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CORRELATION TEST OF LEAF PHOSPHORUS NUTRIENT WITH MANGOSTEEN PRODUCTION[1)]

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ABSTRACT

Leaf analysis can be used as a guide to diagnose nutritional status and as a fertilizer recommendation tool for mangosteen plant. Therefore, sampling technique of standard leaf sampled should be established accurately. Leaf age is the main important factor to estimate plant nutritional status. The best of leaf sampling is the one which has the best correlation between leaf nutrient concentration with growth and yield. Leaf nutrient concentration was investigated on the mangosteen orchard at Bogor, Tasikmalaya, and Purwakarta, West Java. Twenty relatively uniform and representative mangosteen trees had been selected, and every months leaf sample was analyzed for P concentration. Leaf samples were taken at 2 months after flush and then periodically up to 10 months. Observations were done for number of open flower, number of dropped flower, and number as well as weight of fruit per plant. While for fruit quality, analysis was done on the TSS of the flesh and the N, P, and K content of fruit parts. The results showed that leaves of 4 and 5 month ages were the best to be used as leaf samples to diagnose P status since they have the highest correlation (above 0.7) between P concentration in the leaf and fruit yield. P concentration in the leaves decreased as the age of leaves increased. Mangosteen leaves from Purwakarta contained more P than those from Tasikmalaya and Bogor. This results can be used as a guide to estimate fertilizer recommendations for mangosteen.

[**Keywords**: *Garcinia mangostana,* leaf macronutrient, fruit yield]

INTRODUCTION

Mangosteen (*Garcinia mangostana* L.) is considered as Indonesia's export supreme fruit. However, many marketed mangosteens produce from inappropriate cultivated plants resulting in low productivity and quality. Average productivity of Indonesian mangosteen is about 30-70 kg/tree, lower than those of Malaysia and India which reach 200-300 kg/tree. Of that total production, only 25% meet the export quality (Indriyani *et al*. 2002).

One of efforts to increase mangosteen productivity and quality is by nutrient addition to plants. However, until now there is no proper recommendation for amount of nutrients being applied to mangosteen plants.

Some approaches in determining fertilizer requirements on plants which can be applied properly are soil analysis, screenhouse or pot trial, observation on deficiency symptoms and conduct field trial, and plant analysis (Lozano 1990). Soil analysis is commonly used as management tool on seasonal plants, such as tomato, maize, and legumes. However, for fruit crops it is rather difficult to be interpreted because correlation between soil analysis result and fruit production is often improper and since for mature mangosteen plant has vertical-distribute roots, soil sampling is often less represented. Trial in screenhouse or pot for mangosteen plant is also complicated to be carried out because of tall tree and deep root, whereas observing deficiency symptom and nutrient excess on plant is relatively secluded. Meanwhile in most case nutrient deficiency has similar abnormal plant symptom with those caused by pest or disease. To ensure the cause of the abnormalities, plant tissue analysis should be done.

Plant tissue analysis is more practical to determine nutrient status on mangosteen plant than other methods. Nutrient status in plant tissue is also represent nutrient status in soil. This is based on principle that nutrient concentration in plant is a result of interaction of all factors influencing absorption of the nutrients from soil.

Plant tissue generally analyzed is leaf. Leaf is a place where photosynthesis process and other metabolism actively occur. Leaf is also the place for carbohydrate and mineral storage. Nutrients in leaves not only have a role in photosynthesis but also represent plant nutrient status. Leaves also consist of tissues which always available for analysis of plant nutrient status.

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Leaf analysis has been used as indicator in nutrient diagnosis and as basic recommendation for fertilizer application on fruit crops at some countries (Smith 1962; Leece 1976; Shear and Faust 1980), whereas in Indonesia is seldom used. Some purposes of leaf tissue analyses are: (1) to diagnose or strengthen diagnosis of visible symptom, (2) to identify invisible symptom, (3) to find out nutrient deficiency earlier, and (4) as tool in determining fertilizer recommendation.

Leaf tissue analysis is carried out by correlation and calibration tests. Correlation test aims to determine the best relationship between nutrient content in leaves at certain age and yield, while calibration test purposes to find relationship between nutrient content intervals in leaves and plant responses, especially yield parameters (Kidder 1993). Leaves having the best correlation between nutrient content at certain age and yield will be used as a sample leaf at calibration test. Calibration test gives meaning of leaf analysis value obtained from laboratory become interpreted data, whether nutrient concentration in leaf is very low, low, moderate high, and very high. Only plants having low nutrient concentration require fertilizer.

Based on the principles, a study was done to find out a proper leaf as diagnostic tool of nutrient status of nitrogen (N), phosphorus (P), and potassium (K). The objectives of the study were to find out: (1) P concentration change on 2-10 month leaf age at three mangosteen producing centers, (2) relationship between leaf P and soil P concentration, (3) relationship between leaf P concentra-tion and fruit yield, and (4) a proper leaf age as diagnostic tool of N, P, and K status in mangosteen plant.

MATERIALS AND METHODS

The study was conducted in May 2003-May 2004 at three mangosteen producing centers in West Java, namely, Bogor, Purwakarta, and Tasikmalaya. Chemical analyses were carried out at laboratory of Department of Agronomy and Horticulture and Department of Soil Science and Land Resources, Faculty of Agriculture, Bogor Agricultural University.

Leaves from 22 mangosteen trees of each location (Bogor, Purwakarta, and Tasikmalaya) were taken every month. The leaves were taken at 2 month old and periodically every month until 10 months. The leaf samples were taken from four directions (west, east, north, and south), 3-4 leaves each of central branches of each tree, then the leaves were gathered.

Analysis of leaf P concentration was initiated by cleaning the leaves with tissue and dried using an oven at 70^o C. Leaves were then blended and sieved with hole size of 0.5 mm sieve. P concentration was measured by spectrophotometer UV-VIS. Chemical analysis was conducted based on procedure used by Soil Science Laboratory, Bogor Agricultural University.

Soil samples were taken from mangosteen root zone at depths of 0-30 cm and 30-50 cm. The soil was air-dried and sieved with hole size of 2 mm sieve. Subsequently chemical composition analyses were performed consisting of pH (H_2O and HCl), CEC, N, P, and K. Total N was determined using Kjeldahl's method, while P and K using Flame Emission Spectrophotometer (FES).

Observation was done on the yield parameters consisting of number of flower, number of flower and fruit drop off, number of fruit per plant, and total fruit weight per plant. Fruit quality was measured by its sweetness using refractometer (TSS in Brix), and P content in each fruit part (calyx + stalk, peel, flesh, and seed).

Data were subjectes to analysis of variance. If it is obtained significant effect, it is followed by Duncan's multiple range test (DMRT) at significant level of 5%.

Correlation between leaf P content at each age (X) and production (%Y) was measured by simple linear correlation as follows:

$$r_{xy} = \frac{n\Sigma X_i Y_i - (\Sigma X_i)(\Sigma Y_i)}{\sqrt{[n\Sigma X_i^2 - (\Sigma X_i)^2]\,[n\Sigma X_i^2 - (\Sigma X_i)^2]}}$$

where r value represents strength of linear correlation. Correlation value lies at interval of $-1 < r < 1$. Mark - and + indicated correlation direction. Correlation size is as follows: 0.70-1.00 (+ or -) showed high associative degree; correlation value of 0.40-0.70 (+ or -) showed substantial correlation; 0.20-0.40 (+ or -) means low correlation; whereas 0.0-0.20 (+ or -) indicated ignored correlation.

Correlation value obtained is a sample correlation value, which is estimated value from coefficient of population correlation symbolized by p. Furthermore, hypothesis test was done on unknown population correlation coefficient based on estimation of sample correlation coefficient value. Hypothesis test was as follows:

H_0:$\rho = 0$ (there was no correlation between X and Y variables)
H_1:$\rho = 0$ (there was correlation between X and Y variables)

Test statistics used was

$$t = r\sqrt{\frac{n-2}{1-r^2}}$$

where t was obtained from t student distribution with df = n-2, and n is number of observations.

Rejection criteria of H_0 were as follows:
If t calculated more than t table, H_0 was rejected.
If t calculated less than t table, H_0 was not rejected.

Leaf P concentration at age with high correlation value would be determined as sample leaf, and at calibration test only that leaf would be used.

RESULTS AND DISCUSSION

Correlation between Leaf P Concentration and Leaf Age

Result of leaf analysis showed that mangosteen leaves from three locations (Bogor, Purwakarta, and Tasikmalaya) had different P concentrations. Leaf P concentration of mangosteen from Purwakarta was higher than those from Tasikmalaya and Bogor. However, there was a pattern similarity among the three locations, that was the decreasing P concentration occurred in line with the increasing leaf age (Figure 1).

Leaf P concentration was significantly different between 2-10 month age from each location. The highest leaf P concentration from Purwakarta (0.187%) was obtained at 2 month leaf age, while the lowest at 10 month leaf age (0.145%). The leaf P concentration from Purwakarta was twice leaf P concentration from Bogor. The highest leaf P concentration from Bogor was obtained at 2 month leaf age (0.106%), and the lowest was at 10 month leaf age (0.073%), whereas that from Tasikmalaya ranged between leaf P concentration of Purwakarta and Bogor (Table 1 and Figure 1). The difference in leaf P concentration among the three locations was caused by different soil fertility. Soil from Purwakarta had higher P content than those from Tasikmalaya and Bogor (Table 2).

Decrease in leaf P concentration with increasing leaf age was also occurred on other plants, as reported by Rominger *et al.* (1975) on alfalfa and Dow and Robert (1982) on potato. Poovarodom *et al.* (2000) also reported that there was a decrease in leaf P concentration on durian during growth season. Increase in leaf P concentration was only obtained after fertilizer application after harvest.

The same change pattern of leaf P content was also reported by Munson and Nelson (1973) by summarizing their previous studies. The results indicated that P

Table 1. Effect of leaf age on the P content of mangosteen leaves collected from Purwakarta, Tasikmalaya, and Bogor, West Java.

Leaf age (month)	P concentration (%)		
	Purwakarta	Tasikmalaya	Bogor
2	0.187 a	0.165 a	0.106 a
3	0.179 ab	0.155 b	0.097 ab
4	0.173 abc	0.140 c	0.084 cd
5	0.160 cd	0.133 cd	0.084 cd
6	0.163 bc	0.135 cd	0.089 bc
7	0.163 bc	0.130 dc	0.084 cd
8	0.158 cd	0.132 dc	0.075 d
9	0.157 cd	0.130 ef	0.078 cd
10	0.145 d	0.120 f	0.073 d

Number in the same column followed by the same letters are not significantly different according to Duncan's mutiple range test at P = 0.05.

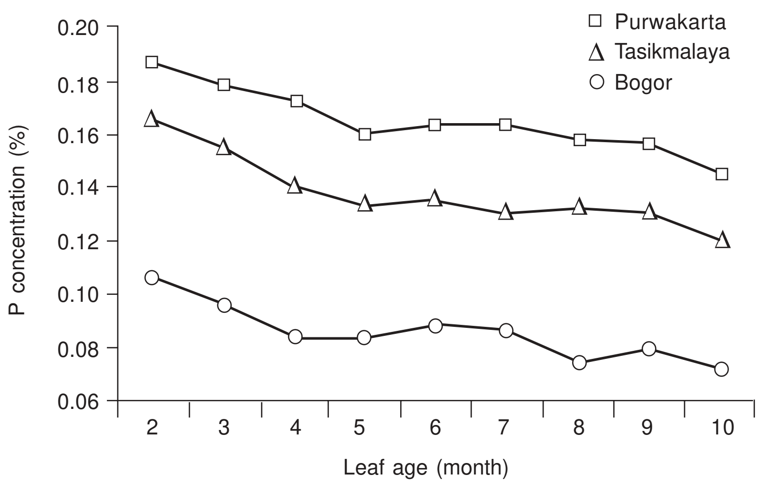


Figure 1. Relationship between leaf age and leaf P concentration on mangosteen collected from three areas.

Table 2. Concentration of NPK nutrients, CEC, and pH of soils collected from three mangosteen orchards in West Java.

Location	Depth (cm)	N (%)	P (ppm)	K .... (me/100 g)	KTK	pH	
						H_2O	KCl
Purwakarta	0-30	0.15	1.68	0.24	18.87	4.64	3.68
	30-50	0.11	1.31	0.22	13.97	4.72	3.73
Tasikmalaya	0-30	0.14	1.36	0.23	19.10	4.74	3.71
	30-50	0.10	1.27	0.22	14.48	4.70	3.66
Bogor	0-30	0.12	1.19	0.22	14.36	4.40	3.43
	30-50	0.09	1.02	0.20	12.95	4.27	3.51

concentration tended to decrease with increasing time; Ca and Mg on maize and soybean inclined to increase, while P concentration on rice, peanut, and potato was slightly change with inceasing age. Other study by Sumner (1979) revealed that during 10 month observation, P concentration was decreasing about 24-32%. At previous study, Sumner (1977) observed P distribution at several growth stages on soybean. The result indicated that P concentration decreased with increasing growth. In addition, Liferdi *et al.* (2005) reported that leaf nutrient change on plant was caused by change in growth stages. Leaf nutrient decreased at flush and generative stages. Therefore, leaf sampling and determination of valuation criteria on interpretation of leaf tissue analysis results had to consider leaf age. If it was not, a fatal failure would occur. As shown in Figure 1, if leaf sample was taken at 2 month age, leaf P concentration at the three locations would be high, but with delaying 1 month on leaf sampling (3 month leaf age), P concentration decreased, even at Bogor P concentration sharply decreased.

Correlation between Leaf P Concentration and Soil Chemical Properties

Results of soil chemical analyses showed that soil N, P, and K concentrations at three locations were 0.15-0.09%, 1.68-1.02%, and 0.24-0.20%, respectively (Table 2). These values were categorized as very low till low based on criteria developed by Indonesian Center for Soil Research. Soil N, P, and K concentration at Purwakarta were higher than those at Tasikmalaya and Bogor and it decreased with increasing soil depth. The same results were reported by Lestari (2003), the deeper soil sampling, the more decreased N, P, and K concentration was obtained. Cation exchange capacity value of the three locations were 19.10-12.95 me/ 100 g or categorized as low-moderate.

Soil pH of the three locations were 4.27-4.74 which were classified as very acid till acid. Soil analysis showed that soil pH of Purwakarta increased with raising soil depth, while those of Tasikmalaya and Bogor decreased.

The difference in soil P availability and pH of each location caused P uptake difference by plant. This was indicated by soil P concentration of Purwakarta which was higher than that of Tasikmalaya and Bogor. Leaf P concentration of Purwakarta was much higher than that of Tasikmalaya and Bogor. The more availability of soil P, the higher nutrient uptake by plant.

Result of leaf analysis could be used to predict soil nutrient concentration if the leaf nutrient concentration had high correlation with soil nutrient. The test result showed that P concentration in leaf had significantly correlated with P concentration in soil. Correlation coefficient of leaf P concentration at 4 month leaf age with soil P concentration was 0.794, whereas correlation coefficient at 5 month leaf age with soil P concentration was 0.756. Leaf P concentration would increase with increasing soil P availability (Figure 2).

Based on linear quotient above, soil P concentration could be estimated. Increasing P concentration 0.1% at 4 month leaf age, soil P availability was required 0.54 ppm. Whereas at leaf of 5 month age, soil P availability was required 0.62 ppm.

Correlation between Leaf P Concentration and Yield

Phosphorus concentration in leaf positively correlated with yield and fruit quality. It means that the higher the leaf P concentration, the higher the yield was found. This could be seen from higher leaf P concentration of mangosteen from three locations consecutively, Purwakarta, Tasikmalaya and Bogor having production and TSS with same consecutive (Figure 1 and Table 3).

Average yield of mangosteen from Purwakarta was significantly higher than that from Bogor and Tasikmalaya, namely 101.97 fruits/plant, while for Bogor it was only 62

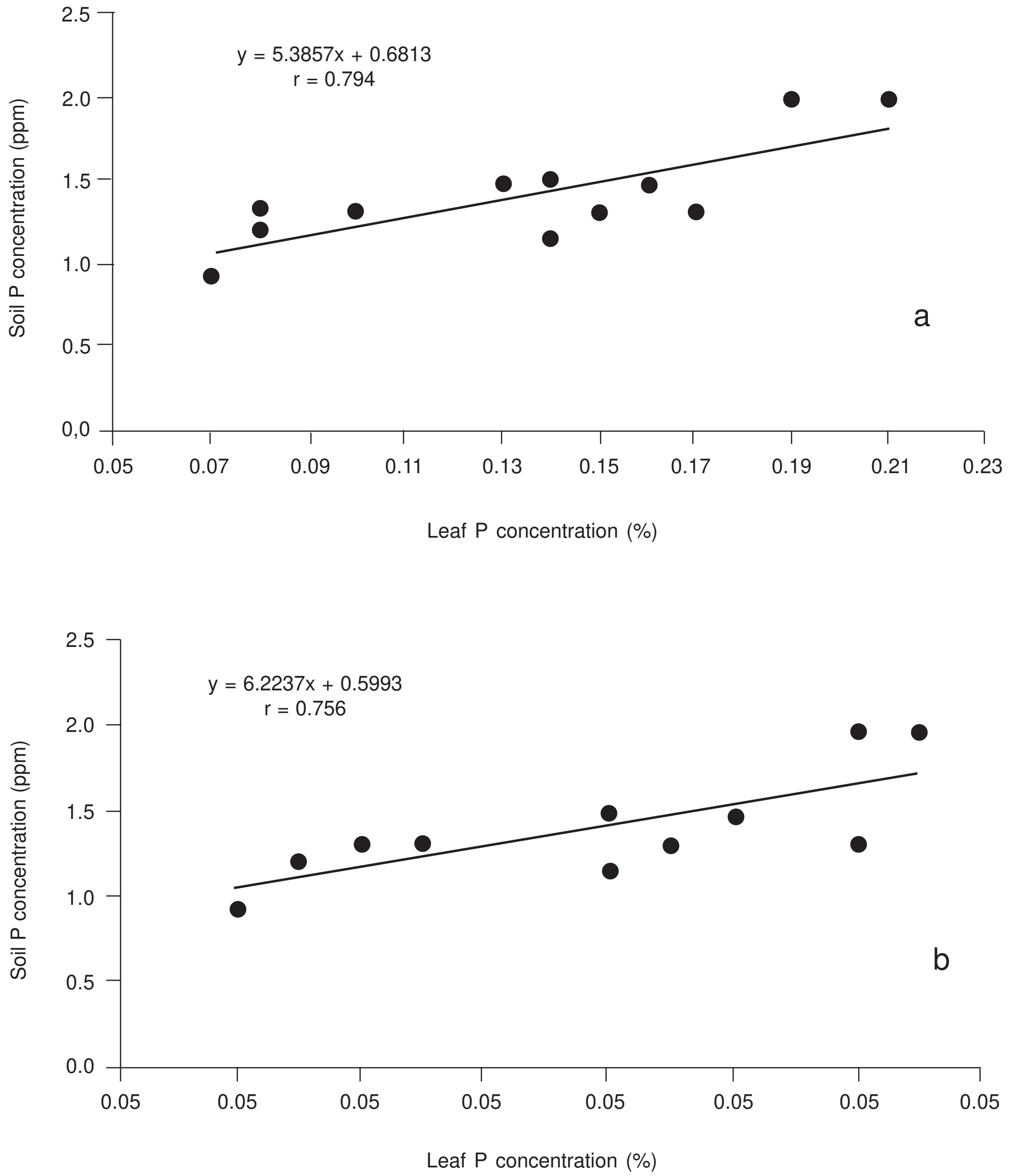


Figure 2. Correlation between P concentration in the mangosteen leaf and in the soil at the leaf age of 4 months (a) and 5 months (b).

Table 3. Number of bud opening, percentage of flower drop off, number of fruit, fruit weight per plant, and TSS of mangosteen from three locations in West Java.

Location	Number of flower per plant		Fruit per plant		
	Opening	Drop off	Number (%)	Weight (g)	TSS (Brix)
Purwakarta	113.30a	10.31b	101.97a	12.288,43a	17.46a
Tasikmalaya	25.43c	5.34c	23.75c	2.328,34c	15.31b
Bogor	75.08b	17.37a	62.00b	5.137,64b	15.28b

Number in the same column followed by the same letters are not significantly different according to Duncan's mutiple range test at P = 0.05.

and Tasikmalaya 23.75 fruits/plant (Table 3). The high mangosteen yield of Purwakarta was caused by high number of flower formed and low percentage of dropped flower, that was 10.31%. Beside, mangosteen from Purwakarta had higher leaf P concentration as well. The low mangosteen yield from Bogor was caused by high number of dropped flower (17.37%) and low leaf P concentration.

Plants with lack of P nutrient became weak resulted in high number of fruit drop off. This was reported by Thompson and Troeh (1978), that P was required by plant to form cell at root and shoot, make stem sturdy, enhance flowering age, stimulate flower initiation, and increase pest and disease resistance.

The low mangosteen yield of Tasikmalaya was caused by plant condition which was in off year. This phenomenon was known as biennial bearing or fluctuative fruit harvesting, that was a grand harvest followed by little harvest on the consecutive year (Liferdi *et al.* 2000).

Mangosteen yield of Tasikmalaya on following year was higher than that of Bogor, but still lower than that of Purwakarta. This was indicated by higher leaf P concentration of the three locations consecutively, Purwakarta, Tasikmalaya, and Bogor which possess same sequence of production and TSS (Figure 2 and Table 3).

Adequate P availability in leaves had enhanced mangosteen of Purwakarta to give optimum yield as shown by number of fruits, that was 100 fruits/plant, which was higher than that of Tasikmalaya and Bogor (Table 3). Beside, this was correlated with P function in plant metabolism as well. P is an essential macronutrient which plays an important role in various processes, such as photosynthesis, assimilation, and respiration. P is a structural component of several essential substances, energy transferred molecule ADP and ATP, NAD, NADH, and genetic information system substances DNA and RNA (Gardner *et al.* 1985).

Phosphorus concentration with high to low values were consecutively occurred in seed, flesh, calyx + stalk, and peel, except for fruit from Bogor, where the highest P concentration occurred in calyx, followed by flesh, seed, and peel. P concentration in mangosteen seed from Purwakarta and Tasikmalaya was significantly higher than that from Bogor (Table 4). P concentration in fruit parts did not indicate P concentration in the leaves of the three locations. The highest P concentration was obtained in mangosteen leaf and peel from Purwakarta. The highest P concentration in flesh and seed was obtained on mangosteen from Tasikmalaya, whereas in stalk and calyx was from Bogor.

Table 4. Phosphorus concentration in fruit parts of mangosteen from three locations in West Java.

Location	P concentration (%)			
	Calyx + stalk	Peel	Flesh	Seed
Purwakarta	0.10a	0.07a	0.12a	0.15a
Tasikmalaya	0.11a	0.06a	0.13a	0.16a
Bogor	0.18a	0.06a	0.12a	0.11b

Number in the same column followed by the same letters are not significantly different according to Duncan's mutiple range test at P = 0.05.

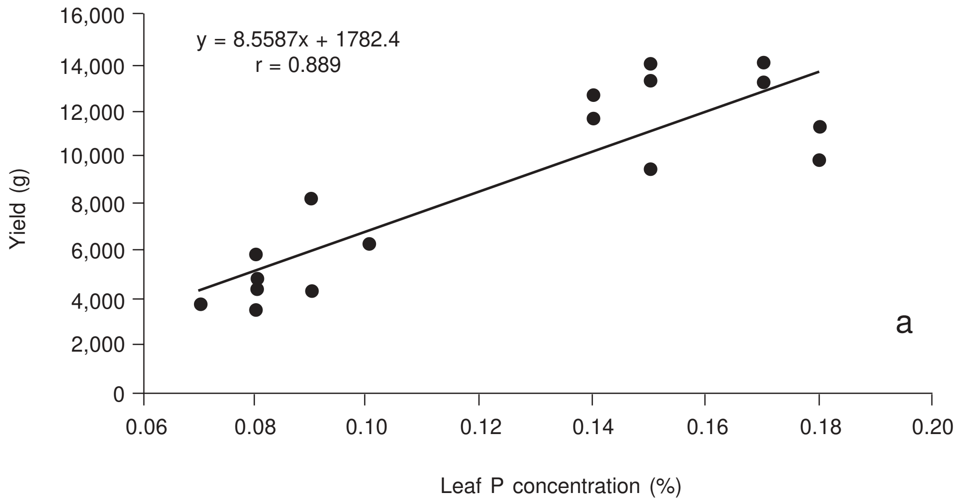
Table 5. Correlation coefficient between leaf P concentration and yield of mangosteen at Purwakarta, Tasikmalaya, and Bogor, West Java.

Leaf age	Correlation coefficient		
	Purwakarta	Tasikmalaya	Bogor
2	0.603*	0.220	0.307
3	0.626*	0.265	0.480
4	0.711**	0.633*	0.608*
5	0.615*	0.532	0.762**
6	0.625*	0.683*	0.402
7	0.579	0.465	0.432
8	0.602*	0.276	0.230
9	0.521	0.344	0.648
10	0.404	0.230	0.509

Correlation Analysis between Leaf P Concentration and Yield

Correlation between leaf P concentration of each leaf age and yield was varied. Highly correlation of leaf P concentration and yield was obtained on 4 month leaf age for Purwakarta mangosteen with r = 0.711, whereas at 2, 3, 4, 5, 6, and 8 month leaf ages were substantially correlated. There was no highly correlation but adequately substantial in leaf P concentration and yield at 4, 5, and 6 month leaf ages with r = 0.633, 0515 and 0.683, respectively. Whereas for mangosteen from Bogor at 5 month leaf age, there was highly correlation between leaf P concentration and yield with r = 0.762 (Table 5).

Mangosteen yield was positively correlated with leaf P concentration. This could be seen from the highest yield on Purwakarta mangosteen which leaf P concentration was higher than other two locations, or in other words, the higher the leaf P concentration, the higher the yield. Result



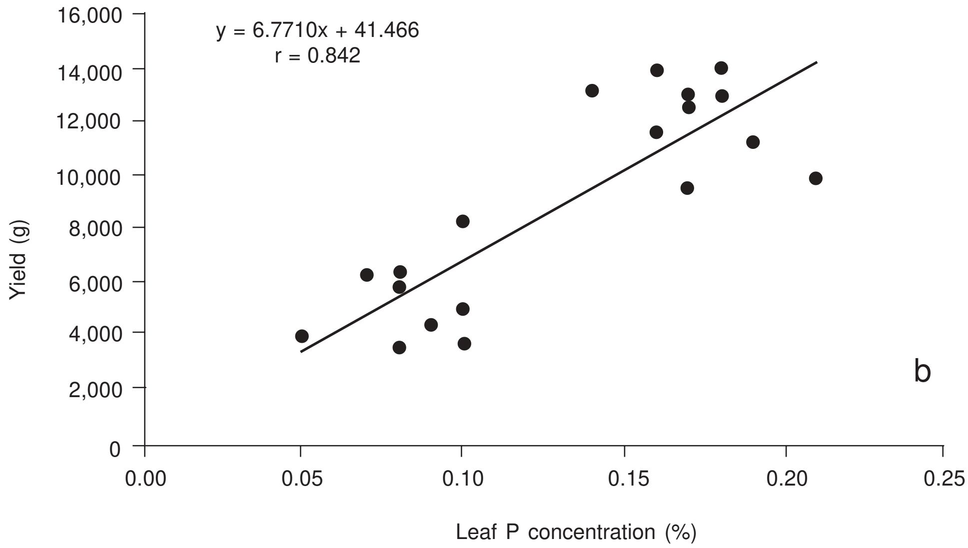


Figure 3. Correlation between leaf P concentration and yield of mangosteen at 4 month old (a) and 5 month old (b).

of leaf P concentration analysis of mangosteen from Purwakarta and Bogor at 4 month old showed r value of 0.889 and at 5 month old the r value was 0.842 (Figure 3).

Based on the r value, leaf P concentration had moderately correlated with yield. The r value of 0.889 showed that 79.03% variance of production change could be explained by leaf P concentration variable, while the remain of 20.97% could be explained by other factors.

Result of leaf tissue analysis could also be used to predict potential yield because leaf P concentration had highly correlation with yield (r = 0.889). Based on linear quotient Y = 8558x - 1782.4, this means that plant production was decreasing 1782.4 g if leaf P concentration was 0%. Whereas every leaf P concentration increased 0.1%, it would increase yield by 855.8 g.

Regression Coefficient Test

Test on simple linear regression coefficient aimed at testing the significance of correlation between leaf P concentration and yield, in other words, leaf P concentration highly affected or did not affect plant yield. Based on measuring result, t value of leaf P concentration at 4-month old was 7.764, while at 5-month old was 6.869. The t table (0.025) with df = 14 was 2.145. Calculated t of leaf P concentration was higher than value of t (2.145). This showed that leaf P concentration highly affected yield.

Leaves of 4 and 5 month age, therefore, could be used as samples and as diagnostic tool for P nutrient status on mangosteen plant. Then at calibration test only 4 and 5 month age leaves could be used.

CONCLUSION

Leaf P concentration in mangosteen was decreasing with increasing leaf age at three mangosteen production centers in West Java (Purwakarta, Tasikmalaya, and Bogor). Leaf P concentration positively correlated with soil P. The higher soil P, the higher leaf P content. With regression quotient, leaf P concentration could predict fruit yield. The higher leaf P concentration, the higher fruit yield. Mangosteen leaves of 4-5 month old were appropriate as samples and as diagnostic tool for P nutrient status on mangosteen plant.

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