a 10X objective and a 10X ocular; the area scanned being a total of 10 microscope fields taken at random along the length of each slide. Total counts were converted into number of grains per 10 $mm^2$ surface (approximately the surface area of a stigma, Patterson and Bitzer, 1966).

(ii) Outcrossing method

In a study of distance over which triticale pollen was disseminated, use was made of a "waxless" mutant in which the waxless characteristic was found by the author to be governed by a single dominant gene (Table X; Fig. 3). About 450 pregerminated waxless marker seedlings were planted in a 15' x 15' (4.57 m x 4.57 m) area and used as a pollen source. Rosner triticale which was used as female parent, was planted on all four sides of the pollen source at distances of 10, 15, 20, 25, 30, 40, 60, 80 and 100 ft. (3.0, 4.6, 6.1, 7.6, 9.1, 12.9, 18.3, 24.4 and 30.5 m; Fig. 2). Hand emasculation was conducted on Rosner plants located on the 10, 40 and 100 ft. (3.0, 12.9 and 30.5 m) distances. Since time and labour did not permit all Rosner parental material to be emasculated in this way, scissor emasculation was used on plants located at the remaining specified distancesfrom the source. To prevent undue pollen contamination, all unemasculated plants were destroyed prior to flowering. Seeds produced on emasculated Rosner parents were planted in the greenhouse and the number of waxless (dominant) and waxy (normal) plants (i.e. true hybrid as opposed to non-hybrid seeds) was recorded.

# RESULTS

## I. Factors affecting pollen dissemination

### (i) Morphology of the plant

#### (a) Pollen grain size -

The analysis of variance on pollen grain diameter in the three triticale lines and Manitou showed that there were significant differences between lines (P = 0.01, d.f = 3; Appendix VI). Duncan's multiple range test showed that there was no significant difference between either Manitou and 6TA204 or between Rosner and T202, (P = 0.05; Table II). However, a significant difference existed between these two pairs of lines. Although Manitou had the shortest anther length and ranked third in anther diameter (Tables III & IV), it had the largest pollen grain diameter (58.9 $\mu$) followed respectively by 6TA204 (57.9 $\mu$), Rosner and T202 (both 53.3 $\mu$). The ratio of pollen diameters of Manitou : 6TA204 : Rosner : T202 was respectively 1.00 : 0.98 : 0.91 : 0.90.

#### (b) Anther size -

An analysis of variance of length and width of anthers of the four triticale and wheat strains revealed that highly significant differences existed between strains for both variables, (P = 0.01, d.f = 3; Appendix VII & VIII). The triticale strain 6TA204 produced the longest anther (7.1 mm), with Rosner, T202 and Manitou following in the descending order of size and significantly different from one another, (P = 0.05, d.f. = 3; Table III). The ratio of lengths of 6TA204 : Rosner : T202 : Manitou was 1.86 : 1.59 : 1.23 : 1.00 respectively.

TABLE I

PEDIGREE OF THE VARIETIES AND STRAINS USED IN THE STUDY

| Variety | Pedigree* |
| --- | --- |
| Marker triticale | Tcl.6A205 (Triticum persicum) [Tcl.6A67 (4x Triticum sp.) Tcl.6A69 (T. persicum)] / [Tcl.8A94 (T. aestivum cv. Prelude) Tcl.6A69 (T. persicum)] Tcl.6A189 (T. durum cv. Ghiza) Tcl.6A20 (T. durum cv. Carlton) |
| Rosner triticale | Tcl.6A189 (T. durum cv. Ghiza) Tcl.6A20 (T. durum cv. Carlton)/Tcl.6A69 (T. persicum) Tcl.6A67 (4x Triticum sp.) |
| 6TA204 triticale | T. aestivum (Nainari 60 dwarf) Tcl. Bulk (4x Triticum sp.)/Tcl.6A274 [Tcl.8x (T. persicum) Tcl.6x (T. durum)] |
| T202 triticale | Tcl.6A189 (T. durum cv. Ghiza) Tcl.6A20 (T. durum cv. Carlton)/Tcl.6A69 (T. persicum) Tcl. (T. durum)/ Tcl. (T. dicoccoides) Tcl. 6A69 (T. persicum)<br><br>An outcross of this hybrid to Mexican wheat is suspected (Zillinsky, personal communication). |
| Manitou wheat | (Thatcher$^7$ x Frontana) (Thatcher$^6$ x Kenya Farmer)/ (Thatcher$^6$ x P.I. 170925) |

* Tcl. designates triticale, followed by the University of Manitoba accession number, and species and cultivar of Triticum in brackets.

In terms of breadth, anthers of the four varieties could be divided into two distinct groups; viz. those of 6TA204 and Rosner (918 and 903($\mu$) respectively) and those of Manitou and T202 (798 and 789($\mu$) respectively). Differences between the two groups were significant (P = 0.05; Table IV) and the ratio of breadths of 6TA204 : Rosner : Manitou : T202 was respectively 1.15 : 1.13 : 1.00 : 0.99.

TABLE II

DUNCAN'S TEST ON DIFFERENCES IN
POLLEN GRAIN DIAMETER ($\mu$)

| Variety | Manitou | 6TA204 | Rosner | T202 |
|---|---|---|---|---|
| Mean | 58.91 $\pm$ 8.10 | 57.88 $\pm$ 5.85 | 53.31 $\pm$ 3.95 | 53.26 $\pm$ 8.31 |
| Ratio of mean | 1.00 | 0.98 | 0.91 | 0.90 |

(P = 0.05)

The means underlined by the same line are not significantly different (Duncan, 1955).

TABLE III

DUNCAN'S TEST ON DIFFERENCES IN ANTHER LENGTH (mm)

| Variety | 6TA204 | Rosner | T202 | Manitou |
|---|---|---|---|---|
| Mean | $7.13 \pm 0.52$ | $6.12 \pm 0.57$ | $4.69 \pm 0.45$ | $3.83 \pm 0.50$ |
| Ratio of mean | 1.86 | 1.59 | 1.23 | 1.00 |

(P = 0.05)

TABLE IV

DUNCAN'S TEST ON DIFFERENCES IN ANTHER DIAMETER ($\mu$)

| Variety | 6TA204 | Rosner | Manitou | T202 |
|---|---|---|---|---|
| Mean | $918 \pm 69$ | $903 \pm 39$ | $798 \pm 58$ | $789 \pm 56$ |
| Ratio | 1.15 | 1.13 | 1.00 | 0.99 |

(P = 0.05)

The means underlined by the same line are not significantly different.

(c) Number of pollen grains per anther -

There were significant differences in the number of pollen grains per anther between triticale lines as well as between wheat and triticale, (P = 0.01, d.f. = 3; Appendix IX & X). Considering the four strains individually, they fell into three groups, with each group differing significantly from the other, viz. 6TA204 and Rosner; Rosner and T202; and Manitou. No significant difference was found within groups, (P = 0.05; Table V). The estimated number of pollen grains per anther within the triticale strains ranged from approximately 15 thousand for T202 to 21 thousand for 6TA204. Rosner was found to be intermediate with an estimated 17 thousand grains/anther while Manitou wheat was significantly below the three triticale lines with only 8 thousand grains/anther. The ratio of number of pollen grains per anther of 6TA204 : Rosner : T202, and Manitou was 2.55 : 2.16 : 1.81 : 1.00 respectively.

TABLE V

DUNCAN'S TEST ON DIFFERENCES IN NUMBER OF POLLEN GRAINS PER ANTHER IN THREE TRITICALE LINES AND MANITOU WHEAT (X 1000)

| Variety | 6TA204 | Rosner | T202 | Manitou |
|---|---|---|---|---|
| Mean | $20.6 \pm 5.9$ | $17.4 \pm 6.1$ | $14.6 \pm 4.0$ | $8.1 \pm 2.1$ |
| Ratio of mean | 2.55 | 2.16 | 1.81 | 1.00 |

(P = 0.05)

The means underlined by the same line are not significantly different.

(d) Percent anther extrusion -

There were significant differences between the lines studied in the degree to which anthers were extruded at flowering time (P = 0.01, d.f. = 5; Appendix XI). Comparing anther extrusion levels on a varietal basis (Table VI; Fig. 4, 5, 6, 7 & 8), it was found that six strains used for this phase of study fell into four groups, viz. Prolific rye and Rosner constituting a group with the highest extrusion level (approximately 89% for each); 6TA204 and T202 forming the second highest extrusion rate (76 and 74% respectively); T202 and Manitou the third highest level, while Manitou and the "genetic marker" triticale were scored with the lowest values (69 and 67% respectively). The ratio of percent anther extrusion of Prolific rye : Rosner : 6TA204 : T202 : Manitou : "genetic marker" triticale was 1.29 : 1.28 : 1.10 : 1.07 : 1.00 : 0.97 respectively.

(e) Pollen load over unit area of crop -

The pollen load in the air over a unit area of crop is represented in theory by the number of pollen grains available for outcrossing produced by the total population of plants within that area. The calculation is based on the knowledge of various factors, viz. number of plants/unit area; tillers/plant; spikelets/tiller; florets/spikelet; anthers/floret; percent anther extrusion and number of pollen grains per anther (Table VII). A brief comment regarding each of these factors follows. The number of plants per square foot (0.09 $m^2$) of crop was more or less the same in the three triticale strains studied ranging from a low of 13.4 in 6TA204 to a high of 15.4 in T202.

TABLE VI

DUNCAN'S TEST ON DIFFERENCES IN PERCENT ANTHER EXTRUSION IN FOUR TRITICALE LINES AND MANITOU WHEAT

| Variety | Prolific | Rosner | 6TA204 | T202 | Manitou | Marker |
|---|---|---|---|---|---|---|
| Mean | 89.22 ± 9.55 | 88.67 ± 5.27 | 76.22 ± 5.43 | 74.14 ± 9.30 | 69.45 ± 15.72 | 67.07 ± 11.41 |
| Ratio of mean | 1.29 | 1.28 | 1.10 | 1.07 | 1.00 | 0.97 |

(P = 0.05)

The means underlined by the same line are not significantly different.

The number of tillers per plant was highest in Manitou wheat with 4.0 tillers/plant. This was followed by Rosner with an average of 3.4 tillers, while T202 and 6TA204 produced an average of 2.8 and 2.5 tillers per plant respectively.

The number of spikelets per tiller fell into three groups in the varieties studied. Triticale 6TA204 with 29.7 spikelets/tiller was significantly higher than the second group, consisting of Rosner and T202 with 20.5 and 19.8 spikelets/tiller respectively. Manitou, which produced 15.2 spikelets/tiller was significantly below the average produced by the triticales.

Rosner had the highest number of florets per spikelet (4.4 florets/spikelet) compared with the other varieties which tended to fall into one class with 3.4, 3.5, and 3.7 florets per spikelet in the varieties Manitou, T202 and 6TA204 respectively. Data pertaining to percent anther extrusion and number of pollen grains per anther were reported previously and appear on pages 22 and 20 of this thesis.

The number of pollen grains available for outcrossing per square foot (0.09 $m^2$) of plant area was significantly different between varieties, ranging from approximately 209 million in Rosner triticale to 61 million in Manitou wheat with 6TA204 and T202 intermediate in number (172 and 99 million respectively). The ratio of number of pollen grains per 1 $ft.^2$ (0.09 $m^2$) of plant area of Rosner : 6TA204 : T202 : Manitou was respectively 3.42 : 2.82 : 1.62 : 1.0.

TABLE VII

FACTORS INFLUENCING POLLEN LOAD PRODUCED
BY TRITICALE AND WHEAT

| Variety | Rosner | 6TA204 | T202 | Manitou |
|---|---|---|---|---|
| Plants/1 ft.$^{2*}$ | 14.53 | 13.40 | 15.35 | 17.13 |
| Tillers/plant | 3.42 | 2.46 | 2.78 | 4.04 |
| Spikelets/tiller | 20.54 | 29.66 | 19.82 | 15.18 |
| Florets/spikelet | 4.42 | 3.74 | 3.50 | 3.44 |
| Anthers/floret | 3.00 | 3.00 | 3.00 | 3.00 |
| Percent anther extrusion | 88.67 | 76.22 | 76.14 | 69.45 |
| Grains/anther (x 1000) | 17.4 | 20.6 | 14.6 | 8.1 |
| Total grains/1 ft.$^2$ of plant area | 235.5 mill. | 226.0 mill. | 129.7 mill. | 878.2 mill. |
| Grains available/1 ft.$^2$ of plant area | 208.8 mill. | 172.3 mill. | 98.8 mill. | 61.0 mill. |
| Ratio of no. of grains available/1 ft.$^2$ of plant area | 3.42 | 2.82 | 1.62 | 1.00 |

* (1 sq. ft. = 0.09 sq. m)

(ii) Pollen viability

The results of pollen viability as tested by pollinating hand-emasculated heads with pollen exposed to air for different time intervals showed that the period of longevity for rye pollen was longer than for either triticale or wheat (Table VIII). Viable pollen was still found in rye in a 26-30 minute exposure period. In comparison, T202 and Rosner had the lowest viability. No viable pollen was recorded after 4 minutes for T202 and 8 minutes for Rosner. Manitou wheat pollen was slightly more tolerant to the effects of exposure in that some pollen could survive at least over a 12 minute exposure. Within triticale strains 6TA204 showed the highest longevity in that viability was recorded in an exposure as much as 26-30 minutes.

TABLE VIII

PERCENT SEED-SET USING POLLEN EXPOSED TO AIR FOR VARIOUS TIME INTERVALS BEFORE POLLINATION

| Variety | Time interval (min.) | | | |
|---|---|---|---|---|
| | 1-4 | 4-8 | 8-12 | 26-30 |
| Rosner | 12.50 | 2.5 | 0 | 0 |
| 6TA204 | 13.75 | 11.25 | 6.25 | 5.00 |
| T202 | 13.75 | 0 | 0 | 0 |
| Manitou | 25.00 | 3.75 | 1.25 | 0 |
| Prolific | 33.75 | 32.50 | 23.75 | 11.25 |

II. Measured range of pollen dissemination

(i) Pollen density count method

Comparing the average number of pollen grains collected on a 10 $mm^2$ slide surface for each of the four varieties used in this study, Rosner rated the highest (Fig. 1; Appendix II, III, IV, & V). On one day at the peak of anthesis, over 120 grains per 10 $mm^2$ surface were trapped from this variety. Its flowering period lasted about a week, a trend similar to that observed in variety 6TA204. The date and period of anthesis of 6TA204 coincided perfectly with Rosner, however, its pollen load was lower. Both T202 and Manitou had a relatively lower pollen load than either Rosner or 6TA204 and a shorter period of anthesis, lasting only about five days. The observed fluctuations in pollen counts were due to a sharp drop in temperature on August 1 and 2 (Appendix I), however, in general, the day-to-day variability in pollen dissemination among the four lines agreed very well. In comparing pollen trapped at different locations within the same variety, highest number of pollen grains per 10 $mm^2$ of slide surface was recorded from traps located in the centre of plots followed by those located in NE and SE corners (Table IX).

(ii) Outcrossing method

The genetic marker used for this phase of study exhibits a "waxless" characteristic shown to be governed by a single dominant gene (Table X). For estimating the distance of pollen dissemination, a plot of waxless marker 15' x 15' (4.6 x 4.6 m) in size provided a source of pollen for emasculated Rosner plants sown on all four sides of the marker in rows at pre-determined distances from its edge (Fig. 2). The highest percent outcrossing was

Fig. 1 Average number of pollen grains per 10 $mm^2$ of slide surface collected during anthesis of three lines of triticale and wheat cultivar Manitou

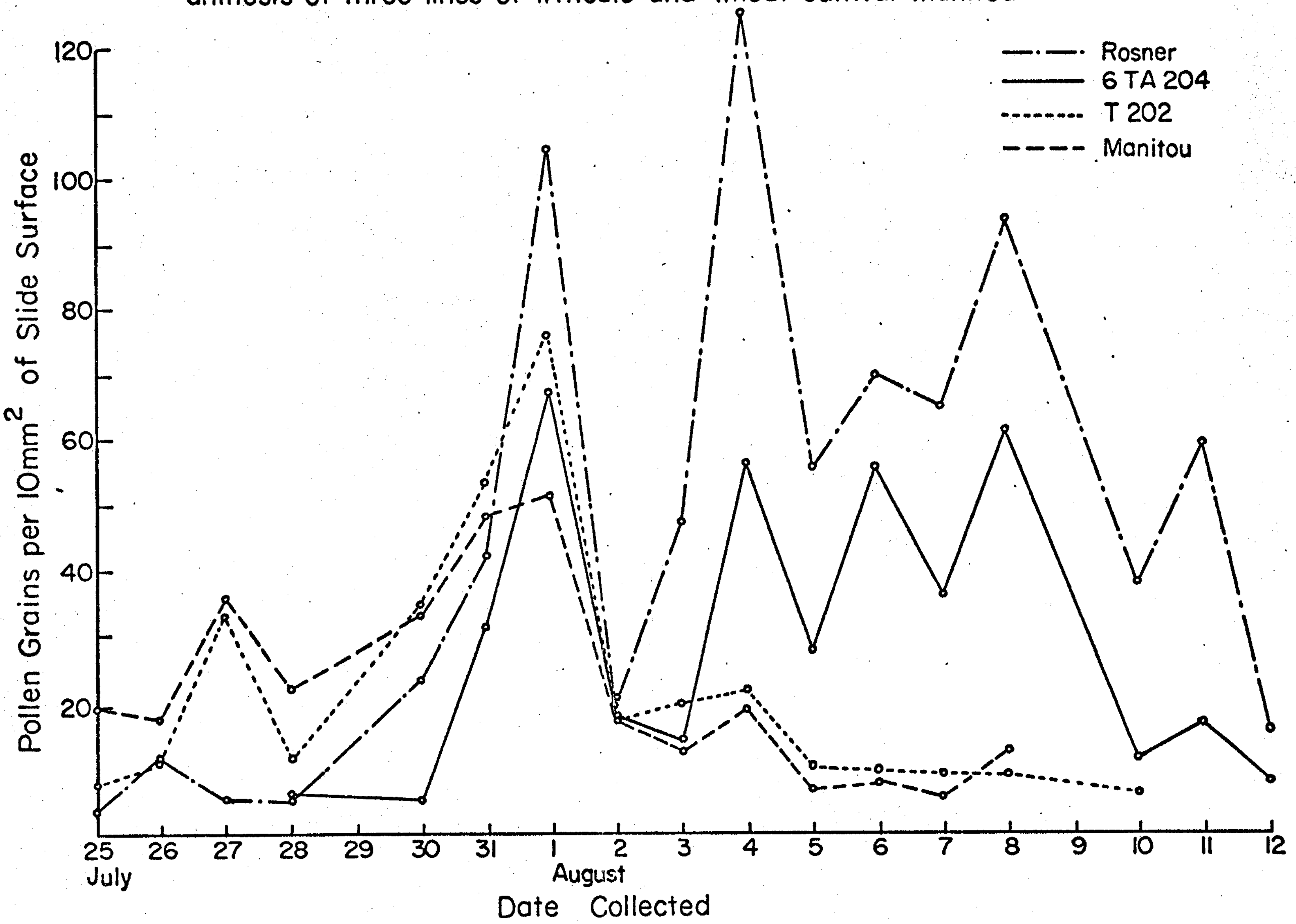
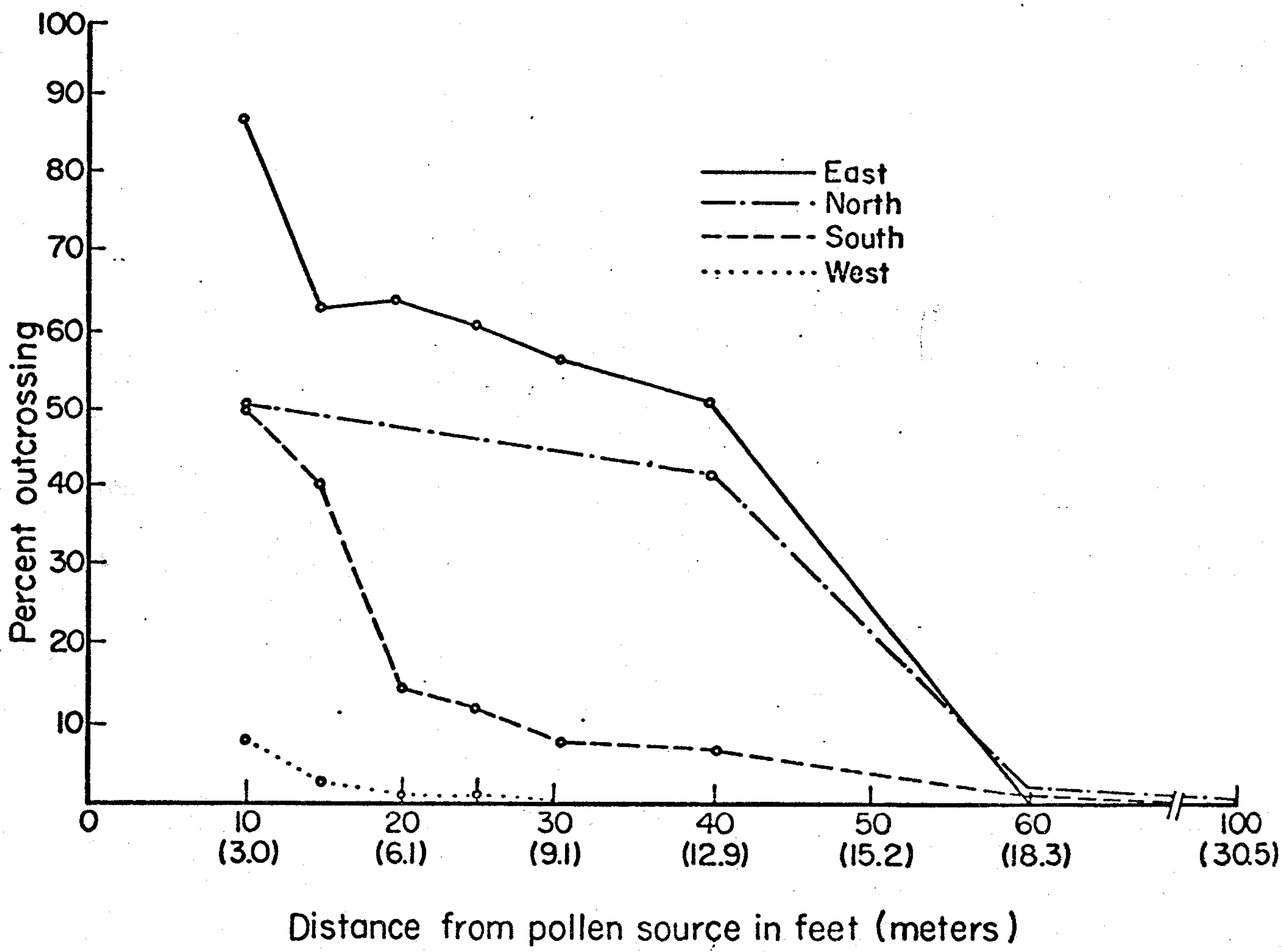


Fig. 2 Influence of direction and distance on percent outcrossing between Rosner and the waxless genetic marker used as pollen source



obtained on the east side of the marker with as much as 86% recorded 10 ft. (3.0 m) from the pollen source. This percentage reduced with increasing distance with 51% recorded at 40 ft. (12.9 m) and 0% at a distance of 60 ft. (18.3 m). Outcrossing on the north side of the marker followed more or less the same trend as that on the east except that the overall percentage was lower. The south side differed from the east and north not only in the lower amount of outcrossing, but also in the rapid decrease in percentage which occurred within a short distance of 20 ft. (6.1 m). At this distance only 15% outcrossing was obtained, followed by a steady decline with the 0% point occurring between 60 to 80 ft. (18.3 to 24.4 m) from the source. Lowest percent outcrossing was recorded on the west side of the marker with less than 10% at 10 ft. (3.0 m) from the pollen source, and 0% at a distance of only 30 ft. (9.1 m).

TABLE IX

AVERAGE NUMBER OF POLLEN GRAINS PER 10 $mm^2$ OF SLIDE SURFACE IN DIFFERENT LOCATIONS WITHIN PLOTS DURING ANTHESIS

| Variety | Location | | | | | Average |
|---|---|---|---|---|---|---|
| | NE | NW | SW | SE | Centre | |
| Rosner | 51.72 | 42.91 | 34.86 | 43.44 | 58.55 | 46.30 |
| 6TA204 | 35.05 | 21.85 | 22.26 | 38.38 | 37.25 | 30.96 |
| T202 | 23.30 | 13.72 | 19.22 | 23.98 | 29.01 | 21.85 |
| Manitou | 17.40 | 17.87 | 16.45 | 26.97 | 28.42 | 21.42 |

TABLE X

CALCULATED $X^2$ FOR GOODNESS OF FIT TO A 3:1 RATIO OF $F_2$ PLANTS FROM A CROSS "WAXLESS" X NORMAL

| Population | No. of Waxless dominant | No. of Waxy normal | Ratio | $X^2$ |
|---|---|---|---|---|
| $F_2$ | 596 | 209 | 3:1 | 0.398 |

Fig. 3 - Normal "waxy" triticale plant (centre) in comparison with genetic marker "waxless"

Anther extrusion of rye, triticale and wheat lines used:

Fig. 4 - Rye cultivar Prolific

Fig. 5 - Rosner triticale

Fig. 6 - 6TA204 triticale

Fig. 7 - T202 triticale

Fig. 8 - Wheat cultivar Manitou

Fig. 4 - Rye cultivar Prolific

Fig. 5 - Rosner triticale

Fig. 6 - 6TA204 triticale

Fig. 7 - T202 triticale

Fig. 8 - Wheat cultivar Manitou

# DISCUSSION

Pollen load in the air at a given time is a function of the amount of pollen produced per anther, the percent of anther extrusion, the number of anthers per unit area and the environmental conditions. Triticale lines, especially Rosner, produced a higher pollen load than wheat (Fig. 1). In addition to evaluating triticales as to their potential pollen disseminating properties, the following discussion will deal with the way in which the various factors affect pollen production and their order of importance.

## I. Influence of environment and morphology of plant on pollen production

### (i) Environment

Weather conditions play an important role in pollen dispersal. Zenven (1968) reported seed-set on male sterile wheat to be only about 10% of normal due to heavy rains during the flowering period. Winds also have a pronounced effect on pollination habits. For example in the present study, pollen dispersal distance as measured by outcrossed seed-set on emasculated plants was higher on the east and north side of the pollen source due to the prevailing south-westerly winds in Manitoba. However, temperature is perhaps an equally important factor controlling pollen dissemination (Jones and Newell, 1946; Brook and Puri, 1963). An outstanding example was experienced in the present study on August 2 (Fig. 1; Appendix I), when there was a drop in temperature of about 10$^{\circ}$F (5.6$^{\circ}$C) and the four varieties which were at their peak of anthesis at this time underwent a sharp drop in pollen dissemination. In Rosner for example, there was a reduction from approximately 100 grains/10 mm$^2$ slide surface/day to only about 20 grains/10 mm$^2$ slide surface/day for the cooler period. When the temperature returned to normal in the days following, pollen counts increased. The same pattern of day-to-day fluctuation in pollen counts within the four varieties, reflects the influence of daily fluctuation in temperature (Fig. 1).

(ii) Morphology of plant

Whether or not the sizes of pollen grain and anther affect pollen load is still debatable. Hodgson (1949) and Pederson *et al*. (1961) reported that a difference in size of pollen is not a factor in determining pollen dispersal. Considering the fact that the natural mode of dissemination of pollen from the grasses and cereals is by wind, slight varietal differences in size (and possibly density) of pollen probably would not be a factor in determining relative distances of dispersal.

Cahn (1925) reported anther length bears close relationship to pollen bearing capacity, a conclusion supported by the results of the present study (Tables III and V). On the other hand, Kherde *et al*. (1967) reported no correlation between seed-set on male sterile wheat and anther size of the pollinators. Whether one needs to breed for large anther size is therefore questionable and the decision would depend to a large extent on the amount of effort one would have to expend on the development of this character in relation to other agronomic characteristics pertaining to hybrid seed production. It should be borne in mind that "pollen productivity" is a complex characteristic of which anther size is only one component. It does not necessarily follow that the development of varieties with large anthers, thus increased number of pollen grains, results in an overall improved level of pollen productivity. Variety 6TA204 of the present study, for example, was found to have the highest number of pollen grains per anther (Table V), yet the amount of pollen trapped and the actual amount available per unit area of crop indicated that it was not necessarily the best pollen disseminator. This was due to the fact that its percent anther extrusion was relatively low compared with that of Rosner even though the total number of pollen grains/1 ft.$^2$ of the crop were very close to each other for these two varieties (Table VII). The importance of the degree of anther extrusion exhibited by a particular strain and its pollen dessiminating properites is further exemplified by the variety Rosner. Although Rosner did not rank highest in a number of the components contributing to overall pollen productivity (pollen grains/anther, anther size, tillers/unit area of crop, spikelets/tiller), it exhibited a level of anther extrusion second only to rye. It is speculated that most probably because of this single factor alone, Rosner ranked highest of the triticales in terms of actual number of grains per unit area of the crop available for outcrossing, and in pollen dissemination as measured by pollen trapping. In comparing Table VII and Fig. 1, there is a good relationship between theoretical pollen load and pollen counts.

Besides percent anther extrusion as just mentioned above, the number of florets per unit area of the crop (a function of plants/unit area, tillers/plant, spikelets/tiller, florets/spikelet) would also have a pronounced effect on overall pollen load since it will give the actual number of anthers for pollen production.

In addition to the actual distance that pollen is carried, pollen grain longevity is also involved. In general, cereal crops with the exception of rye, exhibit a very short pollen longevity period. As reported by D'Souze (1970), Roemer (1932) found rye pollen to be still viable after travelling a distance of 600 m. The results of the present study, along with those of Athwal and Kimber (1970) support the fact that rye pollen has a relatively long viability period.

## II. Triticale as a pollen donor

Triticales in general, produce a relatively larger number of pollen grains per plant and also exhibit a high frequency of anther extrusion, both factors being essential for maximum pollen production and dispersal. D'Souze (1970) reported that the number of pollen grains per anther in rye and triticale was respectively seven and three times as great as in wheat. In the present study, results indicated that this increase was slightly greater than two-fold. Although triticale is an inbreeding species, basically it has the two reproductive characteristics that are present in the rye parent which is a strong outbreeder. For purposes of serving as a pollen donor for hybrid seed production, it is possible that with limited selection pressure a triticale strain exhibiting predominantly outcrossing habits could be derived.

In addition to the aforementioned characteristics favoring seed production, the triticale strains Rosner and 6TA204 have a period of anthesis considerably longer than that of common wheat (Fig. 1). This, together with the fact that outcrossing occurs over a relatively long distance (50% outcross at 40 ft. (12.9 m) from the pollen source), further supports the supposition that triticale is a satisfactory pollen donor.

Not all characteristics, however, favor outcrossing in triticale. The low longevity period of triticale pollen grains relative to that of rye for example, would favor inbreeding. Factors responsible for this low level of viability are worthy of investigation and the possibility of selection of strains with prolonged pollen longevity could prove profitable.

## III. Heterosis in hybrid triticale

In addition to reproductive behavior as it pertains to hybrid seed production the level of heterosis generated from a particular cross combination is extremely important from the practical aspect. Among the small-grained self-pollinated crops, wheat has been studied extensively in regard to the potential yield increase expected from hybrids, however, results are extremely variable depending upon interplant spacing, location effect, etc. (Briggle, 1963). Rodriguez *et al*. (1967), nevertheless are convinced that the magnitude of heterosis encountered in wheat is sufficient to make the production of hybrids feasible. Both Briggle (1963) and Rodriguez *et al*. (1967) reported yields of hybrids varying around the mean yield of the higher yielding parent or in absolute terms, as high as 146% of this parent. Triticale which has an alien genome (rye) added to wheat, may be considered to have a more diverse gene pool which could result in an increased heterotic effect and consequently a greater yield potential. In addition, rye has naturally a heterozygous (outcrossing) genetic system, a condition which would be re-established in the $F_1$ hybrid produced from a cross between inbred triticale strains. This magnitude of expression of heterosis in $F_1$ triticale hybrids is a phase of study still to be done. At this point in time in the triticale breeding program however, completely stable lines have still to be produced. Although very significant progress has been made in this area, it is necessary to ensure that the lines entering such an evaluation are cytologically stable, specifically in the $F_1$ hybrid state. It has been the characteristic of triticale lines produced to date to exhibit some meiotic abnormality, particularly in the $F_1$ hybrid. It is hoped that studies already underway will isolate those lines that are stable both in the parental state as well as in the progeny. Such lines would be the logical material for future use in the evaluation of heterosis in triticale.

# SUMMARY

Experiments were run in Summer 1970 to investigate pollen production and longevity of three triticale lines (Rosner, 6TA204 and T202) in comparison with wheat cultivar Manitou and rye cultivar Prolific.

The following findings were recorded:

(1) Using vaseline-coated microscope slides as pollen traps, Rosner was found to have the highest pollen load of any of the varieties or strains tested. Over 120 grains per 10 $mm^2$ of slide surface was recorded in a 10-hour period. The duration of anthesis was longer in Rosner and 6TA204 than it was in either T202 or Manitou wheat. Temperature was the main factor affecting pollen load.

(2) Differences in anther diameter between 6TA204 and Rosner and between T202 and Manitou were insignificant. However, differences between the two groups were significant. A range in anther diameter from 789 $\mu$ to 918 $\mu$ was found to exist between triticale lines. Varieties also differed significantly in length of anther. Anthers of variety 6TA204, with a length of 7.13 mm, were almost twice as long as those of Manitou wheat.

(3) There were significant differences in pollen grain size ranging from 53 $\mu$ in T202 triticale to 59 $\mu$ in Manitou wheat.

(4) Using a modified methodology, an estimate of the number of pollen grains per anther in each of the triticale strains were 21 thousand for 6TA204; 17 thousand for Rosner; and 15 thousand for T202. Manitou wheat was estimated to produce 8 thousand grains per anther.

(5) A high of 89.2% anther extrusion was recorded for Prolific rye,

while Manitou wheat was lowest with 69.5% extrusion. Triticales ranged from 74.1% for T202 to 88.7% for Rosner.

(6) The ratio of pollen load estimated for a unit area of crop of Rosner : 6TA204 : T202 : Manitou was respectively 3.42 : 2.82 : 1.62 : 1:00.

(7) Over 50% outcrossing in triticale was recorded on emasculated plants up to a distance of 40 ft. (12.9 m) from the pollen source, however, pollen of triticale was trapped at a distance of 100 ft. (30.5 m). The use of a genetic marker stock (waxless) in triticale proved a very effective method in evaluating pollen dispersal distance in this species.

(8) The longevity of rye cultivar Prolific pollen was higher than that of both the triticale lines (Rosner, 6TA204 and T202) and wheat cultivar Manitou. After a 26-30 minute exposure to atmospheric conditions, rye pollen was still functional. Triticale pollen viability was virtually zero after only 4 minutes of exposure for T202 and 8 minutes for Rosner. Triticale 6TA204 pollen was comparatively more viable than T202 and Rosner.

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# APPENDIX I

## TEMPERATURE AND WIND VELOCITY DURING PERIOD OF ANTHESIS*

| Date | Temperature ($^oF.$) Maximum | Minimum | Mean from Max. and Min. | Degree days below $65^oF.$ | Ave. wind velocity (m.p.h.) |
|---|---|---|---|---|---|
| July 24 | 74 | 62 | 68 | - | 17.0 |
| 25 | 85 | 56 | 71 | - | 11.3 |
| 26 | 81 | 62 | 72 | - | 10.1 |
| 27 | 79 | 56 | 68 | - | 7.2 |
| 28 | 87 | 60 | 74 | - | 8.2 |
| 29 | 85 | 69 | 77 | - | 4.9 |
| 30 | 85 | 64 | 75 | - | 7.8 |
| 31 | 73 | 57 | 65 | - | 12.5 |
| Aug. 1 | 86 | 55 | 71 | - | 13.0 |
| 2 | 67 | 49 | 58 | 7 | 14.1 |
| 3 | 72 | 48 | 60 | 5 | 5.2 |
| 4 | 81 | 54 | 68 | - | 7.7 |
| 5 | 86 | 56 | 71 | - | 5.7 |
| 6 | 90 | 60 | 75 | - | 5.1 |
| 7 | 90 | 68 | 79 | - | 8.8 |
| 8 | 88 | 66 | 77 | - | 11.9 |
| 9 | 82 | 55 | 69 | - | 10.8 |
| 10 | 86 | 48 | 67 | - | 5.4 |
| 11 | 92 | 61 | 77 | - | 11.4 |
| 12 | 92 | 58 | 75 | - | 8.5 |

* Courtesy of Meteorological Branch, Department of Transport, Canada. Station located about 8 miles west of University of Manitoba campus.

# APPENDIX II

AVERAGE NUMBER OF POLLEN GRAINS PER 10 $mm^2$ OF SLIDE SURFACE FOR ROSNER

| Date | Location | | | | | Average |
|---|---|---|---|---|---|---|
| | NE | NW | SW | SE | Centre | |
| July 25 | 4.87 | 2.60 | - | - | - | 3.74 |
| 26 | 20.46 | 7.79 | 12.34 | 8.12 | 9.09 | 11.56 |
| 27 | 5.84 | 4.55 | 3.37 | 7.47 | 5.20 | 5.29 |
| 28 | 2.92 | 9.42 | 4.22 | 6.17 | 4.07 | 5.36 |
| 29 | | Rained | | | | |
| 30 | 26.62 | 16.88 | 18.18 | 15.91 | 37.34 | 22.99 |
| 31 | - | 15.26 | - | 52.27 | 59.09 | 42.21 |
| Aug. 1 | 88.31 | 29.22 | 89.94 | 147.08 | 165.91 | 104.09 |
| 2 | 11.36 | 8.44 | 26.95 | 28.90 | 25.00 | 20.13 |
| 3 | 30.20 | 60.39 | 46.75 | 33.12 | 65.58 | 47.21 |
| 4 | 150.65 | 133.12 | 64.61 | 98.05 | 183.44 | 125.97 |
| 5 | 71.75 | 71.43 | 40.99 | 39.61 | 56.17 | 55.99 |
| 6 | 81.17 | 94.48 | 54.87 | 47.40 | 71.43 | 69.87 |
| 7 | 83.77 | 89.29 | 37.66 | 29.22 | 83.44 | 64.68 |
| 8 | 128.57 | 108.77 | 51.30 | 59.42 | 116.56 | 92.92 |
| 9 | | Rained | | | | |
| 10 | 52.60 | 50.97 | 25.65 | 35.39 | 22.08 | 37.34 |
| 11 | 63.96 | 46.70 | 47.73 | 86.51 | 51.95 | 59.37 |
| 12 | 23.70 | 12.99 | 10.07 | 18.83 | 12.99 | 15.72 |
| 13 | 32.47 | 10.07 | 23.05 | 25.00 | 25.97 | 23.31 |

# APPENDIX III

## AVERAGE NUMBER OF POLLEN GRAINS PER 10 $mm^2$ OF SLIDE SURFACE FOR 6TA204

| Date | Location | | | | | Average |
|---|---|---|---|---|---|---|
| | NE | NW | SW | SE | Centre | |
| July 28 | 5.20 | 4.22 | 9.42 | 5.84 | 4.22 | 5.78 |
| 29 | | | Rained | | | |
| 30 | 38.64 | 28.90 | 75.00 | 64.61 | 34.74 | 48.38 |
| 31 | 17.53 | 14.29 | - | - | 60.07 | 30.63 |
| Aug. 1 | 67.53 | 17.86 | 14.29 | 138.31 | 100.00 | 67.60 |
| 2 | 25.97 | 10.07 | 12.34 | 25.65 | 13.31 | 17.47 |
| 3 | 11.04 | 14.61 | 14.94 | 18.83 | 10.71 | 14.03 |
| 4 | 66.88 | 32.47 | 42.53 | 70.78 | 67.53 | 56.04 |
| 5 | 29.55 | 22.08 | 30.84 | 36.36 | 17.53 | 27.27 |
| 6 | 78.90 | 37.01 | 43.51 | 64.61 | 53.57 | 55.52 |
| 7 | 36.36 | 27.60 | 15.91 | 35.39 | 63.64 | 35.78 |
| 8 | 90.91 | 71.43 | 25.65 | 45.45 | 75.65 | 61.81 |
| 9 | | | Rained | | | |
| 10 | 10.71 | 7.14 | 7.79 | 11.04 | 14.29 | 10.19 |
| 11 | 27.92 | 8.44 | 7.14 | 9.74 | 27.92 | 16.23 |
| 12 | 4.87 | 9.74 | 6.17 | 6.49 | 9.74 | 7.40 |
| 13 | 13.64 | - | 6.17 | 4.22 | 5.82 | 7.46 |

APPENDIX IV

AVERAGE NUMBER OF POLLEN GRAINS PER 10 $mm^2$ OF SLIDE SURFACE FOR T202

| Date | Location | | | | | Average |
|---|---|---|---|---|---|---|
| | NE | NW | SW | SE | Centre | |
| July 25 | 13.31 | 3.25 | 3.90 | 9.42 | - | 7.43 |
| 26 | 8.12 | 1.62 | - | 20.45 | 14.94 | 11.28 |
| 27 | 28.57 | 18.83 | - | - | 52.27 | 33.22 |
| 28 | 13.31 | 15.91 | 7.14 | 8.77 | 12.99 | 11.59 |
| 29 | | Rained | | | | |
| 30 | 53.25 | 15.58 | 28.25 | 31.82 | 43.18 | 34.42 |
| 31 | 44.48 | 25.97 | 52.92 | 65.58 | 76.62 | 53.12 |
| Aug. 1 | 86.04 | 34.09 | 61.04 | 98.75 | 101.62 | 76.31 |
| 2 | 7.14 | 9.09 | 19.48 | 25.00 | 24.68 | 17.08 |
| 3 | 17.53 | 16.18 | 19.81 | 21.10 | 22.08 | 19.34 |
| 4 | 27.60 | 19.16 | 17.86 | 20.46 | 23.35 | 21.69 |
| 5 | 12.66 | 9.42 | 10.39 | 6.49 | 8.44 | 9.48 |
| 6 | 16.07 | 5.52 | 5.40 | 7.14 | 10.39 | 8.90 |
| 7 | 9.09 | 10.71 | 10.71 | 8.44 | 5.20 | 8.83 |
| 8 | 6.82 | 15.26 | 7.79 | 4.87 | 7.14 | 8.38 |
| 9 | | Rained | | | | |
| 10 | 5.52 | 5.20 | 5.20 | 7.47 | 3.25 | 5.33 |

APPENDIX V

AVERAGE NUMBER OF POLLEN GRAINS PER 10 $mm^2$
OF SLIDE SURFACE FOR MANITOU

| Date | Location | | | | | Average |
|---|---|---|---|---|---|---|
| | NE | NW | SW | SE | Centre | |
| July 25 | 26.62 | - | 11.04 | - | - | 18.83 |
| 26 | 10.07 | 10.39 | - | 16.23 | 21.10 | 16.95 |
| 27 | 24.35 | 24.35 | 43.51 | 44.81 | 42.86 | 35.98 |
| 28 | 17.86 | 30.64 | 12.01 | 19.16 | 25.97 | 21.13 |
| 29 | | Rained | | | | |
| 30 | 38.31 | 38.96 | 23.05 | 25.33 | 38.64 | 32.86 |
| 31 | 28.25 | 27.92 | 44.16 | 75.33 | 61.04 | 49.14 |
| Aug. 1 | 24.35 | 31.82 | - | 72.08 | 76.62 | 51.22 |
| 2 | 10.39 | 9.42 | 14.29 | 36.04 | 28.90 | 19.81 |
| 3 | 11.04 | 8.44 | 12.01 | 14.61 | 13.96 | 12.01 |
| 4 | 24.03 | 25.33 | 6.82 | 12.66 | 23.05 | 18.38 |
| 5 | 8.12 | 8.77 | 5.20 | 2.60 | 6.49 | 6.24 |
| 6 | 5.20 | 7.15 | 5.84 | 4.22 | 11.04 | 6.69 |
| 7 | 5.52 | 3.25 | 4.55 | 7.79 | 8.77 | 5.98 |
| 8 | 9.42 | 5.84 | 14.94 | 19.81 | 11.04 | 12.21 |

APPENDIX VI

ANALYSIS OF VARIANCE ON POLLEN GRAIN DIAMETER
IN THREE TRITICALE LINES AND MANITOU WHEAT

| Source of variation | Degrees of Freedom | Sums of squares | Mean square | F |
|---|---|---|---|---|
| Varieties | 3 | 2007 | 670 | $15^{**}$ |
| Error | 316 | 13944 | 44 | |
| Total | 319 | 15952 | | |

$^{**}$ (P = 0.01)

# APPENDIX VII

## ANALYSIS OF VARIANCE ON ANTHER LENGTH OF VARIETIES STUDIED

| Source of variation | Degrees of freedom | Sums of squares | Mean square | F |
|---|---|---|---|---|
| Varieties | 3 | 257.67 | 85.89 | 345.78** |
| Error | 156 | 38.76 | 0.25 | |
| Total | 159 | 296.44 | | |

** (P = 0.01)

# APPENDIX VIII

## ANALYSIS OF VARIANCE ON ANTHER DIAMETER OF VARIETIES STUDIED

| Source of variation | Degrees of freedom | Sums of squares | Mean square | F |
|---|---|---|---|---|
| Varieties | 3 | 544147 | 181382 | 56** |
| Error | 156 | 500283 | 3228 | |
| Total | 159 | 1004430 | | |

** (P = 0.01)

## APPENDIX IX

ANALYSIS OF VARIANCE ON THE NUMBER OF POLLEN GRAINS PER ANTHER IN THREE TRITICALE LINES

| Source of variation | Degrees of freedom | Sums of square | Mean square | F |
|---|---|---|---|---|
| Between varieties | 2 | 1768882176.000 | 884441088.0000 | 8.3906** |
| Between vials | 12 | 1264910336.000 | 105409184.0000 | 3.9944** |
| Within vial | 285 | 752096896.000 | 26389392.0000 | |

** (P = 0.01)

## APPENDIX X

ANALYSIS OF VARIANCE ON THE NUMBER OF POLLEN GRAINS PER ANTHER IN THREE TRITICALE LINES AND MANITOU WHEAT

| Source of variation | Degrees of freedom | Sums of square | Mean square | F |
|---|---|---|---|---|
| Between varieties | 3 | 8478064640.000 | 2826021376.0000 | 33.5186** |
| Between vials | 16 | 1348993024.000 | 84312064.0000 | 3.9868** |
| Within vial | 380 | 8036220928.000 | 21147936.0000 | |

** (P = 0.01)

APPENDIX XI

ANALYSIS OF VARIANCE ON PERCENT ANTHER EXTRUSION IN FOUR TRITICALE LINES AND MANITOU WHEAT

| Source of variation | Degrees of freedom | Sums of square | Mean square | F |
|---|---|---|---|---|
| Varieties | 5 | 12581.44 | 2516.29 | 47.04** |
| Error | 294 | 15674.52 | 53.50 | |
| Total | 299 | 28255.96 | | |

** (P = 0.01)

APPENDIX XII

SEED-SET PER HEAD AND GERMINATION OF KERNELS PRODUCED ON SCISSOR-EMASCULATED PLANTS

| Location | No. of heads emasculated by scissors | No. of seeds produced | No. of seeds per head | No. of seeds germinated | % germination |
|---|---|---|---|---|---|
| East 15 ft. | 82 | 753 | 9.18 | 302 | 40.11 |
| 20 | 88 | 745 | 8.47 | 375 | 50.34 |
| 25 | 84 | 384 | 4.57 | 162 | 42.19 |
| 30 | 81 | 336 | 4.15 | 147 | 43.75 |
| 60 | 33 | 93 | 2.82 | 41 | 44.09 |
| 80 | 73 | 71 | 0.97 | 31 | 43.66 |
| West 15 ft. | 44 | 202 | 4.59 | 73 | 36.14 |
| 20 | 118 | 267 | 2.26 | 124 | 46.44 |
| 25 | 68 | 56 | 0.82 | 40 | 71.43 |
| 30 | 56 | 71 | 1.27 | 47 | 66.20 |
| 60 | 125 | 193 | 1.54 | 86 | 44.56 |
| 80 | 225 | 806 | 3.54 | 402 | 49.88 |
| North 15 ft. | 65 | 313 | 4.82 | 258 | 82.43 |
| 20 | 59 | 217 | 3.68 | 175 | 80.65 |
| 25 | 92 | 256 | 3.87 | 275 | 77.25 |
| 30 | 173 | 423 | 2.45 | 312 | 73.76 |
| 60 | 60 | 198 | 3.30 | 143 | 72.22 |
| 80 | 50 | 221 | 4.42 | 165 | 74.66 |
| South 15 ft. | 134 | 650 | 4.85 | 484 | 74.46 |
| 20 | 92 | 245 | 2.66 | 173 | 70.61 |
| 25 | 65 | 169 | 2.60 | 120 | 71.01 |
| 30 | 85 | 77 | 0.91 | 44 | 57.14 |
| 60 | 68 | 118 | 1.74 | 76 | 64.41 |
| 80 | 55 | 166 | 3.02 | 107 | 64.46 |

# APPENDIX XIII

## SEED-SET PER HEAD AND GERMINATION OF KERNELS PRODUCED ON HAND-EMASCULATED PLANTS

| Location | No. of heads emasculated by hand | No. of seeds produced | No. of seeds per head | No. of seeds germinated | % germination |
|---|---|---|---|---|---|
| East 10 ft. | 96 | 793 | 8.26 | 341 | 43.00 |
| 40 | 126 | 153 | 1.21 | 60 | 39.22 |
| 100 | 37 | 31 | 0.84 | 14 | 45.16 |
| West 10 ft. | 83 | 77 | 0.93 | 33 | 42.86 |
| 40 | 34 | 17 | 0.50 | 9 | 52.94 |
| 100 | 4 | 5 | 1.25 | 3 | 60.00 |
| North 10 ft. | 49 | 122 | 2.49 | 84 | 68.85 |
| 40 | 63 | 110 | 1.75 | 62 | 56.36 |
| 100 | 44 | 153 | 3.48 | 107 | 69.93 |
| South 10 ft. | 57 | 240 | 4.21 | 182 | 75.83 |
| 40 | 46 | 75 | 1.63 | 52 | 69.33 |
| 100 | 22 | 47 | 2.14 | 37 | 75.51 |

# APPENDIX XIV

## PERCENT OUTCROSSING ON SCISSOR-EMASCULATED PLANTS AND PROPORTION OF PROGENY REACHING MATURITY

| Location | No. of seeds germinated | No. of waxless dominant | No. of waxy normal | Total no. of plants grown to maturity | % maturity | % outcross |
|---|---|---|---|---|---|---|
| East 15 ft. | 302 | 159 | 94 | 253 | 83.77 | 62.85 |
| 20 | 375 | 213 | 121 | 334 | 89.07 | 63.77 |
| 25 | 162 | 92 | 59 | 151 | 93.21 | 60.93 |
| 30 | 147 | 71 | 55 | 126 | 85.71 | 56.35 |
| 60 | 41 | 0 | 22 | 22 | 85.66 | 0 |
| 80 | 31 | 0 | 26 | 26 | 83.87 | 0 |
| West 15 ft. | 73 | 2 | 57 | 59 | 80.82 | 3.39 |
| 20 | 124 | 1 | 118 | 119 | 95.97 | 0.84 |
| 25 | 40 | 1 | 38 | 39 | 97.50 | 2.63 |
| 30 | 47 | 0 | 40 | 40 | 85.11 | 0 |
| 60 | 86 | 0 | 68 | 68 | 79.07 | 0 |
| 80 | 402 | 0 | 390 | 390 | 97.01 | 0 |
| North 15 ft. | 258 | 28 | 221 | 249 | 96.51 | 11.23 |
| 20 | 175 | 8 | 144 | 152 | 86.86 | 5.26 |
| 25 | 275 | 14 | 228 | 242 | 88.00 | 5.79 |
| 30 | 312 | 5 | 253 | 258 | 82.69 | 1.94 |
| 60 | 143 | 3 | 120 | 123 | 86.01 | 2.44 |
| 80 | 165 | 0 | 153 | 153 | 92.73 | 0 |
| South 15 ft. | 484 | 184 | 273 | 457 | 94.42 | 40.26 |
| 20 | 173 | 23 | 126 | 149 | 86.13 | 15.44 |
| 25 | 120 | 15 | 102 | 117 | 97.50 | 12.82 |
| 30 | 44 | 3 | 33 | 36 | 81.82 | 8.33 |
| 60 | 76 | 1 | 62 | 63 | 82.89 | 1.59 |
| 80 | 107 | 0 | 101 | 101 | 94.39 | 0 |

## APPENDIX XV

PERCENT OUTCROSSING ON HAND-EMASCULATED PLANTS AND PROPORTION OF PROGENY REACHING MATURITY

| Location | No. of seeds germinated | No. of waxless dominant | No. of waxy normal | Total no. of plants grown to maturity | % maturity | % outcross |
|---|---|---|---|---|---|---|
| East 10 ft. | 341 | 280 | 45 | 325 | 95.31 | 86.15 |
| 40 | 60 | 20 | 26 | 54 | 90.00 | 51.85 |
| 100 | 14 | 0 | 0 | 10 | 71.43 | 0 |
| West 10 ft. | 33 | 2 | 25 | 25 | 75.76 | 8.00 |
| 40 | 9 | 0 | 7 | 7 | 77.78 | 0 |
| 100 | 3 | 0 | 3 | 3 | 100.00 | 0 |
| North 10 ft. | 84 | 42 | 40 | 82 | 97.62 | 51.22 |
| 40 | 62 | 26 | 35 | 61 | 98.39 | 42.62 |
| 100 | 107 | 1 | 87 | 88 | 82.24 | 1.14 |
| South 10 ft. | 182 | 80 | 77 | 157 | 86.26 | 50.96 |
| 40 | 52 | 4 | 45 | 49 | 94.23 | 8.16 |
| 100 | 37 | 0 | 36 | 36 | 97.30 | 0 |