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Basic Studies on Hybrid Wheat Breeding IV

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Natural Cross-Fertilization in Male Sterile Wheat[1)]

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Introduction

One of the problems involved in hybrid wheat breeding is the strong tendency of this crop to self-pollinate. Wilson and Ross (1962) and Kihara and Tsunewaki (1964) have reported seed setting of male sterile wheat placed at various distances from the pollinator. They reported that increasing the distance between male sterile plants and the pollinator decreases seed setting in the former.

Since several isogenic lines having different dominant genes as the marker became available in a common wheat, *Triticum aestivum* L. cv. S-615 (Tsunewaki 1961), a critical experiment was designed to determine the distance of pollen transportation for cross-fertilization, and the ability of different genotypes as pollinator. Results are reported in this paper.

Materials and Methods

Normal and four isogenic marker lines of a common wheat, *Triticum aestivum* L. cv. S-615 and a male sterile line of *T. aestivum* cv. Norin 26 were used. Their origin can be shown as follows:

Strain	Origin	Reference
Hg-line of S-615	Jones Fife (*Hg*-carrier) × S-615^{9}	Fig. 2 b
Hp-line of ,,	*Hp*-Chinese Spring × S-615^{8}	Fig. 2 c
B_1-line of ,,	Jones Fife (B_1-carrier) × S-615^{9}	Fig. 2 d
C-line of ,,	Elgin (*C*-carrier) × S-615^{9}	Fig. 2 e
Male sterile Norin 26	*Aegilops ovata* × Norin 26^{14}	Fig. 2 f

Note: Superscripts indicate the number of crosses made, using the indicated variety as the backcross parent.

The four marker lines of S-615 have dominant genes for hairy glume (*Hg*), hairy peduncle (*Hp*), beardlessness (B_1) or compact ear (*C*). Their effects are clearly expressed in the heterozygous condition. The backcross of the F_1 hybrid between S-615 and the

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donor of each marker gene was carried out at least seven times with S-615 as the backcross parent, so that all lines became indistinguishable from normal S-615, except for the character controlled by the respective marker gene.

The male sterile line of Norin 26 with *Aegilops ovata* cytoplasm was originally produced by Fukasawa (1959). Further backcrosses were made by the author. This

Table 1. Location of four marker lines in four replications

Plant in center	Circle	Replication			
		I	II	III	IV
Normal S-615	1	*C*	B_1	*Hp*	*Hg*
	2	*Hp*	*Hg*	*C*	B_1
	3	B_1	*C*	*Hg*	*Hp*
	4	*Hg*	*Hp*	B_1	*C*
ms-Norin 26	1	*Hp*	*C*	B_1	*Hg*
	2	*C*	*Hg*	*Hp*	B_1
	3	B_1	*Hp*	*Hg*	*C*
	4	*Hg*	B_1	*C*	*Hp*

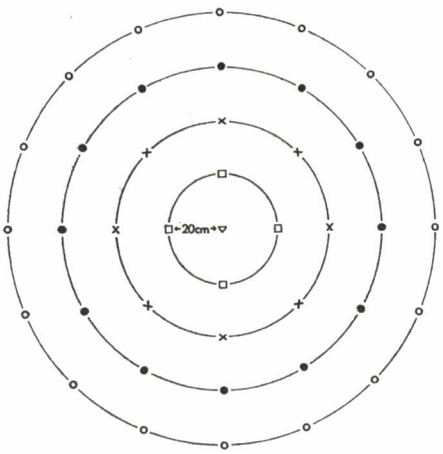

Fig. 1. Design of a plot (Distance between two adjacent plants on the same circle was 31.4 cm).
▽ Male steile Norin 26 or normal S-615.
□, ×, ●, ○ Four different isogenic marker lines of S-615.

line was used because no male sterile line of S-615 was available, and because the heading date of male sterile Norin 26 was almost the same as that of S-615.

To test cross-fertilization of normal and male sterile lines, a latin square design with four replications, four pollinators and four distances was adopted, as shown in

Fig. 2. Isogenic marker lines of S-615.
From left to right: Normal S-615, *Hp*-line (hairy peduncle), B_1-line (awnless), *Hg*-line (hairy glume), *C*-line (compact ear), and male sterile Norin 26.

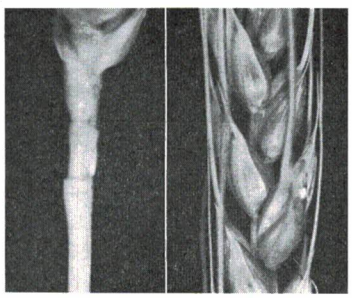

Fig. 3. Hairy peduncle of *Hp*-line (left) and hairy glume of *Hg*-line (right).

Table 1. Design of a plot is given in Fig. 1, where four pollinators (marker lines) were planted along four circles of different radii (20, 40, 60 and 80 cm), taking into consideration variable wind direction during flowering time. A single normal or male sterile plant was placed in the center of each plot. Distance between two neighboring pollinator plants on the same circle was 31.4 cm in all circles.

All seeds set on normal S-615 and male sterile Norin 26 were harvested and planted. The plants obtained were examined at maturity for marked characteristics, on the basis of which the pollen parent of each was determined.

Results and Discussion

The number of plants having different characteristics in the progenies of normal S-615 and male sterile Norin 26 are shown in Table 2. Out of 846 plants from normal S-615 which was surrounded by different marker lines, all but two had the typical

phenotype of normal S-615. This clearly indicates that natural cross-fertilization takes place very rarely in normally fertile wheat. The estimated frequency of cross-fertilization is only 0.24%.

Four progenies from male sterile Norin 26 contained plants of various phenotypes in different frequencies. Most plants were either hairy glume, hairy peduncle, beardlessness or compact ear (carrier of *Hg*, *Hp*, B_1 or *C* gene, respectively). Some were

Table 2. Number of plants having different marker genes in progenies of normal S-615 and male sterile Norin 26

Plant in center	Rep.	Number of plants					
		Total	*Hg*	*Hp*	B_1	*C*	All recessive
Normal S-615	I	239	0	0	1	0	238
	II	406	0	0	1	0	405
	III	203	0	0	0	0	203
	Total	848	0	0	2	0	846
ms-Norin 26	I	276	31	66	125	31	23
	II	326	107	74	101	39	5
	III	438	165	75	164	26	8
	IV	368	99	35	156	63	15
	Total	1,408	402	250	546	159	51

Note: Normal S-615 of Rep. IV died before flowering.

Table 3. Proportion in per cent of various phenotypes in progenies of male sterile Norin 26, and 5% LSD test on the effect of marker genes and distances between male sterile and pollinators

Marker gene	Distance (cm)					5% LSD test
	20	40	60	80	Average	
B_1	37.4	42.5	45.3	31.0	38.53	high
Hg	26.9	32.8	37.7	11.2	27.15	intermediate
Hp	23.9	17.1	22.7	9.5	18.40	low
C	12.0	11.2	17.1	5.9	11.55	low
Average	25.05	25.88	30.70	14.40	24.01	—
5% LSD test	high	high	high	low	—	—

Note: 5% LSD for both marker gene and distance was 8.20%.

recessive for all four characters. These multi-recessive plants were different in morphology from Norin 26, and were assumed to be a hybrid between male sterile Norin 26 and other plants grown near the experimental plots. Relative frequencies of hybrids between male sterile Norin 26 and the four pollinators are shown in Table 3, the distance between them is also indicated.

As to the difference among the four pollinators, B_1-carrier had the highest ability as

the pollen furnisher, followed by *Hg*-carrier. *Hp*- and, particularly, *C*-carrier were least suited to be the pollinator. Since the four pollinators had been backcrossed at least seven times to S-615 before use and their phenotypes, except for the respective marked character, were indistinguishable from those of normal S-615, it can be concluded that a single major gene, such as B_1 for awn suppression or *C* for compact ear, greatly affects the ability of a wheat plant to be a pollen furnisher in cross-fertilization.

The rates of cross-fertilization of a male sterile plant, using the same marker lines planted 20, 40 and 60 cm from it, did not differ from each other. However, pollinators grown 80 cm from the male sterile had low out-cross rates. This indicates that wheat pollen grains can reach as far as 60 cm without losing any efficiency.

Summary

Cross-fertilization of normal and male-sterile wheat (*Triticum aestivum* L.) was studied, using four isogenic marker lines of a cultivar S-615 as the pollinator. Natural cross-fertilization rarely took place in normal wheat, the frequency being 0.24%. The four marker lines had different abilities for pollinating male sterile wheat; B_1 gene-carrier was the best, followed by *Hg*, *Hp* and *C* gene-carriers, in this order. Distance of pollen transportation for effective cross-fertilization of male sterile wheat was estimated to be about 60 cm.

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