Heritability and Correlation for Maturity and Pod Yield in Peanut.

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ABSTRACT:

Fitting large-seeded peanut into cropping systems with limited growing period requires early mature varieties. Knowing genetic variation and correlation for traits of economic importance in a breeding population is necessary for improving peanut to fit into specific agronomic and environmental conditions. The objective of this study was to evaluate heritability in broad sense for maturity, pod yield, 100-seed weight and harvest index of a peanut segregating population and correlation among these traits. Two hundred lines of 10 crosses were evaluated in a randomized complete block design with two replications under fully-irrigated conditions. Variations among crosses for maturity, pod yield, 100-seed weight and harvest index were observed. High heritability estimates were found for maturity and harvest index, but heritability estimates for pod yield and 100-seed weight were low to moderate. Maturity was negatively correlated with pod yield and harvest index, suggesting the possibility to select for early mature genotypes without detrimental effect on pod yield and harvest index. Pod yield was well associated with 100-seed weight and harvest index, suggesting that selection for large seeds and good partitioning should improve yield. Selection for early maturity, high pod yield, large seeds, and high harvest index in this peanut population would be successful.

Key words: Arachis hypogaea L., early maturity, large-seeded peanut, genetic variation, harvest index, pod yield

Introduction

Fitting legume species into crop rotations is highly recommended to reduce the need for an expensive chemical nitrogen fertilizer that adds up to the total cost of crop production (Yusuf et al., 2009; Unrirt, et al., 2009). The benefits of legume green manures or legume crops to improve soils and provide sufficient nutrients to succeeding crops have been well recognized (Unrirt, et al., 2009; Farthofer et al., 2004; Balkcom, K.S. and D.W. Reeves, 2005; Becker, M. and D.E. Johnson, 1999), knowing that every year the land is becoming more productive than it was before. However, adoption of legume green manures in cropping systems has been low for many reasons, depending on the context of the specific cropping systems and socio-economic factors Becker et al., (1995). High labor demand, especially for establishment and timely incorporation of the manure and lack of legume seed and technical support were the most important constraints (Odendo et al., 2000; Unscher et al., 2004).

Intensification of crop production needs shorter growing periods of legume crops and they are substituted by early mature high yielding grain legumes (Becker et al., 1995; Kerr et al., 2007). Intensification and diversification of the crops can bring diverse profits, effective resource use and marketing opportunities. Although many green manure legumes meet this criterion, they still need the application of phosphorus fertilizer and do not provide immediate cash for farmers (Kamanga et al., 2001). For growing large-seeded type peanut (Arachis hypogaea L.) in crop rotations, farmers still need earlier maturing varieties to fit into their cropping systems such as cereal-based rainfed systems when peanut is grown after main crops and rice-based systems when peanut is grown during follow period with or without irrigation before rainy season (Sukharomana, S. and B. Dobkuntod, 2003).
Earliness of maturity is important for peanut adaptation to a wide range of cropping systems in semi-arid tropics. An early maturing variety may escape damage from drought or flooding, and it is advantageous in multiple cropping systems to permit early removal of crop so that the following crop may be planted (Sleper, D.A. and J.M. Poehlman, 2006). For large-seeded peanut of Virginia type, its maturity (more than 125 days) is much longer than small-seeded peanut of Valencia type and Spanish type (100-110 days). In Thailand, the market potential of this peanut type is great if farmer can reduce peanut crop duration in the field.

Early maturity is also disadvantageous. Plant size and yield may be reduced greatly in extremely early cultivars because the plant had shorter growing period to develop, manufacture and store nutrient materials Ali, N. and J.C. Wynne, (1994). In crosses with extremely early parent, seed size of peanut was reduced but seed number was increased for some extent Ali, N. and J.C. Wynne, (1994). The reduced crop duration without reduced seed size and yield penalty is the most challenge of peanut breeding for earliness in case that the earliness is not extreme.

Crops need duration of growth and good partitioning of assimilates to economic yield obtain high yield. In case of limited crop duration, yield depends largely on partitioning of assimilates, including partitioning between reproductive and vegetative structures, length of the pod filling period, and the rate of pod establishment Duncan et al., (1978). Seed number was positively related to crop growth rate and to PGR during the R3-R6.5 phase, while crop growth during the grain-filling phase was positively associated with grain number Haro et al.,(2007) Seed number is generally associated with seed yield rather than weight of individual seeds (Haro et al., 2007; Phakamas et al., 2008a). Gomes and Lopez reported that grain yield in cultivated peanut is influenced directly by the number of pods per plot and seed weight Gomes, R.L.F. and A.C.D.A. Lopez, (2005).

Genetic of maturity in peanut is not well defined largely because of difficulty in defining maturity of indeterminate non-senescent plant. Using hull scrape method, high broad sense heritability was found in peanut population derived from cross of parents with diverse maturity. Few genetic factors might condition maturity in peanut but the effect of environment on maturity is also high. Most breeding for early maturity in peanut has been focused on drought escape Knauft, D.A. and J.C. Wynne, (1995). In the crosses involving Chico as an extremely early parent, heritability estimates for maturity were intermediate to high and the correlation between maturity and seed size was negative and significant Ali, N. and J.C. Wynne, (1994).

In this paper, we report heritability in broad sense and genotypic correlation of maturity, pod yield, seed size and harvest index which would be used as selection criteria for improvement of peanut genotypes with reduced growth period.

Materials and Methods

The experiment was conducted at the agronomy farm of Khon Kaen University during November 2003 to April 2004 with full irrigation. A total number of 200 breeding lines in the F6 generation of ten peanut crosses of five commercial cultivars in Thailand and three introduced germplasm lines were arranged in a randomized complete block designed with two replications. Each cross had 20 progenies and they were selected randomly.

Ethephon at the concentration of 0.02% was applied to the seeds to break possible seed dormancy to ascertain the uniform germination of the seeds. This practice was done because some of parental lines are Virginia type peanut that has seed dormancy. A fungicide chemical (captan) was also applied to the seeds at the rate of 5 g/kg seeds to prevent seedlings from Aspergillus niger damage. Seeds were sowed on two-row plots with 5 m in length and a spacing of 20 x 50 cm, and the seedlings were thinned to one plant per hill at 17 days after sowing. Border rows were also provided so that all plants in the plots could be harvested. A pre-emergence herbicide (alachlor) at the rate of 3,125 ml ha⁻¹ was applied to the crop soon after sowing, and mechanical weeding was also practice two times at 15-20 days and 30 days after sowing. Chemical fertilizers of 12-24-12 of N P2O5 K2O at the rate of 150 kg ha⁻¹ was applied to the crop soon after the first mechanical weeding, and gypsum (CaSO₄) at the rate of 312.5 kg ha⁻¹ was applied to the crop soon after the second mechanical weeding, and cabofuran 3%G was also applied at the same time to prevent pod damage from subterranean ants (Dorylus orientalis Westwood). Leaf diseases and insect pests were adequately controlled during crop growth for optimum yield performance of the crop. Mini-sprinkler irrigation was applied to the crop once a week from sowing to harvest.

Days to maturity was recorded for all entries as number of days for crop to complete crop cycle and the crop is ready for harvest. Maturity was determined by 65-70% of the sampled pods was mature as indicated by brown inner shells. At harvest, the plants in the harvest area of 4 m² were uprooted, mature pods were removed manually from the shoots and the plants were cut at the crowns to remove roots. The shoots were weighted in the field to determine fresh dry weight and 1000 g of the total fresh shoot weight was taken,
oven-dried at 80 °C until constant weight and weighted to determine shoot dry weight of the samples. Shoot dry weight of the samples were later used for calculating shoot dry weight of the plot.

The mature pods were exposed to the sun for several days until the pods were dry with about 8% moisture content, shelled and weighted to determine pod dry weight and seed dry weight. Pod dry weight and seed dry weight were later converted to kg ha⁻¹. Pod dry weight and shoot dry weight of plot were used to calculate harvest index.

Analysis of variance (ANOVA) was conducted for each cross to determine the effects of lines, and heritability was calculated as a ratio of variances, by expressing the proportion of the phenotypic variance that can be attributed to variance of genotypic values:

\[ H^2 = \frac{\sigma_G^2}{\sigma_P^2} \]

where: \( H^2 \) = broad-sense heritability; \( \sigma_G^2 \) = genotypic variance; and \( \sigma_P^2 \) = phenotypic variance Visscher et al., (2008).

Standard deviation for mean of each cross (n=40) was also calculated to determine a range of variation in a cross.

Phenotypic and genotypic correlation coefficients between seven traits were determined according to Kwon and Torrie, (1964).

\[ r_g = \frac{\text{Cov}_{gij}}{\left(\sigma_{g_i} \times \sigma_{g_j}\right)^{1/2}}, r_p = \frac{\text{M}_{ij}}{\left(\text{M}_{ii} \times \text{M}_{jj}\right)^{1/2}} \]

Where \( r_g \) and \( r_p \) is genotypic and phenotypic correlation coefficient \( \text{Cov}_{gij} \) and \( \sigma_{g_i}^2 \) are the estimates of covariance and variance, respectively for traits i and j. \( \text{M}_{ii} \) and \( \text{M}_{jj} \) are genotypes means squares for trait i and j, respectively.

**Results and Discussion**

Variation in maturity was not high, ranging from 115.0±1.2 to 125.5±3.5 days (Table 1). The crosses Luhua 11 x KK 60-1, Luhua 9 x KK 5 and Taiwan 1 x KK 60-1 were interesting because they had low maturity values with low standard deviations (115.0±1.2, 116.7±4.4 and 115.3±1.3 days for Luhua 11 x KK 60-1, Luhua 9 x KK 5 and Taiwan 1 x KK 60-1, respectively). Variation in pod yield was relatively high, ranging from 1150.0±836.2 kg ha⁻¹ to 2868.7±851.2 kg ha⁻¹. The crosses showing high pod yield were Luhua 11 x Tainan 9 (2868.7±851.2 kg ha⁻¹), Luhua 9 x KK 5 (2493.7±606.9 kg ha⁻¹), Taiwan 1 x KK 60-1 (2456.2±1001.2 kg ha⁻¹), Luhua 9 x KUU 1 (2375.0±676.2 kg ha⁻¹), Luhua 11 x KK 60-1 (2300.0±379.4 kg ha⁻¹) and Taiwan 1 x KK 4 (2293.7±780.0 kg ha⁻¹).

Variation in seed size was low, ranging from 36.0±4.9 g in Taiwan 1 x Tainan 9 to 52.6±13.9 g in Luhua 11 x Tainan 9. Because of high standard deviation, the differences among peanut crosses were not statistically significant. However, Luhua 9 x KK 5 (49.3±5.9 g), Luhua 9 x KUU 1 (51.8±10.1 g) and Luhua 11 x Tainan 9 (51.8±8.9 g) seemed to have larger seeds than did Taiwan 1 x Tainan 9 (36.0±4.9 g) because of low standard deviations.

There was rather high variation in harvest index, ranging from 0.17±0.0 in Taiwan 1 x KUU 1 to 0.29±0.1 in Luhua 11 x Tainan 9. Most crosses had higher harvest index than did Taiwan 1 x KUU 1, and the crosses with highest harvest index were Luhua 11 x Tainan 9 (0.29±0.1), Taiwan 1 x KK 60-1 (0.28±0.1), Luhua 11 x KK 60-1 (0.27±0.0), Luhua 9 x KK 4 (0.27±0.1), Luhua 9 x KK 5 (0.26±0.1) and Luhua 9 x KUU 1 (0.26±0.0).

Heritability estimates for maturity were relatively high for most crosses except for the crosses Luhua 11 x KK 60-1(0.20) and Taiwan 1 x KK 60-1 (0.05) (Table 2). High heritability estimates were observed in the crosses Taiwan 1 x KK 4 (0.94), Luhua 11 x Tainan 9 (0.87), Luhua 9 x Tainan 9 (0.83), Luhua 8 x KK 5 (0.83), Luhua 9 x KUU 1 (0.82) and Taiwan 1 x Tainan 9 (0.80).

The heritability estimates for pod yield and seed size were generally low in which only few crosses showed moderate heritability estimates. There was the cross Luhua 9 x KK 4 only that had meaningful heritability estimates for pod yield (0.76) and seed size 0.71.

Most crosses had moderate to high heritability estimates for harvest index except for the crosses Luhua 9 x Tainan 9 (0.00) and Taiwan 1 x Tainan 9 (0.00). The crosses with meaningful heritability estimates were Luhua 9 x KK 4 (0.83), Luhua 11 x Tainan 9 (0.79) and Luhua 9 x KUU 1 (0.78).

The phenotypic and genotypic correlations showed the relationships among characters were different, depending on crosses (data not reported). However, there were general relationships between among maturity, pod yield, seed size and harvest index calculated from all data set of 10 crosses. Pod yield was positively
associated with seed size and harvest index with high and significant correlation coefficients (0.57** and 0.64** for 100-seed weight, 0.83** and 0.88** for harvest index), but it was conversely associated with maturity (-0.24** and -0.29**) (Table 3). It might indicate that, in this peanut population, larger seeds and good partitioning contributed to pod yield rather than did long duration of crop growth. Late maturity could impaire pod yield and harvest index as indicated by negative and significant correlation coefficients (-0.24** and -0.9** for pod yield, -0.22** and -0.26** for harvest index). Seed size was associated well with harvest index (0.40** and 0.41**), indicating that partitioning contributed to larger size of individual seeds rather than high number of seeds.

Discussion:

Jogloy et al. reported the heritability estimates for crop growth rate, pod growth rate, partitioning efficiency and reproductive duration and the correlations among these characters Jogloy et al., (2010). The results that were reported previously pointed towards the possibility to simultaneously improve pod yield and early maturity. In this paper, we reported the heritability estimates for maturity, pod yield, seed size and harvest index and the correlations among these traits. The results showed that selection of individual traits is possible because of sufficiently high heritability estimates for each characters and selection for early maturity in this peanut population is not detrimental to pod yield because of short duration of the crop.

Maturity is influenced largely by environmental conditions in addition to by changing phonology of the crop. Phakamas et al. found in peanut that difference in maturity in peanut was determined by reproductive duration rather than days to flowering and the variation in maturity in the rainy season was smaller than variation in the dry season when temperature was lower Phakamas et al., (2008b). Much of this variation could be attributed to variation in crop growth rate during the critical pod addition period Bell et al., (1993). The similar results might indicate that variation in reproductive duration determined yield variation in peanut. However, peanut has a wide range of maturity, and pod yields are different among different maturity groups. Days to maturity also determines the difference in pod yield. In general, late maturing genotypes yield better than early maturing genotypes Culbreath et al., 1999; Padi, F.K., 2008). Kotzamanidis et al. (2006) found that early maturity in peanut is associated with narrow pod distance from the main stem, leading to more synchronous maturity of the pods.

Phakamas et al. also found that number of pods per unit area is the major determinant for pod-yield differences among peanut lines, and that the differences among lines for this trait are influenced by CGR during the period from R6 to R7 Phakamas et al., (2008a). The early and the late maturing groups were equivalent in both mean pod yield and number of pods per m², but seeds of late mature genotypes were larger than early mature genotypes Phakamas et al., (2008a). Ali and Wynne found negative correlation between maturity and seed size, indicating larger seeds in late maturing genotypes Ali, N. and J.C. Wynne, (1994).

The variation in maturity was rather low in this study possibly due to low genetic variability of parents because most of them are improved varieties with rather high yield in Thailand and China. Another reason is that the extremely early maturity is not required because it is generally associated with yield reduction. High variation in maturity was observed in the crosses that had Chico as extremely early maturity parent Ali, N. and J.C. Wynne, (1994).

Fruit size was highly correlated with seed weight and both were significantly correlated with yield suggesting that selection for large fruit in this population would result in higher yield. In the evaluation of peanut germplasm for early maturity, Upadhyaya et al. (2006) found that correlation between pod yield and 100-seed weight was significant in all the eight seasons individually and overall at 90 DAS. Fruit size was highly correlated with seed weight and both were significantly correlated with yield Chiow, H.Y. and J.C. Wynne, (1983). Pod number per plant also determines pod yield Arslan, M., (2005). The difference in characters determining pod yield should be due to difference in germplasm used. In this study, the materials were focused on large-seeded peanut, and, therefore, pod weight was the most important for pod yield.

Pod yield was significantly correlated with growing degree days, sunshine radiation during gynophore formation, time to maturity and days from emergence to flowering Canavar, O. and M.A. Kaynak, (2010). Gomes and Lopez reported that grain yield in cultivated peanut is influenced directly by the number of pods per plot and seed weight Gomes, R.L.F. and A.C.D.A. Lopez, (2005). It is known that, within a species, available resources during the seed set period are distributed between both yield components, resulting in a trade-off between seed number and seed weight Gamin, B.L. and L. Borras, (2010).

The results were in agreement with Burow et al., who found that maturity was negatively associated with pod yield Burow et al., (2004). They also reported that selection for early maturity might reduce seed size, whereas we did not find detrimental effect on seed size. Similarly, seed size and seed number were positively associated with pod yield, whereas relationship between pod yield and number of days taken to maturity was
negative Chishti et al., (2000). The similarity of the results should be due to the similarity of germplasm in which none of peanut genotypes in these studies was extremely late mature.

Table 1: Means and their associated standard deviations for maturity, pod yield, 100-seed weight and harvest index of 10 peanut crosses in the F6 generation.

<table>
<thead>
<tr>
<th>Cross</th>
<th>Maturity (days)</th>
<th>Pod yield (kg ha⁻¹)</th>
<th>100-seed weight (g)</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luhua 11 x Tainan 9</td>
<td>120.3±5.4</td>
<td>2867.7±851.2</td>
<td>51.8±8.9</td>
<td>0.29±0.1</td>
</tr>
<tr>
<td>Luhua 9 x Tainan 9</td>
<td>121.4±5.8</td>
<td>1925.0±515.0</td>
<td>42.3±9.8</td>
<td>0.22±0.0</td>
</tr>
<tr>
<td>Taiwan 1 x KKW 4</td>
<td>118.9±5.0</td>
<td>1287.5±428.1</td>
<td>38.8±5.3</td>
<td>0.17±0.0</td>
</tr>
<tr>
<td>Luhua 9 x KK 4</td>
<td>124.3±4.0</td>
<td>1150.0±836.2</td>
<td>52.6±13.9</td>
<td>0.27±0.1</td>
</tr>
<tr>
<td>Luhua 11 x KK 60-1</td>
<td>115.0±1.2</td>
<td>2300.0±379.4</td>
<td>42.9±5.1</td>
<td>0.27±0.0</td>
</tr>
<tr>
<td>Luhua 9 x KKW 1</td>
<td>123.2±4.3</td>
<td>2375.0±676.2</td>
<td>51.8±10.1</td>
<td>0.26±0.1</td>
</tr>
<tr>
<td>Luhua 9 x KK 5</td>
<td>116.7±4.4</td>
<td>2493.7±606.0</td>
<td>49.3±5.9</td>
<td>0.26±0.1</td>
</tr>
<tr>
<td>Taiwan 1 x Tainan 9</td>
<td>125.5±3.5</td>
<td>1456.2±296.9</td>
<td>36.0±4.9</td>
<td>0.20±0.0</td>
</tr>
<tr>
<td>Taiwan 1 x KK 4</td>
<td>119.1±6.5</td>
<td>2293.7±780.6</td>
<td>48.1±8.8</td>
<td>0.24±0.1</td>
</tr>
<tr>
<td>Taiwan 1 x KK 60-1</td>
<td>115.3±1.3</td>
<td>2456.2±1001.2</td>
<td>48.2±9.6</td>
<td>0.28±0.1</td>
</tr>
</tbody>
</table>

Table 2: Heritability estimates in broad sense for maturity, pod yield, 100-seed weight and harvest index of 10 peanut crosses in the F6 generation.

<table>
<thead>
<tr>
<th>Cross</th>
<th>Maturity</th>
<th>Pod yield</th>
<th>100-seed weight</th>
<th>Harvest index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luhua 11 x Tainan 9</td>
<td>0.87</td>
<td>0.53</td>
<td>0.66</td>
<td>0.79</td>
</tr>
<tr>
<td>Luhua 9 x Tainan 9</td>
<td>0.83</td>
<td>0.10</td>
<td>0.17</td>
<td>0.00</td>
</tr>
<tr>
<td>Taiwan 1 x KKW 1</td>
<td>0.58</td>
<td>0.42</td>
<td>0.38</td>
<td>0.67</td>
</tr>
<tr>
<td>Luhua 9 x KK 4</td>
<td>0.71</td>
<td>0.76</td>
<td>0.71</td>
<td>0.83</td>
</tr>
<tr>
<td>Luhua 11 x KK 60-1</td>
<td>0.20</td>
<td>0.41</td>
<td>0.28</td>
<td>0.67</td>
</tr>
<tr>
<td>Luhua 9 x KKW 1</td>
<td>0.82</td>
<td>0.46</td>
<td>0.48</td>
<td>0.78</td>
</tr>
<tr>
<td>Luhua 9 x KK 5</td>
<td>0.83</td>
<td>0.08</td>
<td>0.14</td>
<td>0.56</td>
</tr>
<tr>
<td>Taiwan 1 x Tainan 9</td>
<td>0.80</td>
<td>0.00</td>
<td>0.04</td>
<td>0.00</td>
</tr>
<tr>
<td>Taiwan 1 x KK 4</td>
<td>0.94</td>
<td>0.68</td>
<td>0.69</td>
<td>0.64</td>
</tr>
<tr>
<td>Taiwan 1 x KK 60-1</td>
<td>0.05</td>
<td>0.58</td>
<td>0.61</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Table 3: Phenotypic and genotypic correlations (rP and rG) among maturity, pod yield, 100-seed weight and harvest index of 10 peanut crosses in the F6 generation.

| Maturity | Pod yield | 100-seed weight |
|----------|-----------|-----------------|-----------------|
| rP       | rG        | rP              | rG              | rP              | rG              |
| Pod yield| -0.24**   | -0.29**         | -0.06           | 0.57**          | 0.64**          |
| 100-seed weight | -0.05  | -0.26**         | 0.83**          | 0.88**          | 0.40**          |
| Harvest index | -0.22** | -0.26**         | 0.83**          | 0.88**          | 0.41**          |

** Significant at 0.01 probability level

The results might suggest that selection would be more effective for maturity than for pod yield and seed size because of higher heritability estimates. Selection for early maturity can be able to improve pod yield for some extent because of negative correlation between these traits. However, selection for early maturity should not have negative effect on seed size because lack of association between traits. Because pod yield had high correlation with seed size, it can be expected in this population to improve peanut varieties with early maturity, high pod yield and large seed size.

Conclusion:

Improvement of large-seeded peanut for shorter maturity to fit into cropping systems in the tropics is necessary as its crop duration is much longer than Spanish and Valencia type peanut. It might be possible to maintain high yield potential under reduced crop duration if the crop duration is not extremely short. The results indicated that selection for shorter crop duration would not impaired yield as there were negative and significant correlation between maturity and pod yield. Selection for early maturity would also increase harvest index because of negative and significant correlation between these traits, but it would not affect seed size because the correlations between these traits was not significant.

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