

DEVELOPMENT OF ACID-SOIL TOLERANT CORN (*Zea mays* L.) WITH HIGH-QUALITY PROTEIN

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ABSTRACT

Corn is an important food crop in Indonesia. Plant expansion has been hampered by soil-acidity problem and the protein content of many corn varieties was low. This research initiates development of soil-acid-tolerant corn with high-quality-protein content. Research was done on 12 factorial treatments and 3 replications as blocks in RCBD. The first factor was corn populations: Toray-1(G1), Toray-2(G2), GS-5(G3) and GS-10(G4). The second factor was fertilizations: P1(69 kg N+36 kg P₂O₅+15 kg K₂O per ha); P2(115 kg N+54 kg P₂O₅+30 kg K₂O per ha); and P3(161 kg N+72 kg P₂O₅+45 kg K₂O per ha). The observed variables consisted of several agronomic traits, including the protein content. Results indicated that the corn populations, in general, showed good agronomic traits. The differences were mostly between populations, not between fertilizations, and no interaction was observed. The yield potential ranged from 4.25 to 6.47 ton dry seeds per ha. The protein content of seed resulted from cross ranged from 9.84% to 11.30%, as compared to the parents of 9.11% and 12.62%. This research concludes that genetic factors play an important role as confirmed by heritability estimate (h^2)=0.75.

Keywords: corn, protein, acid-soil, tolerance

INTRODUCTION

In line with the increase in human population, food supply needs to increase as well. In Indonesia, corn (*Zea mays* L.), is second to rice as an important food crop. Apart from its function as animal feed, corn is used in food industry and supplement for baby food (Prastowo, 1997; Pradilla *et al.*, 1975). Efforts in

increasing plant productions might be done by increasing yield and by expansion of arable land. The expansion program, however, faces limitation due to the availability of the land that is mostly comprised as marginal soils such as podsolic soil and swampyland that have low pH and nutrient problems (Erdiman and Kasim., 1996; Soewarno *et al.*, 1992; Kasim *et al.*, 1993). With respect to those conditions, approach in developing high yielding variety of corn in Indonesia, therefore, should consider both the ability of the plant to perform appropriate acid-soil and contains high-quality protein (Altschul, 1975; Anderson, 1975; and Pradilla *et al.*, 1975).

Research conducted by Kusdiantari (1999) and Amran (2001) resulted in some crossed populations between acid-soil tolerant accession SA-3 and several national varieties such as Arjuna, and Bisma. Among these crossed populations are GS-5 and GS-10. By the use of water-culture technique developed by Rhue and Grogan (1977), these two populations performed best in acid condition with respect to the length of tap root of the seedling. The SA-3 accession was developed by the CYMMIT, Mexico (Granados *et al.*, 1995) and introduced to Indonesia in 1996 (Halimi, 2000).

Meanwhile, research conducted by Abdurahman (2002) resulted in some crossed populations between high quality protein corn accession (HQPSSS and HQPSCB) and several national varieties of corn. Among these crossed populations are Toray-1 and Toray-2. The protein analysis on the Syn-1 seeds of these two populations was higher than 10 %, and did not show inferiority of weak kernel character that usually occurs on high protein corn variety (Carangal, 1975). As reported by researcher who developed HQPSSS and HQPSCB accessions (Zehr and Hamaker, 1995), these two accessions contain opaque-2 gene that imparts

high quality protein content with hard kernel character. The hard kernel character is very important to fight insect infestation in field and storage. In addition, Zehr and Hamaker(1995) claim that total protein and lysine content of these accessions was very high, which was about 11.73 % and 43.1 g per kg protein respectively. For the purpose of the research, the HQPSSS and HQPSCB accessions were introduced to Indonesia in 1996 (Halimi and Lakitan, 1999).

Furthermore, successful agricultural production is very dependent on the fertilizer application. Nitrogen (N), Phosphorous (P) and Potassium (K) fertilization are important practices in agriculture to increase production. In an appropriate application, N and P promote vegetative and generative growth respectively, while K strengthens the body of the plant. On the other hand, the lack or excess of those nutrients will inhibit growth and development of the plants (Gyles *et al.*, 1997; Power and Papendick, 1997; Lubis *et al.*, 1985).

The objectives of this research are (1) to identify agronomic traits of acid-soil tolerant corn (GS populations) and high-quality protein corn (Toray populations) in the various fertilizing application, and (2) to estimate the role of genetics in developing acid-soil tolerant corn with high-quality protein content.

MATERIALS AND METHODS

Research was conducted at farmland area at Tanjungseteko, Ogan Komering Ilir, South Sumatera. Research was carried out based on the Factorial Experiment in a Randomized Complete Block (RCB) design with 3 replications as blocks. The factorial treatment consisted of 12 combinations as follows:

Factor I: Corn populations consisted of high quality protein accessions of Toray-1(G1); Toray-2 (G2) and acid-soil tolerant accessions of GS-5(G3); and GS-10(G4).

Factor II: Fertilizing treatments of 69 kg N + 36 kg P₂O₅ + 15 kg K₂O per ha (P1); 115 kg N + 54 kg P₂O₅ + 30 kg K₂O per ha (P2) and 161 kg N + 72 kg P₂O₅ + 45 kg K₂O per ha (P3).

Observations were done on the 10 unit samples of plant in a plot size of 3m x 4m and planting space of 75cm x 25cm. Data analysis was carried out by using Analysis of Variance (ANOVA) followed by appropriate Least Significant Difference (LSD) analysis at $\alpha=0.05$.

Measurements were taken on some important agronomic including plant height (cm), day of tasseling, day of silking, length of cob (cm), diameter of cob (cm), dry weight of cob (g), number of seeds per plant, weight of dry seeds per plant (g), weight of 100 dry seeds (g), and protein content of the embryo of the crossed seeds, which were measured as a composite sample.

Furthermore, genetic estimation of heritability (h^2) value was done on the protein content data by using method of "Regression of Offspring on Mid-Parent" (Wricke and Weber, 1986) which is called by (Falconer, 1989) as method of "Mid-Parent Progeny Regression". Statistical calculation was done by using computer program of Statistical Analysis System (SAS Institute, 1988). The linear additive model for regression calculation is as follows:

$$Y_i = b_0 + b_1 X_i$$

Where :

- Y_i = Protein content of the progeny
- X_i = Mean value of protein content of male and female parents (mid-parent)
- b_0 = Intercept
- b_1 = slope

While the formula to estimate heritability value (h^2) and its standard error [SE (h^2)] is as follows:

$$h^2 \approx 2(b_1)$$

$$SE(h^2) \approx SE(b_1)$$

To increase probability of crossing, the seeds were planted in a "multiple planting date system" in three-day period. The fertilizer used consisted of Urea, SP36, and KCl which were applied according to the treatments. The application of urea was split 1/3 during the first planting, and 2/3 at 4 weeks after planting, while SP36 and KCl were applied during the first planting. Other standard practices were applied accordingly, including 5 tons of chicken manure per ha which were applied a week before planting.

Selfing and crossing were done according to the method outlined by Fehr (1987). Selfing and crossing of the GS and Toray populations were carried out at least in 5 plants each. Selfing and crossing were done by spreading mature pollens over the silk of respected plants, 3 to 5 times during period of tasseling and silking.

Crossing was done by using GS population as female parent and Toray populations as male parent. Mature pollens from male parents (Toray) were collected by shaking tassel inside transparent plastic bag, while the ears of female parent (GS) were appropriately isolated by using paper bag 3 days before silking. Standard practices on the silk, ear, tassel, and the changing of paper bag were applied necessarily to promote maximum pollination, fertilization, and seed formation.

RESULTS AND DISCUSSION

Results indicated that agronomic traits of acid-soil tolerant corn (GS populations) and high-quality protein corn (Toray populations) were similar. As indicated in Table 1, the significant differences were only due to a single factor of population effect (G) for variables of tasseling and silking period. In general, tasseling period of Toray populations (46 days after planting) were earlier than GS population (49-52 days after planting). The silking period showed about the same. The silking period of Toray populations were 49 days after planting, while the GS populations were 51-54 days after planting. As stated by Fehr (1987), the tasseling period of corn population is usually 1 to 3 days earlier than silking period and the similarity on many important agronomic traits of the parent accession will lead to a simple way in the effort to develop acid-soil tolerant corn with high-quality protein.

As compared to the growth of parental accession observed by Kusdiantari (1999) and Amran (2001), the growth of GS and Toray populations in this research was about the same. The average plant heights ranged from 228 cm to 250 cm, the tasseling occurred 46 to 53 days after planting, the silking periods were 49 to 54 days after planting, the length of cobs ranged from 12 cm to 15 cm, diameter of cobs ranged from 3.8 cm to 4.3 cm, weights of cobs ranged 90 g to 120 g per plant, the number of seeds per plant ranged from 355 to 420, the weights of dry seeds per plant ranged from 78 g to 103 g, and weights of 100 seeds ranged from 20 g to 26 g. Based on the assumption of plant density of 53 000 plants per ha, the yield potential ranged from 4.2 to 6.5 tons dry seeds per ha. In addition, the effect of fertilizer application of 161 kg N-72 kg

P_2O_5 -45 kg K_2O (P3) per ha resulted in one day earlier (50 days) of silking period and tasseling period (48 days) as compared to other fertilizer application (P1 and P2). As stated by Fehr (1987), the tasseling period of corn population is usually 1 to 3 days earlier than the silking period.

Crossing of parental accession of GS by Toray populations and their selfing initiated an effort to develop acid-soil tolerant corn with high-quality protein. More seeds (>3kg) resulted from each cross indicated no-serious sterility problem occurred in cross progeny populations which was important in corn breeding (Fehr, 1987).

Furthermore, in order to make the best measurement, the protein analysis was carried out on a composite sample of embryo of crossed seeds without endosperm as outlined by Villegas (1975). Copeland (1976) stated that protein content, especially lysine and tryptophane of the corn seed, was concentrated on the embryo. In addition, Kozlowski (1972), stated that the embryo contains 2 set chromosomes, each derived from male and female sources, while the endosperm contains 3 set chromosomes, 1 set from male and 2 set from female parents. The results of protein analysis (Figure 1) indicated the protein content of Toray 1 (G1) was 13.27%; Toray-2 (G2) was 11.96%, while GS5 (G3) and GS10 (G4) were 9.11 %. Meanwhile, all four crossed progeny populations (G3xG1; G3xG2; G4xG1;G4xG2) contained higher protein content than female parent (GS population), which ultimately indicated a successful genetic recombination of acid-soil tolerant and high-quality protein. Also shown in Figure 1, the protein content of all four crossed progeny populations were intermediate to both of the parents. This intermediate response phenomenon, by Falconer (1989) and Wricke and Weber (1986) suggests the presence of polygenic inheritance and significant role of additive gene action. This indication was confirmed by the estimation of heritability value (h^2) of the protein content of 0.75 with standard error estimate of $2 \times (SE h^2) = 0.53$. The value predicates useful response to selection since the lower estimate of h^2 was greater than zero ($0.75-0.53=0.22>0$) (Halimi *et al.*, 1994). The presence of polygenic and significant role of additive gene action in corn research was also reported by Granados *et al.* (1993).

Table 1. The F-value and coefficient of variation (CV) on some important agronomic traits

Agronomic Traits	F-Value			CV (%)
	P (Fertilization)	G (Population)	PXG (Interaction)	
Plant Height	0.30	0.97	0.33	7.28
Tasseling	0.27	36.10*	0.29	2.88
Silking	0.29	25.16*	0.34	2.79
Length of cob	0.60	1.27	0.27	12.26
Diameter of cob	1.06	1.69	1.03	6.02
Weight of cob (g)	0.56	2.31	0.55	19.94
Number of seeds per plant	0.12	0.67	0.66	16.45
Weight of dry seeds per plant	0.59	1.57	0.74	19.49
Weight of 100 dry seeds	2.24	2.31	0.95	9.39
F-table $\alpha = 0.05$	3.98	3.89	3.03	

Remarks: *: Statistically significant at $\alpha=0.05$ (Source Purba, 2007)

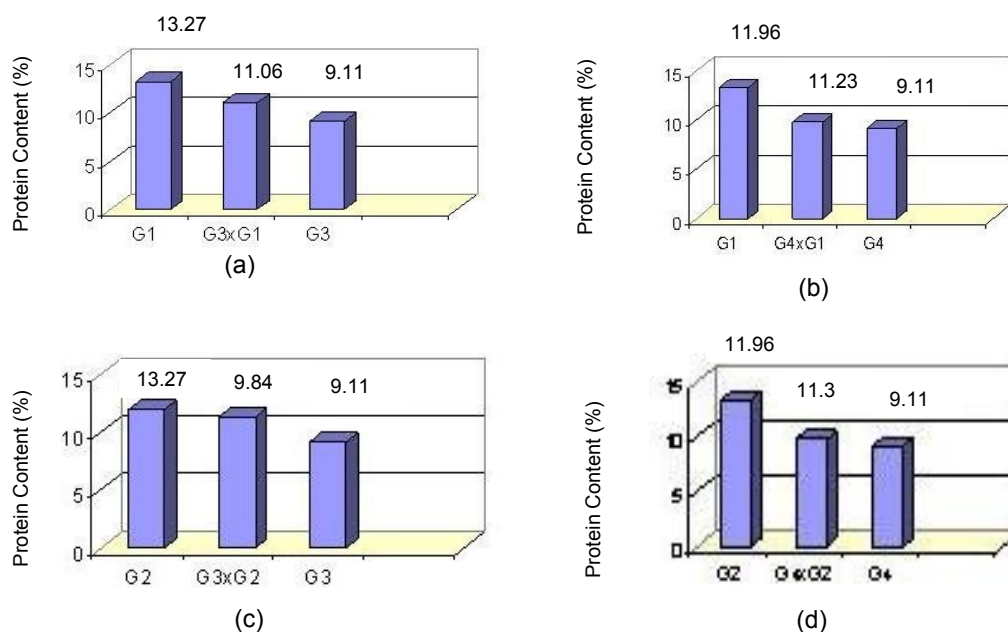


Figure 1. Protein content (%) of Toray (G1, G2) as male parent; acid-soil tolerant accession (G3, G4) as female parent, and their respected cross progeny populations (G3xG1; G3xG2; G4xG1; G4xG2). (Source: Pransiswa, 2010)

CONCLUSIONS AND SUGGESTIONS

CONCLUSIONS

This research concluded that development of acid-soil tolerant corn with high-quality protein content might be initiated. Respected parental accessions showed good agronomic traits, and therefore, selection on the crossed progeny population might be relatively simple to reach homogeneity. The differences in response to fertilization should also be relatively low.

The yield potential of the new accessions ranged from 4.25 to 6.47 tons dry seeds per ha with protein content of 9.84 % to 11.30%. There was a strong indication that additive gene action played an important role, which was confirmed by a meaningful value of heritability estimate of $(h^2) = 0.75$ and the standardized error of $2 \times (SE h^2) = 0.53$.

SUGGESTIONS

Based on this research, it is recommended that research be expanded to establish a new corn variety that is tolerant to acidic soil and contains high-quality protein.

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