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Correlation and Path Analysis of Palm Oil Yield Components in Oil Palm (*Elaeis guineensis* Jacq.)

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ABSTRACT

This research aimed to evaluate the correlation coefficients, direct effects and indirect effects of agronomic characters on palm oil yield components for selection and improvement of next-generation oil palm populations. The seven crosses of oil palms aged 4 yr were investigated at three locations in southern Thailand. The experiment at each location was designed as a completely randomized design with five replications. Data on bunch yield, yield components and bunch components were collected from July 2009 to June 2010. Combined analysis was used to estimate the variance and covariance for the calculation of correlation coefficient and path coefficient values. The results showed that the bunch yield, single weight, fresh mesocarp per fruit and fruit per bunch had positive genotypic and phenotypic correlation coefficient values with regard to palm oil yield (1.03, 0.93, 1.70, 0.13 and 0.85, 0.56, 0.32, 0.34, respectively). The path analysis indicated that the bunch yield, fresh mesocarp per fruit and fruit per bunch had a positive direct effect on both the genotype and phenotype of palm oil yield (1.32, 0.68, 0.27 and 0.94, 0.20, 0.31, respectively). Although, the single weight had a positive correlation coefficient value for both genotype and phenotype, it had a negative direct genotypic and phenotypic effect on palm oil yield. Therefore, palm oil yield improvement should be considered especially in terms of the bunch yield, fresh mesocarp per fruit and fruit per bunch, because these characters had high, positive direct genotypic and phenotypic effects on palm oil yield.
Keywords: correlation, path analysis, oil yield, oil palm

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) can produce a greater oil yield than other oil plants (Corley and Tinker, 2003). Its oil is used by various consumers (Eksomtramage, 2010a). In Thailand, oil palm demand has been increasing continuously since 2006, but the domestic production of palm oil inside country has been balanced with palm oil demand; however, climatic variability may be causing the bunch yield and palm oil yield to decline (Bureau of Agricultural Economics Research, 2012). To avoid the risk of insufficient palm oil, it is essential to increase palm oil yield to correspond with consumer's demand and storage requirements. One of the many methods available is oil palm breeding to augment oil yield.

Palm oil yield is involved with many agronomic characters; moreover, environmental influences on this phenotype are considerable and so heritability is low (Rafii *et al*., 2002; Noh *et al*., 2010). It is very difficult to improve palm

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oil yield directly. Consequently, palm oil yield enhancement should consider other agronomic characters that relate to oil yield traits.

The correlation coefficient is a parameter that is used to evaluate the relation between traits. The range of the correlation coefficient is between -1 and 1. A positive correlation between traits indicates that if one character increases, the other character increases too. On the other hand (a negative correlation), if one character increases, the other character will decrease. The genotypic correlation coefficient is another parameter that is used by breeders and is applied to pleiotropic genes and linkage genes. The correlation coefficient value associated with pleiotropic genes is important because it is the net effect of genes controlling traits that are correlated. Furthermore, the effect of pleiotropic genes can be obtained every generation. This contrasts with linkage genes which are expressed especially in early generations (Dobholkar, 1992). To improve plants, the correlation coefficient is essential to determine the criteria of selection (Falconer, 1981).

Since the value of the correlation coefficient between characters is the sum of the effects that influence the character of interest, this value has a combined indirect effect. It is necessary to subtract the indirect effect from the total effect. The remaining value is the direct effect that describes the direct relation of one trait to the trait of interest. These processes are analyzed by path analysis which is essential to plant breeders because it helps breeders to choose correctly the important and related traits to the trait of interest.

The objective of this research was the evaluation of the correlation coefficients, direct effects and indirect effects of agronomic characters on the palm oil yield of seven oil palm crosses. These data can be applied to select and improve oil palm populations in future generations.

MATERIALS AND METHODS

The seven oil palm crosses were from a single cross from Dura (D) × Pisifera (P) planted at three locations in southern Thailand—Huea Khlong district, Krabi province, and Ronphibon district and Cha Uat district, Nakhon Si Thammarat province. At each location, the experiment was set up as a completely randomized design with five replications (that is, five oil palm trees). The bunch yield, yield components and bunch components of oil palm crosses aged 4 yr were collected in July 2009 –June 2010 by the method of Blaak *et al.*(1963) as cited in Corley and Tinker (2003). Finally, all data were analyzed by combined analysis to estimate the variance and covariance for calculation of the correlation coefficient value and path coefficient value of the genotype and phenotype.

To separate the variance and covariance components of combined analysis (Table 1), the variance and covariance components were substituted in Equations 1 and 2 to calculate the correlation coefficient value.

$$r_g = \frac{\sigma_{xy(g)}}{\sqrt{\sigma^2_{x(g)}\ \sigma^2_{y(g)}}} \quad (1)$$

$$r_p = \frac{\sigma_{xyp}}{\sqrt{\sigma^2_{x(p)}\ \sigma^2_{y(p)}}} \quad (2)$$

where r_g is the genotypic correlation coefficient value and r_p is the phenotypic correlation coefficient value

The significance of the correlation coefficient value can be tested by comparison with an r table using the degrees of freedom being n-2.

The correlation coefficient value was used to in the path analysis to calculate the direct and indirect effects of other traits on the trait of interest (Arnhold *et al.*, 2006). Singh and Chaudhary (1979) explained path analysis method using Equation 3 as follows:

From the correlation coefficient value

$$r_p = \frac{\sigma_{xyp}}{\sqrt{\sigma^2_{x(p)}\ \sigma^2_{y(p)}}} \quad (3)$$

The path coefficient value can be calculated from

$$a = \frac{\sigma_{x1}}{\sigma_Y}$$

Likewise

$$b = \frac{\sigma_{x2}}{\sigma_Y}$$

and so on. Then, the path coefficient values (a, b, c,…) can be substituted in the simultaneous equation r (x_1,Y) = a + r(x1 , x2)b + r(x1 , x3) c …

RESULTS AND DISCUSSION

Average agronomic characters

Tables 2 and 3 show that the crosses did not affect the agronomic trait averages, so the different crosses did not influence the traits. On the other hand, location and the interaction between locations with crosses affected the average of agronomic traits significantly at both the $P \leq 0.05$ and $P \leq 0.01$ levels. Consequently, different factors would influence the differences in traits.

Correlation

The bunch yield, single weight, fresh mesocarp per fruit and fruit per bunch had positive

Table 1 Variance and covariance component of combined analysis.

Source of Variance	df	Expected mean square		
		X	Y	XY
Location (L)	l–1	$\sigma^2_{x(e)}+r\sigma^2_{x(lg)}+rv\sigma^2_{x(l)}$	$\sigma^2_{y(e)}+r\sigma^2_{y(lg)}+rv\sigma^2_{y(l)}$	$\sigma_{xy(e)}+r\sigma_{xy(lg)}+rv\sigma_{xy(l)}$
Variety (V)	v–1	$\sigma^2_{x(e)}+r\sigma^2_{x(lg)}+rl\sigma^2_{x(g)}$	$\sigma^2_{y(e)}+r\sigma^2_{y(lg)}+rl\sigma^2_{y(g)}$	$\sigma_{xy(e)}+r\sigma_{xy(lg)}+rl\sigma_{xy(g)}$
L×V	(l–1)(v–1)	$\sigma^2_{x(e)}+r\sigma^2_{x(lg)}$	$\sigma^2_{y(e)}+r\sigma^2_{y(lg)}$	$\sigma_{xy(e)}+r\sigma_{xy(lg)}$
Error	l(v–1)	$\sigma^2_{x(e)}$	$\sigma^2_{y(e)}$	$\sigma_{xy(e)}$
Total	lv–1			

df = Degrees of freedom, l = Number of locations, v = Number of varieties.

Table 2 Agronomic characters of palm oil yield components.

Cross	Oil yield	Yield	NB	SW	DMFM	FB	FMF	ODM	OB
501	8.10	38.61	16.47	2.38	69.02	54.76	74.64	70.50	19.93
506	7.81	36.1	14.00	2.68	67.59	57.22	78.19	73.91	21.87
512	12.11	55.23	16.60	3.22	68.29	56.18	76.26	73.15	21.32
514	7.78	40.19	14.00	2.85	65.36	59.17	70.56	71.86	19.61
521	6.92	33.51	13.53	2.69	65.16	57.00	71.37	75.19	19.89
523	8.08	38.63	13.07	3.11	66.34	59.15	73.11	74.16	21.09
530	5.67	27.87	13.40	2.28	66.21	53.91	72.56	75.79	19.89
Mean	8.07	38.59	14.44	2.74	66.85	56.77	73.81	73.51	20.51

OY = Oil yield, NB = Number of bunch, ODM = Oil per dry mesocarp, Y = Bunch yield, FMF = Fresh mesocarp per fruit, FB = Fruit / Bunch, SW = Single weight, DMFM = Dry mesocarp per fresh mesocarp, OB = Oil per bunch.

genotypic and phenotypic correlation coefficient values for palm oil yield (1.03, 0.93, 1.70, 0.13 and 0.85, 0.56, 0.32, 0.34, respectively) as shown in Table 4. Clearly, if the bunch yield, single weight, fresh mesocarp per fruit and fruit per bunch were improved, the oil yield might be increased. In particular, the bunch yield had a high positive phenotypic correlation and so is an important trait for palm oil yield. Kushairi *et al*. (1999) and Okoye *et al*. (2009) reported that the bunch yield had a significant correlation with palm oil yield. The fresh mesocarp per fruit was another character that was important; it was also positively correlated with palm oil yield (Table 4).

Path analysis

From the genotypic path analysis of the agronomic characters affecting palm oil yield, it was clear that the bunch yield, fresh mesocarp per fruit and fruit per bunch had a great direct effect on palm oil yield (1.32, 0.68 and 0.27, respectively). In addition, the genotypic correlation of both traits was also high. On the other hand, single weight had a negative genotypic path coefficient value but it had a positive genotypic correlation coefficient value on palm oil yield due to the single weight character having a positive indirect effect on palm oil yield through other traits, especially the bunch yield (Table 5).

Table 3 Analysis of variance of agronomic characters of palm oil yield components.

SOV	df	Mean square								
		OY	BY	SW	NB	FMF	DMFM	ODM	FB	OB
Cross (C)	6	58.99^{ns}	1066.34^{ns}	1.81^{ns}	32.38^{ns}	111.08^{ns}	32.77^{ns}	51.29^{ns}	60.61^{ns}	11.94^{ns}
Location (L)	2	400.95**	6731.34**	15.48**	909.07**	1214.11**	1289.42**	109.28**	371.14**	251.05**
C×L	12	55.75**	972.18**	0.96**	40.66**	45.05**	82.49**	18.93^{ns}	38.03^{ns}	22.35*
error	84	7.26	111.38	0.30	8.28	13.82	32.37	11.38	46.74	10.98

^{ns} = No significant difference, * = Significant difference at $P \leq 0.05$, ** = Significant difference at $P \leq 0.01$.

OY = Oil yield, NB = Number of bunch, ODM = Oil per dry mesocarp, Y = Bunch yield, FMF = Fresh mesocarp per fruit, FB = Fruit / Bunch, SW = Single weight, DMFM = Dry mesocarp per fresh mesocarp, OB = Oil per bunch.

Table 4 Genotypic correlation (upper slope) and phenotypic correlation (lower slope)

	OY	Y	SW	NB	FMF	DMFM	ODM	FB	OB
OY		1.03	0.93	N/A	1.70	N/A	-4.05	0.13	N/A
Y	0.85**		0.93	N/A	1.09	N/A	-3.25	0.88	N/A
SW	0.56**	0.71 **		N/A	0.25	N/A	-0.52	1.12	N/A
NB	0.38**	0.40 **	-0.27 **		N/A	N/A	N/A	N/A	N/A
FMF	0.32 **	0.17 ^{ns}	0.13 ^{ns}	0.00 ^{ns}		N/A	-0.29	-0.70	N/A
DMFM	0.30 **	0.10 ^{ns}	0.07 ^{ns}	0.02 ^{ns}	0.28 **		N/A	N/A	N/A
ODM	-0.24 *	-0.47 **	-0.31 **	-0.22 *	-0.04 ^{ns}	0.02 ^{ns}		-0.38	N/A
FB	0.34 **	0.05 ^{ns}	0.05 ^{ns}	-0.01 ^{ns}	-0.05 ^{ns}	-0.25 **	0.03 ^{ns}		N/A
OB	0.46 **	-0.02 ^{ns}	0.00 ^{ns}	-0.03 ^{ns}	0.39 **	0.36 **	0.31 **	0.66 **	

N/A = Not available because genetic variation = 0.

^{ns} = No significant difference, * = Significant difference at $P \leq 0.05$, ** = Significant difference at $P \leq 0.01$.

OY = Oil yield, NB = Number of bunch, ODM = Oil per dry mesocarp, Y = Bunch yield, FMF = Fresh mesocarp per fruit, FB = Fruit / Bunch, SW = Single weight, DMFM = Dry mesocarp per fresh mesocarp, OB = Oil per bunch.

Table 6 shows that the bunch yield, fresh mesocarp per fruit and fruit per bunch had high direct phenotypic effects on palm oil yield (0.94, 0.20 and 0.31, respectively). Correspondingly, their phenotypic correlation coefficient values were quite high. According to Eksomtramage (2010b), the bunch yield and fresh mesocarp per fruit had a direct phenotypic effect on palm oil yield. Conversely, single weight had a negative phenotypic path coefficient value but its phenotypic correlation coefficient value was negative due to the single weight character which was expressed mostly through the positive indirect effect on the bunch yield character.

CONCLUSION

The evaluation correlation coefficient of agronomic characters of palm oil yield showed that the bunch yield, single weight, fresh mesocarp per fruit and fruit per bunch had positive genotypic and phenotypic correlation coefficient values for oil yield. The path analysis indicated that the bunch yield, fresh mesocarp per fruit and fruit per bunch had positive genotypic and phenotypic direct effects on palm oil yield. Thus, the bunch yield, fresh mesocarp per fruit and fruit per bunch should be considered when selecting for improvement in palm oil characters. While the single weight had positive genotypic and phenotypic correlation coefficient values, it had a negative genotypic and phenotypic direct effect. However, the single weight character had a high positive genotypic and phenotypic indirect effect through the bunch yield character.

Table 5 Genotypic path analysis of agronomic characters of palm oil yield.

Variable	Direct and indirect effect					r
	Y	SW	FMF	ODM	FB	
Y	<u>1.32</u>	-0.63	0.74	-0.64	0.24	1.03
SW	1.23	<u>-0.67</u>	0.17	-0.10	0.31	0.93
FMF	1.44	-0.17	<u>0.68</u>	-0.06	-0.19	1.70
ODM	-4.30	0.35	-0.20	<u>0.20</u>	-0.10	-4.05
FB	1.16	-0.76	-0.47	-0.08	<u>0.27</u>	0.13

The underlined numbers show a direct effect while numbers not underlined show an indirect effect.
Y = Bunch yield, SW = Single weight, FMF = Fresh mesocarp per fruit, ODM = Oil per dry mesocarp, FB = Fruit per bunch.

Table 6 Phenotypic path analysis of agronomic characters of palm oil yield.

Variable	Direct and indirect effect					r
	Y	SW	FMF	ODM	FB	
Y	<u>0.94</u>	-0.06	0.03	-0.08	0.01	0.85
SW	0.67	<u>-0.09</u>	0.02	-0.05	0.02	0.56
FMF	0.16	-0.01	<u>0.20</u>	-0.01	-0.02	0.32
ODM	-0.44	0.03	-0.01	<u>0.17</u>	0.01	-0.24
FB	0.04	0.00	-0.01	0.00	<u>0.31</u>	0.34

The underlined numbers show a direct effect while numbers not underlined show an indirect effect. Residual (P_R^2) = 0.125.
Y = Bunch yield, SW = Single weight, FMF = Fresh mesocarp per fruit, ODM = Oil per dry mesocarp, , FB = Fruit per bunch.

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