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Agronomic Performance of Corn Population Selected for Nutrient Efficiency in Marginal Land

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ABSTRACT

Low soil fertility is the most important factor constraining corn (*Zea mays* L.) yield in marginal land due to soil acidity. Corn cultivars with high nutrient efficiency and tolerance to soil acidity offer an alternative to solve the problem. A Complex population had been formed by natural crossing among six cultivars/line expected to carry the nutrient efficiency character; Sukmaraga, Lamuru, Srikandi Kuning, Bisma, Bayu, and Toray and used as a genetic material in this study. The objectives were (i) to evaluate the agronomic performance of complex population in marginal land under limited nutrient supply, (ii) to select the superior entries in each population for nutrient efficiency, and (iii) to identify the characters relate to yield (nutrient efficiency). The selection of nutrient efficiency was based on the ear dry weight produced per plant (yield). The experiment was conducted in marginal land at Agro Techno Park, Indralaya, South Sumatra in January to April 2008. Randomized Complete Block Design with four replications was used. The treatment was number of entries that grouped into six populations based on a female parent. Plants were fertilized with Urea, SP-36, and KCl at 30% of standard rate. Sukmaraga population had the best agronomic performance among six populations evaluated. The superior entries selected were top 10% of the total entries in each population with ear weight more than 150 g. All the characters (ear length and diameter, plant height, leaf chlorophyll, leaf numbers above the ear, and ear leaf area) related to yield (nutrient efficiency) but plant height is the only character measured before anthesis. The results suggest that Sukmaraga population had use nutrient more efficiently than the other populations and plant height may be used as selection criterion in early screening large numbers of corn entries or lines for nutrient efficiency.

Key words: Agronomic characters, corn, marginal land, nutrient efficiency

INTRODUCTION

Marginal land is the most potential land for corn production in Indonesia, especially in South Sumatra. Low soil fertility (deficiency of macro elements such as N, P, K, Ca, Mg) and toxicity of Al, Fe, and Mn caused by soil acidity in this type of land is the most important factor constraining corn yield (Granados *et al.*, 1993). The soil condition can be corrected by liming and high rate of chemical fertilizers, but it is not economically feasible for poor farmers. Djafar and Halimi (1998) in their survey found out that the corn farmers in South Sumatra have never limed the land and only fertilized the corn plants with 75, 50, and 50 kg ha^{-1} Urea, SP-36, and KCl, respectively which is considered under optimum fertilizer rate for optimum corn production. Corn cultivars with high nutrient efficiency offer an alternative to solve the problem.

Genotype difference in nutrient efficiency is usually defined by the difference in the yield when grown in a deficient soil. Nutrient efficient genotype has the ability to produce a higher yield than other genotypes in a soil that is limiting in one or more mineral nutrients (Marschner, 1986; Worku *et al*., 2007). There is a genetic variation in nutrient efficiency (Streeter and Barta, 1984; Presterl *et al*., 2003), so developing nutrient efficient genotypes by breeding program is quite possible.

Genotypic Recurrent Selection is chosen as a breeding method to develop nutrient efficient genotypes in marginal land because the method has been successfully used in developing corn cultivars in America (Fehr, 1987) as well as cultivars tolerant to soil acidity, Sukmaraga, and to drought, Lamuru in Indonesia (Yasin, 2005). Population selection to get the superior plants or entries is the first step in the cycle of recurrent selection. Direct selection in deficient soil condition at a target environment is more effective to increase the nutrient efficiency and yield compared to indirect selection in optimum nutrient environment (Atlin and Frey, 1990; Banziger *et al*., 1997; Presterl *et al.*, 2003; Sutoro *et al*., 2006). Some very valuable characteristics related to nutrient efficiency may have been repressed in the process of selecting for agronomic

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characters when the selection conducted on nutrient rich soils (Streeter and Barta, 1984).

A complex population had been formed in the previous experiment by natural cross (polycross) among the selected parental cultivars expected to carry the nutrient efficiency characters; Sukmaraga, Lamuru, Srikandi Kuning, Bisma, Bayu and Toray. The first five cultivars are the national cultivars and Toray is the high protein line developed by Halimi (1999). It was expected that each parent would give the genetic contribution to the population formed. In this type of population we can only identify the female parent of seeds produced in the ear. The objectives of the experiment were (i) to evaluate the agronomic performance of the complex population in the marginal land with limited nutrient supply, (ii) to select the superior entries in each population for nutrient efficiency to be used as parents in the next cycle and (iii) to identify the agronomic characters relate to yield (nutrient efficiency). Selection for nutrient efficiency was based on yield (ear dry weight) performance. Information of other agronomic characters related to yield may be beneficial for plant breeders as selection criteria in developing nutrient efficiency corn genotypes.

MATERIAL AND METHOD

The complex population as genetic material used in this study was developed in 2007 in marginal land at Agro Techno Park, located in Indralaya, South Sumatra. The soil in the experimental site is dominated by sand (66 %) with 4.9 pH, 20.4 g kg^{-1} organic matter, 2.1 g kg^{-1} total N, 6.89 mg kg^{-1} P Bray, 0.31, 0.42, 0.11, 0.42, 0.69 cmol kg^{-1} exchangeable K, Ca, Mg, Na, Al, respectively and 11.34 cation exchange capacity. The evaluation and selection of complex population was also conducted at Agro Techno Park in January to April 2008. The experimental design was randomized complete block design (RCB) with four replications. The treatment was the number of entries that grouped into six populations based on the female parent.

Seeds of each entry in the population were manually planted in a single - row 2-m plot with 10 plants per row (plot). Plants were fertilized with 90, 30, and 15 kg ha^{-1} Urea, SP-36, and KCl, respectively (30% of standard rate). Urea (30 kg ha^{-1}), SP-36, and KCl were applied at planting and the rest of Urea was applied at 4 weeks after planting (WAP).

Plant height was measured at 6 WAP and leaf chlorophyll was measured on the second top leaf using a chlorophyll meter at 7 WAP when most of the plants were at anthesis. The number of leaves above the ear and ear leaf area were measured at 10 WAP. Ear leaf area was measured non-destructively by using the formula [0.5875 x (ear leaf length x maximum ear leaf width) + 86.284] (Ismail, 2001). The sample numbers for growth characteristics were three plants for each entry.

Ears of three plants per entry were hand harvested at 13-14 WAP, air dried in a drying room for two weeks and weighted. Data on the following characters as the average of three plants were obtained (i) ear dry weight (g ear^{-1} at 130 g kg^{-1} moisture), (ii) ear length, and (iii) ear diameter. The selection for nutrient efficiency in this experiment was based on ear dry weight produced per plant (yield).

Some plants were infected with downy mildews (*Sclerospora maydis*). This had caused the loss of some entries in certain replication in the population. The data of ear dry weight for all entries in four replications were combined and presented as relative frequency distribution of each population.

RESULTS AND DISCUSSION

The plants in the entries of each population mostly produced an ear with weight more than 100 g ear^{-1} (Figure 1); 76 to 82 % of the total entries for Sukmaraga, Lamuru, and Srikandi Kuning populations, and 63 to 75% for Toray, Bayu, and Bisma populations. The mean of Sukmaraga population for ear dry weight was 132 g ear^{-1} plant^{-1} with the highest frequency (22%) at 140-159 g ear^{-1} plant^{-1} which was the best among six populations (Figure 1). This suggests that the plants in the entries of Sukmaraga population have used nutrient more efficiently than other populations. The superior entries selected to be used as parents in the next cycle were top 10 % of the total entries in each population with ear weight more than 150 g ear^{-1} plant^{-1} which was higher than population mean (Figure 1). The mean ear dry weight of population was 12 to 42 g greater than the mean of original parent previously planted at Agro Techno Park under limited nutrient supply (30 % of standard rate) (data not presented). This indicates the improvement in nutrient efficiency character.

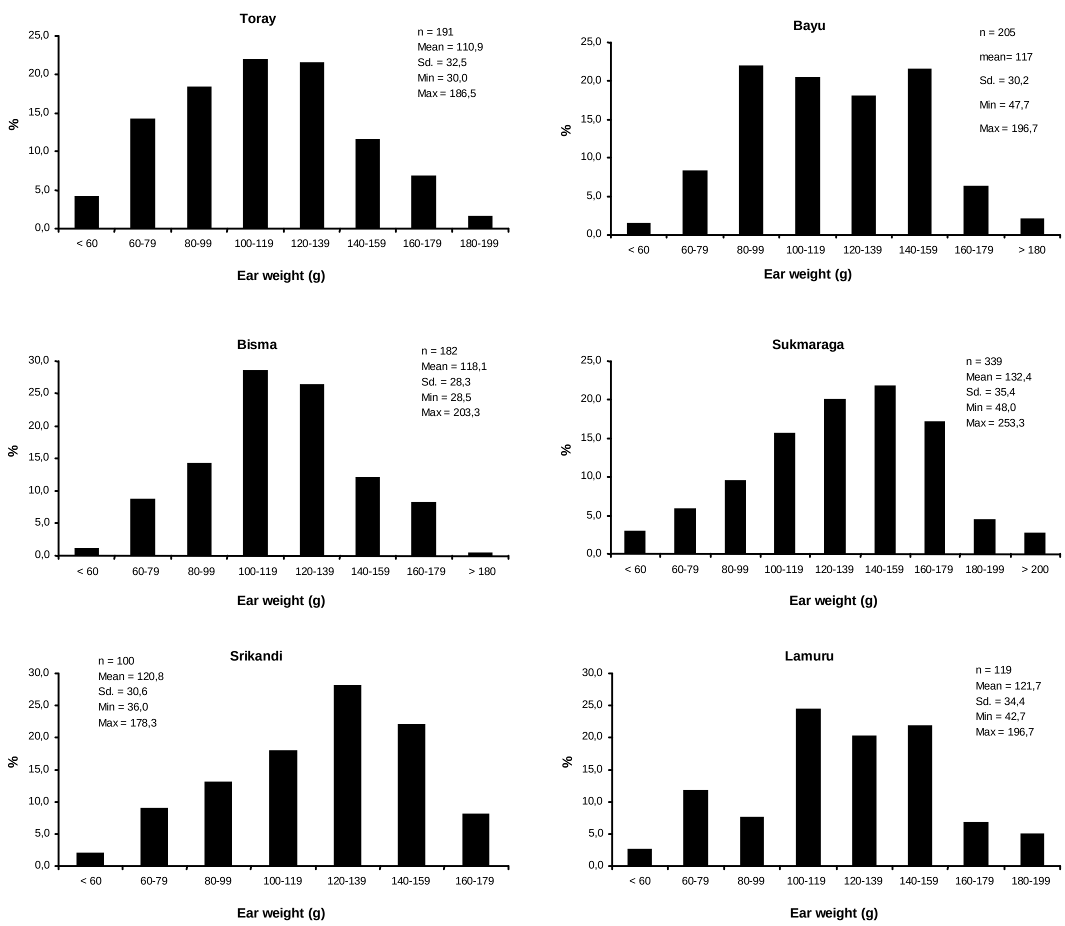

Figure 1. Ear weight (g/ear/plant) relative frequency distribution of complex population based on female parent in the evaluation and selection for nutrient efficiency at marginal land

The ear length varied from 7.2 to 18.3 and the ear diameter varied from 2.4 to 3.9 cm for all populations evaluated (Table 1). Generally, based on the mean data, Sukmaraga, Lamuru, and Srikandi Kuning populations had better ear characteristics (weight, length, and diameter) than Toray, Bisma, and Bayu populations with Sukmaraga populations as the best. Sukmaraga is the cultivar developed for tolerance to acid soil. Apparently, the character of female parent has contributed to the progeny performance in the population.

Table 1. Ear characteristics of complex population based on female parent in the evaluation and selection for nutrient efficiency at marginal land

Population	Number of entries	Ear length (cm)				Ear diameter (cm)			
		Mean	Sd.	Min	Max	Mean	Sd.	Min	Max
Toray-1	191	12.4	1.9	7.8	16.9	3.7	0.4	2.4	4.7
Bayu	205	12.9	1.8	8.9	17.6	3.8	0.3	3.0	5.4
Bisma	181	12.7	1.6	7.2	17.1	3.9	0.3	2.9	4.7
Sukmaraga	339	13.4	1.9	8.4	18.3	3.9	0.4	2.7	4.9
Srikandi Kuning	100	13.3	1.9	7.6	18.3	3.9	0.3	2.5	4.6
Lamuru	119	13.1	2.0	7.5	17.2	3.9	0.3	3.1	4.7

The selection for nutrient efficiency did not restrict the other characters such as plant height. The minimum plant height among six populations at 6 WAP was 64 cm (Bisma) and the maximum was 210 cm (Toray). The leaf chlorophyll (24 – 55) varied less than plant height. The Bisma population had the lowest mean for chlorophyll and plant height, while Sukmaraga population had the highest mean for chlorophyll and the second for plant height (Table 2).

Table 2. Plant height and leaf chlorophyll of complex population based on female parent in the evaluation and selection for nutrient efficiency at marginal land

Population	Number of entries	Plant height (cm)				Chlorophyll			
		Mean	Sd.	Min	Max	Mean	Sd.	Min	Max
Toray-1	191	136	25	76	210	40.5	5.2	28.4	51.5
Bayu	205	147	27	76	209	40.9	4.5	29.6	54.5
Bisma	181	125	21	64	195	38.9	4.6	28.3	49.8
Sukmaraga	339	143	29	69	209	41.4	4.8	24.0	52.8
Srikandi Kuning	100	128	23	83	175	40.1	4.5	29.0	49.9
Lamuru	119	133	26	74	195	40.0	5.5	28.3	51.5

The leaf number above the ear varied from 5 – 8 leaves and the ear leaf area varied from 290 – 700 cm2. The variation in leaf number was less than the variation in leaf area. Toray population had the lowest mean for leaf number and leaf area, whereas Sukmaraga population had the highest for both characters (Table 3). In general, Sukmaraga population had the best agronomic performance among six populations, suggests that this population had better nutrient efficiency.

Table 3. Number of leaves above the ear and ear leaf area of population based on female parent in the evaluation and selection for nutrient efficiency at marginal land

Population	Number of entries	Leaf number				Leaf area (cm^2)			
		Mean	Sd.	Min	Max	Mean	Sd.	Min	Max
Toray-1	191	6.1	0.5	5.0	7.7	446	71	294	618
Bayu	205	6.3	0.6	5.0	8.3	470	60	343	703
Bisma	181	6.4	0.5	5.3	8.0	481	62	326	604
Sukmaraga	339	6.6	0.6	5.0	8.3	494	66	307	697
Srikandi Kuning	100	6.3	0.6	5.0	8.0	479	72	313	681
Lamuru	119	6.3	0.6	5.0	7.7	478	62	347	603

The correlation coefficients (r) between the ear weight/plant (yield) and ear as well as growth characteristics were determined to identify these agronomic characters related to yield (nutrient efficiency). The ear weight had a significant positive correlation with ear length and ear diameter for all populations (Table 4). This indicates that the ear weight plant^{-1} tends to increase by increasing the size of the ear (ear length and ear diameter). Ear length is related to the number of seeds per row and ear diameter is related to the number of rows per ear. The ear primordial develops very early during the vegetative growth (Stevens *et al.*, 1986) and the maximum potential seeds per row on the ear are reached about a week before silking (Egli, 1998). This suggests that vegetative growth is important and corn plants with better vegetative growth tends to have better nutrient efficiency reflected by the weight of ear produced.

The important of vegetative growth is supported by the present of significant positive correlation between ear weight/plant and plant height at vegetative growth (6 WAP) (Table 4). This indicates that taller plants tend to produce ear with higher weight. Generally, taller plants have more new leaves formed at the top of the plants above the older ones. This favorable position enables the newer and younger leaves to intercept the light for photosynthesis more efficiently than the older leaves. This characteristic benefits the taller plants to intercept more sunlight than the shorter plants in a community (Brown, 1984). The plants of superior entries selected (weight > 150 g ear^{-1}) were taller than the average plants in each population (data not presented). This is supported by Kraja and Dudley (2000) who found that the elite corn hybrid (FR 1064 x LH 185) had higher grain yield (9.1 ton ha^{-1}) was taller (223.8 cm) than the mid - parent LH 185 value (yield 3.7 ton ha^{-1} and plant height 160 cm).

Table 4. Phenotype correlation coefficient between ear weight (g/ear/plant) and ear characteristics as well as plant growth characteristics in the evaluation and selection for nutrient efficiency at marginal land

	Correlation coefficient (r)					
	Sukmaraga	Srikandi	Toray	Bayu	Bisma	Lamuru
Ear Length	0.729**	0.559**	0.690**	0.618**	0.557**	0.678**
Ear Diameter	0.662**	0.495**	0.671**	0.517**	0.553**	0.601**
Plant Height	0.534**	0.630**	0.472**	0.503**	0.402**	0.458**
Leaf Chlorophyll	0.463**	0.447**	0.444**	0.274ns	0.282**	0.551**
Leaf Number	0.444**	0.452**	0.369**	0.376**	0.242**	0.447**
Leaf Area	0.610**	0.637**	0.616**	0.537**	0.439**	0.587**

** Significant at the 0.01 probability level   ns : non significant

Typically taller plants are more susceptible to lodging, so some breeders conducted the breeding program to reduce plant height. Johnson *et al.* (1986) successfully reduced the corn plant height from 282 cm to 179 cm through 15 cycles of recurrent selections, but the ear weight also decreased from 121.3 to 106.1 g plant^{-1}. According to Payne *et al.* (1986), selection against taller plants may have limited advancement in grain yield potential. Selection for nutrient efficiency did not restrict the other characters such as plant height.

The ear weight/plant also had significant positive correlation with numbers of leaves above the ear and the ear leaf area (Table 4). The data suggests that plants with higher numbers of leaves above the ear and higher ear leaf area tend to have higher ear weight plant^{-1}. The ear dry weight and seeds dry weight plant^{-1} are influenced by the supply of photosynthate from the leaves especially from the ear leaf (Edmeades *et al.*, 1979) and the leaves above the ear because the photosynthate is transported from the upper leaves especially the leaf closest to the ear through the phloem. Higher supply of photosynthate to the ear due to increased in leaf area had increased the yield of corn hybrid in short season areas (Hunter, 1980). Corn elite hybrid with higher numbers of leaves also had higher grain yield (Cross, 1990).

The ear weight plant^{-1} (yield) also significantly had positive correlation with leaf chlorophyll. This suggests that high chlorophyll content at the top leaves tend to increase the weight of ear produced. Chlorophyll is the primary pigment for photosynthesis and photosynthetic rate was significantly and linearly correlated with leaf chlorophyll measured by chlorophyll meter SPAD-502 (Ma, 1995).

All the characters evaluated significantly correlated with ear weight plant^{-1} (yield) for sample number $\geq$ 100. Plant height is the only character measured at vegetative growth (before anthesis) and its r value was quite high (0.402 to 0.534) just below the r value for ear leaf area (0.439 to 0.610). So, plant height may be used as selection criterion in early screening large numbers of corn entries or lines for nutrient efficiency character.

CONCLUSIONS

1. Sukmaraga population generally had the best agronomic performance under limited nutrient supply among six populations evaluated with the mean ear weight 132.4 g ear^{-1}; ear length 13.4 cm; ear diameter 3.9 cm; plant height 143 cm; chlorophyll 41.4; numbers of leaves above the ear 6.6; and ear leaf area 494 cm^2.
2. The superior entries selected were top 10 % of the total entries in each population with ear weight more than 150 g at 130 g kg^{-1} moisture.
3. All the characters evaluated related to yield (nutrient efficiency) but plant height is the only character measured before anthesis.

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REFERENCES

Atlin, G.N., K.J. Frey. 1990. Selecting oat lines for yield in low productivity environment. Crop Sci. 30:556-561.

Banziger, M., F.J. Betran, H.R. Lafitte. 1997. Efficiency of high-nitrogen selection environments for improving maize for low-nitrogen target environments. Crop Sci. 37:1103-1109.

Brown, R.H. 1984. Growth of the green plant. p. 153-174. *In* M.B. Tesar (*ed.*). Physiological basis of crop growth and development. ASA, CSSA, Madison, Wisconsin, USA.

Cross, H.Z. 1990. Selection for rapid leaf expansion. Crop Sci. 30:1029-1032.

Djafar, Z.R., E.S. Halimi. 1998. Upaya peningkatan produksi jagung di Sumatera Selatan. J. Tanaman Tropika. 1:128-134.

Edmeades, G.O., N.A. Fairey, T.B. Daynard. 1979. Influence of plant density on the distribution of 14C-labeled assimilates in maize at flowering. Can. J. Plant Sci. 59:577-584.

Egli, D.B. 1998. Seed Biology and the Yield of Grain Crops. Department of Agronomy, University of Kentucky.

Fehr, W.R. 1987. Principles of Cultivar Development. Vol I. Theory and technique. Iowa State University. Macmillan Inc. New York.

Granados, G., S. Pandey, H. Ceballos. 1993. Response to selection for tolerance to acid soils in tropical maize population. Crop Sci. 33:936-940.

Halimi, E.S. 1999. Seleksi genotype tanaman jagung yang memiliki karakteristik kadar protein tinggi. J. Tanaman Tropika 2:59-67.

Horst. 2007. Nitrogen uptake and utilization in contrasting nitrogen tropical maize hybrids. Crop Sci. 47:519-528.

Hunter, R.B. 1980. Increased leaf area (source) and yield of maize in short season areas. Crop Sci. 20:571-574.

Ismail, A.Z. 2001. Studi hasil tanaman tebaran radiasi surya dan karakteristik gulma pada tumpang sari tanaman jagung varietas hibrida C-7 dan cabai varietas Cemeti-1 pada beberapa kerapatan populasi. Tesis. Program Magister Ilmu Tanaman Program Pasca Sarjana Universitas Sriwijaya, Palembang.

Kraja, A., J.W. Dudley. 2000. Identification of tropical and temperate maize populations having favorable alleles for yield and other photosynthetic traits. Crop Sci. 40:941-947.

Ma, B.L., M.J. Morrison, H.D. Voldeng. 1995. Leaf greenness and photosynthetic rates in soybean. Crop Sci. 35:1411-1414.

Marschner, H. 1986. Mineral Nutrition of Higher plants. Academic Press Inc. London.

Payne, T.S., D.D. Stuthman, R.L. McGraw, P.P. Bregitzer. 1986. Physiological changes associated with three cycles of recurrent selection for grain yield improvement in oats. Crop Sci. 26:734-736.

Presterl, T., G.Seitz, M. Lanbeck, E.M. Thiemt, W. Schmidt, H.H. Geiger. 2003. Improving nitrogen-use efficiency in European maize. Estimation of quantitative genetic parameters. Crop Sci. 43:1259-1265.

Stevens, S.J., E.J. Stevens, K.W. Lee., A.D. Flowerday, C.O. Gardner. 1986. Organogenesis of the staminate and pistillate inflorescences of crop and dent corns: relationship to leaf stages. Crop Sci. 26:712-718.

Streeter, J.G., A.L. Barta. 1984. Nitrogen and minerals, p. 175-200. ***In*** M.B. Tesar (*ed.*) Physiological basis of crop growth and development, ASA, CSSA, Madison, Wisconsin, USA.

Sutoro, A. Bari, Subandi, S. Yahya. 2006. Parameter genetik jagung populasi Bisma pada pemupukan berbeda I. Ragam aditif- dominant bobot biji jagung. J. Agrobiogen 2:60-67.

Worku, M., M. Banziger, G.S.auf'm Early, D. Friesen, A.O. Diallo, W.J. Horst. 2007. Nitrogen uptake and utilization in contrasting nitrogen efficient tropical maize hybrids. Crop Sci. 47:519-528.

Yasin, H.G.M. 2005. Perbaikan ketahanan populasi jagung terhadap lingkungan sulfat masam dan kekeringan. Makalah seminar jagung. Balai Penelitian Serealia dan Jagung. Badan Litbang Pertanian. Maros, Sulawesi Selatan.