Genetic Estimation and Correlation between Yield and Some Quantitative Characters of Accessions of the Pineapple (*Ananas comosus* L. Merr) Germplasm Collection at the Center for Tropical Fruit Studies Bogor Agricultural University (IPB)

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Abstract

Information on genetic variabilities, heritabilities and correlations between quantitative characters and yield are important parameters for supporting selection programs. The objectives of this research were to estimate these factors on several accessions of pineapples. Field experiments were conducted at the Pasir Kuda Experiment Station, from October 2004 to November 2006 with a completely randomized block design, comprising 26 treatments (accessions) and two replications. The results demonstrated that number of leaves, length of leaf, number of hapas, days to flowering, days to harvesting, peduncle diameter, fruit length, fruit diameter, number of spirals, flesh thickness, total acid, and vitamin C concentration had wide genotypic and phenotypic variabilities and high heritabilities. Plant height, width of leaf, days to harvesting, peduncle diameter, fruit length, number of spiral, fruit diameter, flesh thickness, core diameter, and vitamin C were positively and significantly correlated with fruit weight. Plant height, canopy diameter, number of spirals, fruit diameter, flesh thickness, core diameter, and total acid had positive direct effects on fruit weight. The indirect effects on fruit weight via fruit diameter was shown by the number of spirals and flesh thickness; via number of spiral showed by fruit diameter and core diameter; via flesh thickness shown by number of spirals, fruit diameter and core diameter shown by fruit diameter, flesh thickness, and core diameter. The number of spiral and flesh thickness should be used as selection criteria for fruit weight improvement.

INTRODUCTION

The pineapple (*Ananas comosus* (L.) Merr.) is one of the members of the family *Bromeliaceae* (monocots) and consists of 2,000 species. In the international world trade, pineapple cultivars are grouped into four main classes namely: 'Smooth Cayenne', 'Red Spanish', 'Queen' and 'Abacaxi' (Py et al., 1987).

The low production of pineapples in Indonesia is caused by low productivity which is around 10 t per ha, while that in Thailand and The Philippines reaches 23-35 t per ha (FAOSTAT, 2007). To increase productivity, some attempts have previously been made, including identifying the best genotypes from available pineapple genotypes. Therefore, more intensive research and development particularly in pineapple plant breeding, is required in Indonesia.

The priorities of breeding programs are to obtain pineapples that are fast growing, spineless, and high yielding. The fruit should be cylindrical with uniform maturity, have more yellow fruit flesh, and have low calcium oxalate content. In addition, breeding is aimed to obtain genotypes resistant to a wide range of pest and diseases while, at the same time, complying with fresh fruit and processed fruit standards (Py et al., 1987; Boertjes and van Harten, 1988).

To improve the genotypes of pineapples, germplasm with wide genotypic characters are needed. High genetic diversity has a higher probability of providing

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progeny with superior characters than where narrow genetic variability is used. The selected characters should have high heritability, because those characters can easily be transferred and selection can be done in earlier generations (Fehr, 1987).

To improve the genetics of the pineapples, besides characterization and identification, information on the causal relationships between yield and yield components are needed. These can be analysed with correlation analysis. The correlation coefficient is useful to determine the relationship between one character and others. However, correlation analysis has several disadvantages because it might lead to inaccurate estimation due to interactions between yield components (colinearity). These disadvantages, according to Singh and Chaudhary (1979) and Gazpersz (1995), can be overcome with path analysis. According to Mohammadi et al. (2003), by using path-coefficient analysis we can decide the relative contribution of the yield components on the yields, either directly or indirectly.

The use of path analysis will enable identification of the direct and indirect influences among the independent and dependent variables. Selection for the characters that have direct influence on yield can more easily be applied by breeders and form the bases for selection in plant breeding programs.

MATERIAL AND METHOD

The genetic material used comprised 26 accessions of pineapples from PKBT IPB which consisted of 'Smooth Cayenne', 'Cayenne' and 'Queen' types from several areas in Java, Sumatera, and Kalimantan. This research used grouped randomized design with 26 treatments (26 accession numbers) and two replications.

The characters scored were both vegetative and generative. Scoring techniques for both followed the "Descriptors for pineapple" by the International Board for Plant Genetic Resources (IBPGR, 1991).

The estimation of the genetic parameters namely the genetic and phenotypic variation, genotypic variation coefficient (GVC), and phenotypic variation coefficient (PVC) with the results of ANOVA were used to assess performance (Singh and Chaudary, 1979). Furthermore, the estimation value of wide heritability (h_{bs}^2) was determined by the formula = σ_g^2 / σ_p^2; with σ_g^2 and σ_p^2, each being the genetic and phenotypic variability, respectively. Heritability value criteria were based on McWhirter (1979).

Based on the expected mean product value, both characters of the genotype and phenotype variability analysis, such as character n could result in formulas to estimate phenotypic covariance ($Cov_{p\text{-}mn}$) and genetic covariance ($Cov_{g\text{-}mn}$) as follows: $Cov_{p.mn}=MP_{g.mn}/r$; $Cov_{g.mn}=MP_{g.mn}-MP_{e..mn}/r$. The correlation coefficient is determined by using the simple correlation formula following Singh and Chaudhary (1979). The significance of the correlation coefficient was tested by comparing the correlation coefficient with the table of Snedecor (1946) in Steel and Torrie (1995). To determine the characters which significantly influenced fruit weight, the backward elimination procedure was applied after Draper and Smith (1992). To determine the direct and indirect influences of the selected characters of the multiple regression, a path analysis was done. The interpretation of direct influence strength of the characters followed Singh and Chaudhary (1979).

RESULTS AND DISCUSSION

Number of leaves, length of leaf, number of leaves, number of hapas, number of suckers, days to flowering, days to harvesting, peduncle diameter, fruit weight, fruit length, number of spirals, fruit diameter, flesh thickness, skin thickness, total acid, and vitamin C concentration all had wide variability, either genetically or phenotypically (Table 1). The characters with narrow genetic and wide phenotypic variability were plant height, canopy diameter, leaf width, slip number, peduncle length, petal weight, fruit diameter, core thickness, eye depth, and total soluble solids concentration (TSS). Similar results were reported by Hadiati (2002), in her research on 24 pineapple accessions, where the leaf length, seedling number, peduncle length, fruit weight, spiral number, fruit diameter, fruit length, flesh thickness, core diameter, eye depth, TSS, acid acid, and vitamin C had wide genetic and phenotypic variability.

Wide genetic variability suggests that the tested germplasm had different genetic variability. The selection of characters with wide genetic and phenotypic variability, can bring a lot of genetic advantages, and increases the possibility of finding good genotypes by selection. In contrast, characters with narrow genetic variability, selection will not be as successful although the phenotypic variability is wide because the phenotypic variability is caused by environmental factors. Furthermore, selection will be more difficult to do with narrow genetic and wide phenotypic characters. Fehr (1987) stated that selection effectiveness is highly influenced by genetic variability. According to Allard (1960), wide genetic variability suggests that the genetic influence is more dominant than the environmental influence.

The data in Table 1 indicate that heritability estimate values, in the wider sense, for the number of leaves, length of leaf, number of hapas, days to flowering, days to harvesting, peduncle diameter, fruit weight, fruit length, spiral number, fruit diameter, flesh thickness, total acid, vitamin C, are relatively high. Heritability was considered to be medium in: canopy diameter, width of leaf, number of shoots, number of suckers, peduncle length, crown weight, fruit diameter, core thickness, eye depth, skin thickness, and TSS. The heredity of plant height and number of slips was considered to be low.

The high heritability value of a character is paralleled by wide genetic variability, suggesting that the appearance of those characters is more influenced by genetic factors. Hence, selection in such populations will be more efficient and more effective. Characters with medium heritability value and narrow genetic variability suggests that selection for those characters will be less effective.

Fruit weight is one of the characters which determines pineapple fruit quality. The hereditary of fruit weight is complex and could involve a number of characters which need to be considered in selections to improve the fruit weight. To determine the importance of such characters information about correlation between characters and the improved progeny are needed. The correlation coefficient measures the degree of correlation between two or more characters. Knowledge of the correlation between characters is useful to improve the correlation response in indirect selection.

In Table 2, genotypic and phenotypic correlation coefficients between plant height, canopy diameter, width of leaf, days to harvesting, peduncle diameter, fruit length, number of spirals, flesh thickness, core thickness, and vitamin C concentration on fruit weight positively correlated and was very significant (P=0.01) and fruit diameter was positively and significantly correlated with fruit weight (P=0.05). Thus, an increase of any of those characters will increase fruit weight. The coefficient of leaf length, number of slips, number of hapas, number of shoots, number of suckers, crown weight, eye depth, TSS, and total acid significantly negatively correlated (P=0.01) with fruit weight. Thus, an increase in any of those characters will decrease fruit weight. D'Eeckenbrugge and Leal (2003) stated that the increase of fruit size of *Ananas comosus* was the result of the increase of the other organ sizes, namely width of leaf, length and diameter of peduncles.

The relative roles of each character on fruit weight can be measured by both direct and indirect influences. The values of those effects on plant height, harvest age, spiral number, fruit diameter, flesh thickness, core thickness, eye depth, and acid concentration on fruit weight can be seen in Table 3 where the most direct effects were given by fruit diameter (P_4=0,335), followed by flesh thickness (P_5=0,277), spiral number (P_3=0,273) and plant height (P_1=0,202). The indirect effects of fruit diameter, flesh thickness, and spiral number were also high. This suggests that those three characters are the three main components that influenced fruit weight.

The results of the path analysis showed that quantitative characters cannot be used as criteria for selection. According to Singh and Chaudhary (1985), a character can be used as the best selection criterion if correlation and direct effects are significant. In this study, core thickness, eye depth, and total acid had significant correlation coefficients with fruit weight, but the direct effects of those characters were not significant. Thus those characters do not meet the requirement for selection criteria. Furthermore, Singh and Chaudhary (1985) suggest that if those characters are used as selection criteria, researchers have to take into account the presence of other components which support the correlation to become positive. In this case, besides fruit diameter, flesh thickness, number of spirals and core thickness need to be employed as selection criteria. However, this character is not used as the selection criteria due to the absence of indirect effects through core diameter characteristics. Based on the result of path analysis, fruit diameter, flesh thickness, number of spirals, and plant height have to be considered together as selection criteria.

CONCLUSIONS

The results of this study demonstrated that : (1) wide genetic variability and high heritability was observed in almost all characters studied except plant height, canopy diameter, width of leaves, crown weight, fruit diameter, core diameter, eye depth, and TSS showed narrow genetic diversity which showed low to medium heritability; (2) positive genotypic correlation coefficients were significant for fruit weight showed by plant height, canopy diameter, width of leaves, harvest age, peduncle diameter, fruit length, number of spirals, fruit diameter, flesh thickness, and vitamin C; (3) direct effects on fruit weight were from the number of spirals, fruit diameter, and flesh thickness. The indirect effects on fruit weight were days to harvesting and eye depth; and (4) number of spirals, flesh thickness and fruit diameter should all be used together as selection criteria to improve fruit weight in pineapple.

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Tables

Table 1. Genotype and phenotype variability and heritability of 26 pineapple accessions.

No	Characters	σ genotype and criteria	σ phenotype and criteria	Heritability (h^2_{bs})
1	Plant height	0.019 ± 0.020 (N)	0.105 ± 0.017(W)	0.178
2	Canopy diameter	0.014 ± 0.012 (N)	0.060 ± 0.010(W)	0.237
3	Number of leaves	0.027 ± 0.011 (W)	0.049 ± 0.010(W)	0.543
4	Width of leaf	0.168 ± 0.147 (N)	0.747 ± 0.125(W)	0.225
5	Length of leaf	0.017 ± 0.006 (W)	0.028 ± 0.006(W)	0.596
6	Number of slips	0.014 ± 0.022 (N)	5.090 ± 0.819(W)	0.120
7	Number of hapas	0.014 ± 0.006 (W)	0.025 ± 0.005(W)	0.524
8	Number of shoots	0.036 ± 0.102 (N)	0.102 ± 0.019(W)	0.342
9	Number of suckers	0.067 ± 0.031 (W)	0.146 ± 0.029(W)	0.456
10	Days to flowering	0.333 ± 0.099 (W)	0.391 ± 0.099(W)	0.852
11	Days to harvesting	0.482 ± 0.139 (W)	0.539 ± 0.139(W)	0.894
12	Peduncle length	5.301 ± 3.217 (N)	15.853 ± 2.879(W)	0.334
13	Peduncle diameter	0.324 ± 0.121 (W)	0.537 ± 0.117(W)	0.603
14	Crown weigth	0.006 ± 0.004 (N)	0.021 ± 0.004(W)	0.295
15	Fruit weigth	0.276 ± 0.115 (W)	0.527 ± 0.109(W)	0.523
16	Fruit length	16.250 ± 6.026 (W)	26.764 ± 5.853(W)	0.607
17	Number of spiral	3.735 ± 1.585 (W)	7.342 ± 1.507(W)	0.509
18	Fruit diameter	1.106 ± 0.086 (W)	4.364 ± 0.744(W)	0.523
19	Flesh thickness	0.440 ± 0.136 (W)	0.552 ± 0.135(W)	0.799
20	Core diameter	0.126 ± 0.077 (N)	0.380 ± 0.069(W)	0.333
21	Eyes depth	4.182 ± 2.366 (N)	11.562 ± 2.143(W)	0.362
22	Skin thickness	0.011 ± 0.004 (W)	0.049 ± 0.226(W)	0.262
23	TSS (°Brix)	1.473 ± 0.871 (N)	4.278 ± 0.783(W)	0.344
24	Total acid	0.046 ± 0.017 (W)	0.077 ± 0.017(W)	0.596
25	Vitamin C	0.033 ± 0.009 (W)	0.036 ± 0.009(W)	0.909

N = narrow; W = wide.

Table 2. Genotypes (r_g) and phenotypes correlation coefficients (r_p) between fruit weight and some quantitative characters of pineapples.

No	Characters	Fruit weight (gram)	
		r_g	r_p
1	Plant height	0.485**	0.223**
2	Canopy diameter	0.171*	0.145
3	Number of leaves	0.110	0.070
4	Width of leaf	0.361**	0.209**
5	Length of leaf	-0.071	-0.052
6	Number of slips	-0.341**	0.072
7	Number of hapas	-0.341**	0.143
8	Number of shoots	-0.343**	0.094
9	Number of suckers	-0.323**	0.098
10	Days to flowering	0.111	0.184**
11	Days to harvesting	0.304**	0.168**
12	Peduncle length	0.131	0.032
13	Peduncle diameter	0.892**	0.256**
14	Crown weigth	-0.054	0.150
15	Fruit length	0.754**	0.795**
16	Number of spiral	0.341**	0.305**
17	Fruit diameter	0.613**	0.362**
18	Flesh thickness	0.991**	0.302**
19	Core diameter	0.790**	0.332**
20	Eyes depth	-0.352**	-0.085
21	Skin thickness	0.130	0.088
22	TSS (°Brix)	-0.490**	-0.099
23	Total acid	-0.205**	-0.046
24	Vitamin C	0.408**	0.266**

** ,* = significantly correlated on P=0,01 and P=0,05.

Table 3. Direct and indirect effects of some quantitative characters on fruit weight of pineapple germplasm in PKBT.

Character	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9 (Y)
X_1	**0.202**	-0.013	0.051	0.110	0.040	0.006	-0.036	-0.016	0.345
X_2	0.021	**-0.123**	0.030	0.006	-0.003	-0.025	0.016	0.027	-0.051
X_3	0.038	-0.014	**0.273**	0.164	0.105	0.083	-0.015	-0.009	0.624
X_4	0.066	-0.002	0.134	**0.335**	0.161	0.066	0.018	-0.007	0.771
X_5	0.029	0.001	0.103	0.195	**0.277**	0.099	0.020	-0.034	0.690
X_6	0.007	0.018	0.133	0.129	0.161	**0.170**	-0.002	-0.021	0.595
X7	0.043	0.012	0.025	-0.036	-0.032	0.002	-0.171	0.001	-0.157
X8	-0.024	-0.025	0.018	-0.017	0.001	-0.027	-0.001	0.132	0.050

X_1= plant height, X_2= days to harvesting, X_3= number of spirals, X_4= fruit diameter, X_5= flesh thickness, X_6= core thickness, X_7=eye dept, and X_8= total acid. Diagonal (bold) = direct effect; Horizontal = indirect effect.