Time and Distance of Pollen Dispersal in Grain Sorghum

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The objective of the present study was to determine the time of day when pollens were dispersed and the distance travelled by pollen in grain sorghum. Time of the active pollen dispersal was estimated from seed set on panicle of an A-line (Experiment 1). The distance for pollen dispersal was measured from seed set on panicles of A-lines which were grown at various distances and directions around pollen dispersal field for three years. The isolation distance necessary to produce certified hybrid seeds of grain sorghum was estimated (Experiment 2).

When paper envelopes were removed from panicles of the A-line before 0400 and/or after 1200, seed set on the panicle was not observed. However, seed set was observed between 0600 and 1000. Time of active pollen dispersal is, therefore, from 0600 to 1000. The isolated plots in which seed set was observed were located less than 400m from the pollen dispersal field. Seed set was not observed in some isolated plots less than 400m, as wind direction and obstacles near the isolated plot prevented pollination. Pollen was dispersed into the isolated plot within 250m from the pollen dispersal field, even though the isolated plot was surrounded by houses and was located on the windward side of main wind direction. Adequate isolation distance for certified hybrid seed production was approximately 400 to 500m, with modifications down to 250 to 300m permitted under certain conditions.

Introduction

The breeding of grain sorghum in Japan as well as in the United States has utilized cytoplasmic male-sterility. The maintenance and propagation of male-sterile strains and production of hybrid seeds are necessary for certification of highly purified seed. The seeds of allogamous crops and hybrids produced with male-sterile A-lines are usually produced under isolated field conditions. In our breeding programs the maintenance of male-sterile A-line and hybrid seed production have been conducted by hand pollination and the approach method (bottle filled with water, for which one head of the pollen parent is placed, tied to A-line and A-line is crossed with pollen parent in envelope). The time of pollen dispersal is an important factor in obtaining good seed set using these pollination methods. Isolated cultivation by mechanical barriers produces highly purified seeds, but equipment and operational expenses are costly (Ito 1977), while isolated cultivation by distance is an inexpensive method if adequate isolation from fertile plants is possible.

This work was intended to provide data which would be useful in seed production of grain sorghum. Time of pollen dispersal and distance travelled by pollen after dispersal in grain sorghum were investigated at the Chugoku National Agricultural Experiment Station, Fukuyama-shi, in 1975, 1976 and 1977.

Materials and Methods

Time of pollen dispersal (Experiment 1): The male-sterile A-line (Early Wheatland-A)

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was sown at a spacing of 65 cm (interrow spacing) $\times$ 20 cm (intrarow spacing) on 22 and 25 May 1976 in 3-row plots, 6 m long. Three panicles of the A-line were treated from 27 to 28 July. The pollen source was a fertility-restoring R-line which was grown surrounding the A-line. In 1977, Wheatland-A was used as the A-line and the pollen source was Wheatland-B (B-line : male-fertile, non pollen-restoring). The A-line was sown by hand at a spacing of 65 cm $\times$ 20 cm on 17, 24, and 31 May in 2 rows, 18 m long. To adjust the flowering time of A- and B-line, the B-line was sown three days later in 5 rows at the same spacing as the A-line. The A-line was surrounded with two B-line rows on one side and 1 row on the opposite side. These planting dates will be referred to as I, II, and III in all tables and the text. The experiment was conducted from 1 to 2, 2 to 3, and 3 to 4 August on I, II, and III, respectively. The panicles of the A-line were bagged with paper envelopes before flowering to prevent outcrossing. When the panicles reached the end of flowering, the paper envelopes were removed from the panicles and the panicles were exposed to allow outcrossing under open pollinated conditions for two hours. The exposed panicles were bagged again with the same envelopes. Four panicles were used in each treatment. The number of seed set on the panicle of each A-line was counted at maturity and the conditions of pollen dispersal versus time were based on the number of seed set on the panicle of the A-line.

In another experiment, pollen from the R-line was forcibly applied on the panicle of

the A-line at two hour intervals from 0400 to 2000. One panicle was used in each treatment. After each treatment, the panicle was again bagged. The existence of viable pollen per time was estimated from the number of seed set on the panicle of the A-line.

The distance of pollen dispersal (Experiment 2): Male-sterile strains used were 399-A in 1975, 399-A, Martin-A, and Redlan-A in 1976, and Redlan-A and Wheatland-A in 1977. Seeds were sown in paper pots in late May. Two to eight seedling plants per A-line were transplanted into several isolated plots around the Chugoku National Agricultural Experiment Station. The confirmation of pollen dispersal was based on seed set on the panicles of the A-lines in these isolated plots. The distance between the isolated plot and the pollen dispersal

Fig. 1. Relationship between the pollen dispersal fields and the isolated plots indicating direction and distance.

Note : The pollen dispersal field for the isolated plots A to I was S_1 in 1975, 1976 and S_2 in 1977. P means pond. Map scale is a 1/3000.

field was estimated with a 1/3000 scale map published by the city office of Fukuyama-shi. The panicle from a tiller was bagged with a paper envelope before flowering and the sterility of the A-line was checked in each isolated plot. Since the fertile plants crossed with sorghum were not grown near the experimental field, the pollen sources were S_1 , S_2 , and S_3 in Fig. 1.

Climate conditions: The climate conditions for experiment 1 were very similar in both 1976 and 1977. Mean wind speed were 1.0 to 1.5 m/sec. before 1000 and after 1800, and 2.0 to 3.0 m/sec. from 1000 to 1800. The main wind directions were north, north west and north east from early morning to noon, and south and south west during the afternoon. The fields were hit by a typhoon with an 11.0 m/sec. wind speed on August 17 in 1975.

Results and Discussion

Time of pollen dispersal (Experiment 1)

The number of seed set per A-line panicle on a time basis is shown in Table 1. There was almost no seed set before 0400 and/or after 1200, but numerous seed were set between 0600 and 1000. This suggested that the time for active pollen dispersal was between 0600 and 1000. The effect of pollen shedding time on number of seed set per panicle is shown in Table 2. Seed set was numerous at 0600 and 0800. Pollen with high viability must have been in abundance at 0600 and 0800, although SANCHEZ *et al* (1965) reported that pollen is shed in abundance only after 0900. Number of seed set decreased rapidly after 1200 suggesting that pollen is carried away by wind and pollen viability decreased rapidly after 1200 (SANCHEZ *et al* 1965, UJIHARA *et al* 1979). HITAKA (1976) reported that flowering of grain sorghum began at 0300 to 0500 and terminated at 0500 to 0700. The time lag between flowering time reported by HITAKA (1976) and active pollen dispersal time

observed in this experiment suggests that pollen dispersal may occur a few hours after flowering. There was a low seed set on the A-line panicles because the

Table 1. Number of seed set per panicle of A-line for debagging time

Debagging time	1976*	1977**		
	I	I	II	III
2000-0400	1.3	1.5	0.0	0.3
0400-0600	31.7	4.0	4.5	4.0
0600-0800	96.3	17.0	7.0	28.0
0800-1000	17.7	21.8	1.8	18.3
1000-1200	26.0	5.3	0.3	1.3
1200-1400	1.0	0.8	0.0	0.3
1400-1600	1.3	0.3	0.5	0.8
1600-1800	0.0	0.5	0.0	0.0
1800-2000	0.0	0.0	0.0	0.0
Open	132.0	39.0	7.5	50.0
Close	0.7	0.3	0.0	0.0

* Panicles of A-line were treated from 27 to 28 July.

** Panicles of A-line were treated from 1 to 2, 2 to 3, and 3 to 4 August in I, II and III, respectively.

Table 2. Number of seed set per panicle of A-line at each treatment time

Treatment time	1977*		
	I	II	III
2000	2	1	0
0400	132	224	567
0600	1995	1055	1414
0800	2603	779	1925
1000	617	3	1082
1200	458	29	37
1400	22	0	6
1600	12	0	0
1800	0	0	0

* I, II, and III are the same with I, II, and III shown in Table 1.

active flowering period of B-line did not coincide with the treatment day debagged from the A-line panicle.

Hand pollination must be conducted at the time of active flowering in B- and R-line, while the approach method must be conducted at the time of no pollen dispersal to avoid the contamination with unexpected pollens. It can be concluded from these results that hand pollination should be conducted before 1000 when sufficient pollen with high viability is in abundance while the approach method should be conducted in the afternoon when pollen does not disperse normally.

The distance of pollen dispersal (Experiment 2)

The isolated plots around the pollen dispersal fields are illustrated in Fig. 1. Maximum number of seed sets per panicle of the A-line in the isolated plot is shown in Table 3. S_1 and S_2 are the pollen dispersal field for the isolated plots A to I, while S_3 is the pollen dispersal field for the isolated plot J. There were many seed sets in A, C, E, and J. A was located on the leeward side of the main wind direction in early morning when pollen dispersal was in abundance. C and E were located on the leeward side of the wind but not in the main wind direction, and C was also near the pollen dispersal field. These isolated plots are located less than 400 m from the pollen dispersal field. Number of seed sets in J of 1975 increased in comparison with other isolated plots because of typhoon winds from the south during flowering of the A-line. The isolation distance of B is shorter than that of A, E, and J. B is located close to E and also on the leeward of the main wind direction during early morning. There was no seed set in B for three years. The reason may be associated with macro- and microclimatic factors, such as wind flow near the isolated plot.

D, F, G, and H are located to the north-west and on the leeward side of the main wind direction in the afternoon when pollen dispersal seldom occur (Table 1, 2). Seed set was observed in D but not in F, G, and H. It may be concluded that pollen can disperse into the isolated plot within 250 m, even though the isolated plot is surrounded by houses or is located on the windward side of the main wind direction. Isolation distance for I was too far for seed set.

Table 3. Maximum number of seed set per panicle of A-line in the isolated plot and conditions between the isolated plot and the pollen dispersal field

Isolated plot	Isolation distance(m)*	1975	1976	1977	Direction**	Condition
A	398(510)	11	2	2	SE	No barrier
B	330(435)	0	0	0	SW	No barrier
C	180	9			W	No barrier
D	240(186)	3	3	0	NW	Houses, Clump
E	(345)			48	W	No barrier
F	(330)			0	NW	Under a bank
G	(540)			0	NW	Houses
H	428(315)		0	0	NNW	Houses, Clump
I	(690)			0	E	Hill
J	315	119	4	8	N	No barrier

* Value in parenthesis shows the isolation distance from S_2 in 1977.

** Direction of the isolated field viewed from the pollen dispersal field.

The flowering period of the A-line in the isolated plots was from 5 to 10 August. Number of the flowering panicle in pollen dispersal field at that time was estimated to be more than 2000 panicles. The amount of pollen was adequate for the estimation of the distance travelled by pollen. The minimum isolation distance required for production of highly purified seeds is variable. This variability depends on the crop, pollination mode, wind direction, and barriers between the isolated plot and the pollen dispersal field (HARTMANN *et al* 1968). The amount of pollen found in isolated plot which increase the probability of outcrossing is dependent on the amount of pollen produced in the pollen dispersal field. As the A-line and the R-line are usually grown together in isolated plots, the chance of outcrossing between the A-line in the isolated plot and the fertile plant in other fields decreases. Adequate isolation distance for producing highly purified seeds was approximately 400 to 500 m, with modifications down to 250 to 300 m permitted under certain conditions.

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グレインソルガム花粉の飛散時刻と飛散距離の推定

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グレインソルガムの採種において、交配操作中の他花粉との混り交雑を防ぎ、純度の高い種子を多量に採種するために、花粉の飛散時刻を調査した。雄性不稔系統 (A-line) を稔性回復系統 (R-line) あるいは雄性不稔維持系統 (B-line) と隣接して栽培し、雄性不稔系統の開花終期に一定時間除袋処理を行った (実験1)。この結果、午前4時以前および午前12時以降の処理ではほとんど着粒が認められなかった。午前6時から10時までの処理で多くの着粒が認められ、この間が花粉飛散の最盛時刻と言える。本試験の結果から、花粉飛散の多い午前10時までに手掛け法 (hand pollination) による人工交配を行えば多くの交配種子を得ることができるであろう。また、花粉飛散の少ない午後にビン掛け法 (approach method) による人工交配を行えば交配操作中の他花粉との混り交雑を防ぐことができるであろう。

純度の高い F_1 種子を放任採種するのに必要な隔離距離を推定するために、A-line を花粉飛散源の周囲に隔離栽培し、隔離圃場における A-line 穂の着粒数を調査した (実験2)。この結果、着粒が認められた隔離圃場はいずれも花粉飛散源との距離が 400 m 以内であった。しかし、隔離距離が 400 m 以内であっても着粒が認められなかった隔離圃場もあった。隔離圃場が花粉飛散源の風上に位置し、かつ、人家に囲まれ、隔離距離が 250 m 以内の隔離圃場では僅かに着粒が認められた。 F_1 採種の隔離圃場では A-line と R-line とが栽植されているため、例えば、目的としない異花粉の飛散があったとしても他殖の機会はかなり減少すると考えられる。本試験の結果から、純度の高い F_1 種子を放任採種するために必要な隔離距離はおおよそ 400 ないし 500 m と推定される。ただし、立地条件を考慮に入れて隔離圃場を選択するならば、隔離距離はおおよそ 250 ないし 300 m まで短縮できるであろう。