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Inbred Planting Technique for Nakhon Sawan 3 Hybrid Maize Seed Production

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ABSTRACT

In Nakhon Sawan 3 hybrid seed production, conventional planting uses a 4:1 ratio of female to male rows. After pollination has finished, the male rows are eliminated, causing an empty space in the production field. To increase the yield and utilization of the area by female plants, in 2008, an experiment was conducted to study a compact planting technique involving planting male inbreds between female rows at the Nakhon Sawan Field Crops Research Center. The experiment used a split-plot design with three replications, with the main plot consisting of two plantings of parent material: 1) planting female and male inbreds on the same day; and 2) planting female inbreds two days later. Sub-plots consisted of four male planting methods: 1) compact planting between 65 cm female rows; 2) compact planting between 75 cm female rows; 3) compact planting between 85 cm female rows; and 4) planting female to male rows in the ratio of 4:1. The results showed that all compact plantings tended to increase yield by 12-28% compared with that of a female to male row planting ratio of 4:1. Compact planting between 75 cm female rows produced the highest yield of 2,381 kg ha^{-1}. Compact planting between female rows at 85 cm, 65 cm and planting female to male rows at a ratio of 4:1 produced a yield of 2,288, 2,081 and 1,856 kg ha^{-1}, respectively. Increased yield was due to the number of ears harvested per hectare increasing by up to 10-25%. All compact planting options delayed the time to 50% pollen shedding from 63 d (in planting female to male rows at a ratio of 4:1) to 64, 65 and 66 d in compact planting between rows of 85 cm, 75 cm and 65 cm, respectively. There was no effect of compact planting on the number of days to 50% silking of female inbreds and on male and female height. The results showed that planting inbreds on the same day tended to increase yield by 20% compared with that of planting female two days later.

Keywords: hybrid maize seed production, planting technique

INTRODUCTION

To acquire a maximum yield and good quality of seed for hybrid maize seed production, research must be conducted into many aspects, such as the planting parents row ratio, planting date, plant density and optimum harvesting time (Koshawatana *et al.,* 2002). However, in general practice, male inbred plants are totally removed after pollination resulting in an empty space in the production field. Hence, in order to utilize the empty space, a compact planting technique was

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used to increase seed yield per area by planting female plants in a full production area and planting male plants between female rows. This technique was reported to increase utilization of the full area by the female plants (Beck, 2004). Therefore, in the current study, it was expected that this technique would be practical and increase the seed production yield of the drought-tolerant maize hybrid "Nakhon Sawan 3". For Nakhon Sawan 3, an optimun planting row ratio for female (Tak Fa 1) to a male inbred (Tak Fa 3) was reported as 4:1, with one plant per hill and spacing between rows and plants of 65 and 15 cm, respectively (Field Crops Research Institute, 2005). Compact planting has been previously investigated, including a delay of the planting of the male inbred (Koshawatana *et al*., 2007). However, this row spacing was possibly too narrow for compact planting. Therefore, ranges of planting-in spacing for male inbreds were additionally investigated to ensure maximum yield with no effect on plant growth and pollen shedding.

MATERIALS AND METHODS

An experiment was conducted at the Nakhon Sawan Field Crops Research Center (NSFCRC) during July-October 2008. Plots were arranged in a split-plot experimental design with three replications. The main plot consisted of two plantings of parent materials: 1) planting female and male inbreds on the same day; and 2) planting female inbreds two days later. Sub-plots consisted of four male inbred planting methods: 1) compact planting between 65 cm female rows; 2) compact planting between 75 cm female rows; 3) compact planting between 85 cm female rows; and 4) conventional planting of female to male rows, with 65 cm row spacing. A common planting spacing was used of 65 cm between rows and 15 cm between plants, with one plant per hill. Rows were 5.1 m long. Each sub-plot consisted of 16 rows, 12 female rows and 4 male rows planted at the ratio of 4:1; sub-plot sizes following the four male planting methods were 39, 40.5, 42 and 48.75 m^2, respectively. For each side of a sub-plot, four rows of sorghum (Late Hegari Variety) were planted to prevent pollen contamination among the sub-plots. Before pollen shedding, tassels of female plants were pulled off. After pollination, male inbred and sorghum plants were removed from the plots. Collected data included plant height, number of days to 50% pollen shedding of male plants, 50% silking of female plants, plant number per area, ear number per plot (four rows), ear weight, 1000 seed weight, and seed yield.

RESULTS

Effect of compact planting on yield, ear numbers and plant numbers of female "Tak Fa 1" inbred

The results showed that all compact planting options tended to increase yield from 12 to 28% compared with that of common planting involving female to male rows (Table 1). Compact planting between 75 cm female rows produced the highest yield of 2,381 kg ha^{-1}, which was 28% higher than that of common planting (female to male rows). Compact planting between female rows at 85 cm, 65 cm and planting female to male rows had a yield of 2,288, 2,081 and 1,856 kg ha^{-1}, respectively. The yield from compact planting was 23 and 12% higher than that of planting female to male rows. Planting female and male inbreds on the same day tended to increase the yield by 20% compared with that of planting females two days later.

Among compact planting techniques, ear number per hectare significantly increased ranging from 10 to 25% compared with that of the common planting. The results were consistent with an increase in plant numbers per hectare from 16 to 28% (Table 1).

Table 1 Effect of compact planting on yield and some agronomic characteristics of female inbred "Tak Fa 1" for Nakhon Sawan 3 hybrid seed production.

Planting-date regime	Male planting methods	Yield (kg ha^{-1}) (%)	Yield increase	Ear no. (ear ha^{-1}) (%)	Ear no. increase (kg)	Ear weight per plot (g)	1000 seed weight	Plant no. (plant ha^{-1}) (%)	Plant no. increase
1. Planting on the same day	1. compact, planting-in spacing 65 cm	2,078.8	12	84,431	25	5.14	251.7	94,538	28
	2. compact, planting-in spacing 75 cm	2,380.6	28	82,525	22	5.81	232.1	92,469	25
	3. compact, planting-in spacing 85 cm	2,287.5	23	79,306	18	5.85	239.6	86,100	16
	4. female : male row, spacing 65 cm	1,855.0	0	67,538	0	5.79	253.8	74,169	0
	Average	2,150.0		78,462		5.65	244.3	86,819	
2. Planting female 2 days later	1. compact, planting-in spacing 65 cm	1,824.4	18	77,700	13	4.88	253.9	94,019	21
	2. compact, planting-in spacing 75 cm	1,778.1	15	76,806	12	4.74	257.2	93,713	21
	3. compact, planting-in spacing 85 cm	1,720.6	12	75,756	10	4.75	251.9	90,906	17
	4. female : male row, spacing 65 cm	1,540.6	0	68,781	0	5.31	255.5	77,688	0
	Average	1,716.2		74,762		4.92	254.6	89,081	
	C.V. (Planting dates) (%)	23.5		3.2		16.9	3.1	0.3	
	C.V. (Male planting methods) (%)	18.8		7.3		15.0	8.0	2.5	
	Planting date (P)	ns		ns		ns	ns	ns	
	Male planting methods (M)	ns		**		ns	ns	**	
	PxM	ns		ns		ns	ns	ns	

**significantly different at p ≤0.01 ns = not significantly different

Effect of compact planting on pollen shedding, silking and inbred height

All compact planting delayed the number of days to 50% pollen shedding of the male inbred "Tak Fa 3" for 1-3 d compared with that of common planting female to male rows. The number of days to 50% pollen shedding of compact planting with spacings of 85, 75, 65 cm and common planting was 64, 65, 66 and 63 days after planting, respectively (Table 2). These results showed that the narrower the planting-in row was, the more pollen shedding was delayed. However, the delay of 50% silking date of the female inbred "Tak Fa 1" was not pronounced among male planting methods, which were approximately 60-61 days for planting inbreds on the same day and 59-60 days for planting females two days later.

To investigate the effect of male planting methods on plant growth or shedding effect, female height was measured both in the planting-in row with competition from the male inbred plants and in the row with no male inbred competition from 21 days after planting (DAP) to 56 DAP. It was found that there was no effect of compact planting on female and male inbred height (Table 3).

DISCUSSION

It was possible to increase yield for seed production of hybrid maize "Nakhon Sawan 3" by using a compact planting technique. Female inbred "Tak Fa 1" was planted in a full area using 65 cm row spacing and male inbred "Tak Fa 3" was planted-in between the female rows. However, spacing between planted-in female rows should be extended from 65 cm to 75 cm to produce the maximum yield (Table 1). The yield increase was due to a significant increase in the ear number per hectare and plant number per hectare with the different planting-in methods. The increase was not due to an increase in the yield component, since ear weight per plot and 1000 seed weight were not directly affected by different compact planting methods (Table 1). Thus, the results confirmed the efficiency of greater area utilization of female plants under compact planting compared with common planting. However, it was noticed that plant numbers were approximately 10% higher than ear numbers. For this experiment, ear number included the number of barren ears and poor seed-filled ears. Thus, seed producers should take into account that increasing yield by a compact planting technique not only involved planting-in male rows, but also manipulation of every single female plant to produce good seed-filled ears. Good management of cultivation practices should be performed, and there should be more studies on optimum fertilizer application, especially on the male and female inbreds in planting-in rows. In general, the recommended row spacing for seed production planting in Takli black soil is 65 cm. (Field Crops Research Institute, 2005). The spacing could be extended or narrowed depending on soil type, soil fertility and topography, amongst other factors. Study of fertilizer application should occur concomitant with an investigation of efficient techniques to promote pollination to ensure increased ear numbers and well-filled ears.

As row spacing was narrowed, compact planting caused a delay in male flowering for 1-3 d (Table 2). Thus, an intermediate female row spacing at 75 cm was recommended, since a delay of 1-2 d had no effect on yield (Table 1). This experiment was conducted in the rainy season; consequently, there was no temperature effect from cold weather on vegetative growth and flowering delay. If the seed production area were planted in winter, there may be an effect on growth and flowering delay from cold weather, especially for male inbreds. The combination effect of cold weather and compact planting may cause a failure of synchronization resulting in a yield decrease. Producers may plan carefully to grow inbreds using a wider planting-in spacing, such as 85 cm or by split planting time of male inbred into two.

Table 2 Effect of compact planting on flowering date of female inbred "Tak Fa 1" and male inbred "Tak Fa 3" for Nakhon Sawan 3 hybrid seed production.

Planting-date regime	Male planting methods	Days toof 50% pollen shedding of male inbred	Days of to 50% silking of female inbred
1. Planting on the same day	1. compact, planting-in spacing 65 cm	65	60
	2. compact, planting-in spacing 75 cm	63	61
	3. compact, planting-in spacing 85 cm	63	60
	4. female : male row, spacing 65 cm	63	61
	average	63	61
2. Planting female 2 days later	1. compact, planting-in spacing 65 cm	67	59
	2. compact, planting-in spacing 75 cm	66	60
	3. compact, planting-in spacing 85 cm	65	60
	4. female : male row, spacing 65 cm	64	60
	average	66	60
	C.V. (Planting dates) (%)	5.5	1.6
	C.V. (Male planting methods) (%)	3.5	1.0
	Planting date (P)	ns	
	Male planting methods (M)	ns	
	PxM	ns	

ns = not significantly different

Table 3 Plant height of female inbred "Tak Fa 1" and male inbred "Tak Fa 3" at different planting dates and male planting methods for Nakhon Sawan 3 hybrid seed production.

Planting-date regime	Male planting methods	Female height of planting-in row at 49 DAP (cm)	Female height at 49 DAP (cm)	Male Height at 49 DAP (cm)	Female height of planting-in row at 56 DAP (cm)	Female height at 56 DAP (cm)	Male height at 56 DAP (cm)
1. Planting on the same day	1. compact, planting-in spacing 65 cm	126.5	127.2	105.0	176.2	174.0	141.9
	2. compact, planting-in spacing 75 cm	126.5	127.0	101.7	177.0	177.3	137.0
	3. compact, planting-in spacing 85 cm	135.1	127.5	99.4	183.4	180.5	140.5
	4. female : male row, spacing 65 cm	120.9	120.9	91.1	176.1	176.1	134.3
2. Planting female 2 days later	1. compact, planting-in spacing 65 cm	132.5	141.3	100.5	179.4	182.2	135.0
	2. compact, planting-in spacing 75 cm	136.2	134.4	94.3	177.1	175.6	130.5
	3. compact, planting-in spacing 85 cm	131.9	130.7	90.5	175.7	175.4	125.9
	4. female : male row, spacing 65 cm	138.1	138.1	90.6	180.3	180.3	137.9
	C.V. (Planting dates) (%)	9.6	8.2	9.3	6.2	7.0	10.8
	C.V. (Male planting methods) (%)	5.9	5.7	5.2	3.2	4.0	5.4
	Planting date (P)	ns	ns	ns	ns	ns	ns
	Male planting methods (M)	ns	ns	ns	ns	ns	ns
	PxM	ns	ns	ns	ns	ns	ns

ns = not significantly different

Compact planting had no effect on female and male inbred height (Table 3), but producers must be careful if planting is done in different types of soil or at different locations, since the male inbred height was slightly shorter than that of the female inbred. Different practices or weather conditions that affect compact planting may cause yield reductions, due to the intolerance of some inbreds to denser planting (Beck, 2004). Overshadowing resulted in poor tassel formation and pollen production. In a previous experiment (Koshawatana *et al.*, 2007), male inbreds of planting-in rows were grown for 5 d after the females and the male inbreds were overshadowed by female plants at 35 DAP, resulting in a decrease in plant height of approximately 40% at 56 DAP when compared with that of male normal plants. Consequently, the late planting male inbreds failed to develop fertile tassels. Thus, there should be further experimentation to investigate production resulting from differences in soil type, location, weather or other conditions to confirm the results of compact planting techniques with regard to increasing yield.

CONCLUSION

To increase yield for seed production of the drought-tolerant hybrid "Nakhon Sawan 3", compact planting could be practiced in the field by planting the female inbred "Tak Fa 1" using a row spacing of 65 cm for the entire field and planting-in rows for the male inbred "Tak Fa 3" at 75 cm. Female and male inbreds should be planted on the same day at the ratio of 4:1. This compact planting technique tended to increase yield by up to 28% compared with that of common planting of female to male rows. The yield increase was due to an increase in the number of female plants per area and ear number per area rather than an increase in ear weight or seed weight, since compact planting did not directly affect the yield component. It was noticeable that compact planting with a narrow planting-in row could cause a delay in male flowering of 1-3 d.

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