Seed Yield and Quality of Three-Way Cross Hybrid Maize Production in South and Central Sulawesi of Indonesia

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ABSTRACT. Production of hybrids seed is technically similar to production of a breeder's seed of Open Pollinated Varieties. All agronomic management are carried out at each critical stage to maintain and preserve genetic purity and morphological homogeneity. Particularly in producing hybrids seed, carefully arrange nicking-time of both parent lines is essential. Research on the effect of three-way cross hybrid towards seed yield and quality was carried out at two sites in Labuan Toposo, Donggala, Central Sulawesi and in Al Qomar Farmers Group, Takalar, South Sulawesi, Indonesia from August to December 2010. Treatments are differences of female single-cross (BIMA-5) planting days prior to male inbred line (MAL-01), i.e. 3 days, 4 days, and 5 days, with exception for Takalar site used 6 days instead of 5 days. Results shows that 3 days female planting gave the highest seed yield in Donggala (4,85 t ha^{-1}) also in Takalar (3,04 t ha^{-1}). Which mean 3 days is the best treatment to obtain full synchronization of flowering, thus gives optimum yield for this three-way cross hybrid. Seed quality evaluation was carried out at ICERI's Seed Testing Laboratory, and the results shows that seed harvested from Donggala are more vigourus and viable. Also quality in term of electrical conductivity seed from Donggala have low conductance compared to Takalar site, which mean there was no leaching of seed organic substances thus seed are highly viable.

Keywords: maize, three-way cross, seed yield, seed quality

Introduction

The demand for maize in Indonesia is steadily increasing within the last 5 years, especially to supply high amount of raw materials needed for poultry feed industries. One effort to increase maize productivity is by cultivating hybrids maize rather than composite varieties and the type of hybrids widely uses are single-cross hybrids. Disadvantage of planting hybrids is that farmers would have to purchase seed for each season, which make them dependent to private seed company. Small scale farmer who cannot afford to buy seed for each planting season used the F2 of hybrids instead. However, this practice leads to decrease in yield of 15% to 20% in succeeding crop cycle, because an increase of heterogeneity and there was small percentage of inbreeding depression occurred. Considering, the high cost of private hybrids seed and the need of affordable maize hybrids in several maize-growing areas. Indonesian Cereals Research Institute (ICERI) believes that it is necessary to provide affordable-adequate hybrids seed for these farmers to cultivate.

Conventional hybrids consist of three types of crosses, which include single-cross, three-way cross and double-cross. Single-cross hybrids are based on pairing two elite inbred lines, whereas three-way cross production first require a single-cross hybrids as female parent to be crossed by an elite inbred lines as a male parent (Vasal 1988). Single-cross hybrids are common and widely use due to its practicality of production and high yield performance. The downside of single-cross F1 production is that F1 seed yield is relatively low compared to three-way cross or double-cross. This is because the seed obtain from the female parent is low, due the fact that yield potential of inbred lines only gives 1-3 t/ha. While three-way cross research conducted at two production sites in Central and South Sulawesi, was proven able to produce 3-7 t/ha of seed yield (Arief *et al.* 2010). Therefore, problem of low F1 seed yield from single-cross production can be solved by production of F1 seed from three-way cross hybrids. Furthermore, in the developing world three-way cross hybrids are the most common type of hybrids currently grown (Beck 2002).

There are genetic and environmental constraints in producing F1 hybrids that can affect and reduce seed yield. Difference in days to flower in both female and male significantly affect yield, because longer Anthesis Silking Interval (ASI) would influence flowering synchronization and ovule fertilization. Another critical consideration is the ratio of male to female parent. Because inbred lines develop small tassel compare to hybrids, therefore produce less pollen. This makes the ratio of male parent must provide enough pollen to effectively fertilize female silk, and the common ratio use by ICERI is 1 male for 3 female (1:3) for production of F1 hybrids. In order to understand the effect

of different parents planting time of three-way cross hybrids production on F1 seed yield and its quality. ICERI conducted research on farmer's field at two different locations in South and Central Sulawesi of Indonesia.

Methodology

This research was conducted on farmer's field at Donggala District of Central Sulawesi, and at Takalar District of South Sulawesi from August to December 2010. This three-way cross used BIMA-5 as female parent, and inbred line MAL-01 used as male parent. For this research the ratio of male : female was 1:4, with plant spacing of 70 cm x 20 cm and 1 seed/hole. For this research the treatments are differences of female days of planting, which are consist as follows:

1. Female parent sown 3 days prior to male parent
2. Female parent sown 4 days prior to male parent
3. Female parent sown 5 days prior to male parent

There is 1 different treatment applied at Takalar, which used 6 days female parent planting prior to male parent instead of 5 days.

Fertilizer application consist of 200 kg/ha urea (N:46%), and 400 kg/ha Phonska (N:15%; P_2O_5: 15%; K_2O: 15%; and S:10%). The amount of fertilizers used for the first application (7 Days After Sowing) are 50% of total fertilizers, and second application at 35 DAS are the remaining fertilizers. After harvest, F1 seeds yield quality were tested at ICERI's Seed Testing Laboratory. And for analysis of physical and chemical characteristics of soil in each location were conducted at ICERI's Soil and Chemical Laboratory in Maros, South Sulawesi.

Data collected from field observation are : (1) plant emergence after 14 DAS (%), (2) Male parent days to flower/anthesis (days), (3) Female parent days to flower/silking (days), (4) plant height (cm), (5) seed yield (t ha^{-1}), (6) shelling percentage (%), (7) grain moisture content (%), (8) seed quality evaluation, which consist of : seed germination (%), speed of germination, electrical conductivity, length of shoot and root ratio.

Results and Discussion

Seed Production and Biophysical Condition of Production Site

Seed production in both area (Donggala, Central Sulawesi and Takalar, South Sulawesi were carried out on Alluvial soil, with loam soil texture. While, soil texture in Takalar was silty loam. In general soil fertility in Labuan Toposo, Donggala, Central Sulwesi was higher than that in Bajeng, Takalar, South Sulawesi in term of soil acidity, soil organic matter, available cation exchange, and base saturation (Table 1).

During the research there was high rainfall in September/October in Takalar and flood occurred in the production area for several days at vegetative stage, which caused small decrease in plant population. Because of this environmental intrusion to plant population, it affected field observation of plant emergence as shown in Table 2.

Agronomic management of producing hybrids should be carefully assessed to maintain plant homogeneity and genetic purity. Before planting each parent on the field, seed quality inspection was performed to keep off type and volunteer seed off the field. Roguing or the removal of all undesirable plants was carried out during vegetative cycle by carefully rogue the field of all easily recognizable off type. And prior to flowering rogue was performed to maintain genetic purities of parents, especially male parent. Another critical step was detasseling, which is difficult period to manage in maize hybrid production. Tassels from female plant were manually removed before pollen shedding and or before silk emergence. All of these steps were meticulously performed in each site to achieve the necessary genetic purity standards according to both parent descriptions (Saenong *et al.* 1996).

Table 1. Soil chemical and physical characteristics in seed production Sites [1)]

Soil chemical and physical characteristics	Labuan Toposo, Donggala, Central Sulawesi	Bajeng, Takalar, South Sulawesi
Texture	Loam	Silty loam
Clay (%)	15	47
Silt (%)	37	44
Sand (%)	48	9
pH H_2O (1:2,5)	7.2	6.26
KCl (1:2,5)	6.5	5.28 near acid
Corg (%)	1.21	0.73 v.low
N total (%)	0.12	0.09 v.low
C/N	10.08	8.11 low
P Bray (ppm)	11.38	35.20 high
Available cation exchange (me/100 g)		
K	0.28	0.35 medium
Ca	23.74	9.06 medium
Mg	3.24	3.91 high
Na	0.21	0.32 medium
Al avail (me/100g)	0	0
H+ (me/100g)	0.05	0.03
CEC (me/100g)	18.13	11.27
Base saturation (%)	151.52	121.03

1) soil was analyzed in soil and chemIcal laboratory of Indonesian Cereals Research Institute. 2010

Differences in flowering days of both parent means to obtain optimum yield potential, synchronization of Anthesis Silking Interval (ASI) to be minimum is crucial. This is because with low days of ASI (1-2 days) when pollen shed, silks of female parent should have already emerged, viable and receptive. Based on the results shown in table 2, analysis of DMRT found that there is no significant difference in parent plant emergence, and female days of flowering at Donggala site. Whereas for male days of flowering there is significant difference between 3 and 4 days treatments compared to 5 days. And there is no significant difference in plant height of male parent. By planting female 6 days prior to male parent, there is significant difference in the percentage of male flowering (40,90%), which affected seed yield (3,62 t ha^{-1}) as shown in table 3.

Seed production in Labuan Toposo, Donggala shows that female seed parent sown 3 days earlier than male parent gave the highest flowering synchronization between male and female parent. At 55 days after sowing female seed parent, table 2 shows that flowering percentage of male parent were 51,70% and the female flowering were 55.45%. It means that flowering days of both parents at >50% occurred almost at the same day. Although female parent emerge slightly before pollen shed, silk still can remain viable to receive pollen.

Different crop performance showed in seed production at farmers' field of Al Qomar farmers group in Bajeng, Takalar. At 14 days after sowing, plant emergence percentage of male parent were low, ranged from 50.76% – 65.40% and female seed parent 83.565% - 85.60% (Table 2). Female seed parent had higher vigor than male parent, because female seed parent was single cross hybrid (Bima-5) and male parent was inbred lines (MAL-01). In this production site, at 10 days after female seed parent were sown, several days of high rainfall caused flood in many

Table 2. Plant emergence of male and female parents at 14 DAS, plant height of male parent, flowering percentage of male and female parent at 55 DAS at two seed production site. 2010.

Different planting time between male and female parent (days)	Plant emergence of male parent (%)	Plant emergence of female parent (%)	Flowering of male parent at 55 DAS (%)	Flowering of female parent at 55 DAS (%)	Plant height of male parent (cm)
Labuan Toposo, Donggala, Central Sulawesi, Indonesia*[1)]					
3	98,17 [ns]	99,50 [ns]	51,70 [a]	55,45 [ns]	188,9 [a]
4	98,00	98,60	50,55 [a]	54,25	187,5 [a]
5	97,95	98,50	40,90 [b]	54,50	185,7 [ab]
Bajeng, Takalar, South Sulawesi, Indonesia [*1)]					
3	65,40 [a]	85,60 [ns]	48,70 [a]	51,55 [ns]	168,9 [a]
4	55,80 [b]	83,56	43,55 [ab]	51,25	163,5 [ab]
6	50,76 [c]	85,60	40,20 [bc]	50,50	165,7 [a]

[*1)]Numbers followed by the same letter in a column in each location were not significantly different by DMRT at 5% level; ns = not significant; DAS = Days After Sowing

Table 3. Seed yield at 15.15% moisture content, shelling percentage, 100 seed weight at 11% moisture content, cob length (cm), cob diameter (cm).

Different planting time between male and female parent (days)	Seed yield mc. 15.15% (t ha^{-1})	Shelling percentage (%)	100 seed weight mc.11% (g)	Cob length (cm)	Cob diameter (cm)
Labuan Toposo, Donggala, Sulteng [*1)]					
3	4,85 a	80,02 a	35,32 a	21,54 [ns]	5,32 [ns]
4	4,33 ab	79,65 a	34,56 a	21,40	5,12
5	3,62 c	77,23 ab	30,29 c	20,75	4,94
Bajeng, Takalar, Sulsel [*1)]					
3	3,04 a	67,85 a	28,43 a	19,65 tn	4,99 a
4	2,97 ab	64,32 ab	27,65 a	18,64	4,64 ab
6	2,65 bc	60,78 bc	26,43 ab	18,40	3,93 c

[*1)]Numbers followed by the same letter in a column in each location were not significantly different by DMRT at 5% level; ns = not significant; DAS = Days After Sowing

Table 4. Vigor of harvest seeds from Labuan Toposo, Central Sulawesi and Bajeng, Takalar, South Sulawesi. 2010

Different planting time between male and female parent (days)	Germination (%)	Germination speed (%/etmal)	Electric conductivity (µS/cm/g)	Shoot–root length ratio
Labuan Toposo, Donggala, Sulteng*1)				
3	100,00 ns	31,80 ns	14,3 c	0,54 a
4	99,33	31,40	16,4 ab	0,51 ab
5	99,33	30,73	20,6 a	0,50 bc
Bajeng, Takalar, Sulsel*1)				
3	98,00 tn	31,96 tn	19,10 bc	0,65 a
4	97,00	29,93	21,95 ab	0,56 b
6	93,00	29,91	24,92 a	0,56 b

*1)Numbers followed by the same letter in a column in each location were not significantly different by DMRT at 5% level; ns = not significant

parents' rows so there were losses of small plant population. This environment incident effect field observation, which make this site results differ from Donggala site. Plant emergence showed that female seed parent emerges more vigorously than male parent, due to the nature of heterosis posses in single-cross. Even though flood occurred of over two consecutive days, plant emergence is still above 80%. Whereas, male parent tent to have low vigor due to the genetic nature of inbred lines. Another reason for poor plant emergence beside inbred lines low vigor was plant competition with weed that grow rapidly than the inbred lines. The competition for nutrient intake where competition with the abundant amount of weed caused slightly pale yellow coloration of the male parent leaves.

Duncan's Multiple Range Test of seed yield in table 3, shows that there is significant difference of 5 days treatment compared to 3 and 4 days in Donggala site. The highest yield was achieved at 3 days female planting prior to male (4.84 t/ha), which also correlate with 100 seed weight result (35.32 g). Whereas, no significant difference in shelling percentage for each treatment, also for cob length and cob diameter.

Grain yield for seed at Bajeng site ranged from 2.65 – 3.04 t/ha, with shelling percentage of only 60.9% – 67.9%. While in Labuan Toposo site shelling percentage reached 77.2% - 80.0%. The lower seed yield and yield components in Bajeng was probably caused by the variation of local biophysics environment (soil fertility, rainfall, humidity etc.). Another reason for low seed yield was due to higher percentage of barren cob, which ranged between 40% – 60% from total harvested cobs. Barren cob could only result from high percentage of unfertilized ovule, which occurred because of high Anthesis Silking Interval (ASI).

Seed Quality Evaluation

Seed quality testing in table 4 shows that seed obtain from Labuan Toposo production site had higher initial vigor in term of germination, speed of germination, and electrical conductivity than seed from Bajeng production site. After seed reached its physiological maturity, seed moisture content was still high, so it is better to keep the plant on the field for drying until moisture content reached at the suitable percentage for harvest. According to Delouche (1990) harvesting the seeds at high moisture content would increase mechanical injury at the processing stage due to seed fracture. Seed quality from Bajeng, Takalar production site was lower than that of Labuan Toposo. Its electrical conductivity of seed soaked in water reached 24.92 µS/cm/g (table 4). High electrical conductivity means that membrane cell of the seeds had become lysis, therefore high amount organic and anorganic content leached out and were released from membrane cell (Copeland and Mc. Donald 1985; Delouche 1990). .

Conclusion

- Seed yield obtained from Labuan Toposo production site reached 4.85 t/ha and shelling percentage of 80%. However, lower seed yield was found in Bajeng production site with only 3.04 t/ha and shelling percentage of 67.9%.
- Sowing female parent 3 days prior to male parent showed the highest vigor and seed yield in both production sites.
- Seed quality of harvested seed lots from Labuan Toposo gave higher seed quality than Bajeng due to higher germination speed and lower electrical conductivity.

- Biophysical environment of the sites and rainfall affect each stage of male and female parent development, thus influence plant vigor, seed yield and quality.

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