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Correlation Between Nitrogen, Phosphorus and Potassium Leaf Nutrient with Fruit Production of Pummelo Citrus (*Citrus maxima*)

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ABSTRACT

Nutrient status of nitrogen, phosphorus and potassium in citrus leaf tissue more accurately reflects the nutrient concentrations associated with changes in production. This study aimed to establish the proper leaf to diagnosis nutrient status of N, P and K in pummelo citrus. The survey was conducted on farmer's pummelo citrus lands in Pangkep, South Sulawesi, Indonesia, with altitude of 17-35 m above sea level. Chemical analysis was performed in Soil Laboratory of South Sulawesi Assessment Institute for Agricultural Technology. The study used 150 productive citrus trees, aged 5-8 years, with relatively homogenous management. Post harvest sampling was carried out on the 3rd-4th leaf and 5th-6th with the position of the upper branches. The results showed that 3rd-4th leaf has the best correlation with earlier fruit production than 5th-6th leaf and later fruit production. Concentrations of N, P and K in earlier fruit production with 3rd-4th leaf, respectively are: low (<1.38; <0.11 and <1.13%), moderate (1.38-2.15, 0.11-0.20 and 1.02-2.31%) and high (>2.22; >0.20 and >2.31%). While the optimum concentration with 85% of relative production are 1.77, 0.16, 1.67%, respectively. Concentrations of N, P and K in later fruit production with 3rd-4th leaf respectively are low (<1.48; <0.15 and <1.43%), moderate (1.48-2.00, 0.15-0.21 and 1.43-1.79%) and high (>2.00; >0.21 and >1.79%). While the optimum concentration by projecting 75% of production target are 1.69, 0.19, 1.55%, respectively. The results of this study can be used as a guide in formulating fertilizer recommendations for pummelo citrus.

Key words: *Citrus maxima*, leaf nutrient, fertilizer recommendation

INTRODUCTION

Determination of fertilizer recommendations on annual crops, particularly fruits trees, in developed countries has been carried out by leaf tissue analysis method (Obreza *et al*., 2008). While in Indonesia, the method has not yet been widely applied for fruit trees (Poerwanto, 2003). The results of leaf tissue analysis can be useful if has a positive correlation with plant response. If the value of leaf tissue analysis is low, then the plant growth will be retarded or production is low. Conversely, if the value is high, potential maximum production can be achieved.

Leaf analysis is a method of estimating plant nutrient requirement based on the assumption that within certain limits, there is positive relationship between nutrient availability, leaf nutrient content, yield and quality of fruits (Srivastava and Singh, 2004; Srivastava and Alila, 2006). Nutrient availability in a given period has a positive effect on plant nutrient and fruit production of the following year as a direct response to soil nutrient content (Bhargava, 2002; Wall, 2010). Leaf tissue analysis as a diagnostic tool has been widely performed to determine the annual crop nutrient needs prior to nutrient interference (Obreza *et al.*, 2008). Stebbins and Wilder (2003) reported that leaf nutrient concentrations can be used as a guide to determine nutrient status of plant that are directly related to the pattern of growth and crop production, although the leaf nutrient concentration is influenced by the location or position of the leaf in the canopy. Citrus is characterized by crown that appeared only once and all the leaves have the same age within a trubus (Bhargava, 2002; Verheij, 1986).

As so far, for Pamelo citrus, it is not known yet where the position of leaf with the right timing can best describe the nutrient status, although Pushparajah (1994) reported that the most appropriate leaf tissue as sample is at position 3rd or 4th for cocoa and coffee and 14th and 17th for coconut and palm oil. Based on these reason, research on relationship between the concentration of N, P and K on the position of the leaves with fruit production in pummelo citrus is needed.

The purpose of this study is to determine leaves with the right time to diagnosis of the status of N, P and K based on the best relationship between the concentration of N, P and K with relative earlier and later yield of fruit.

MATERIALS AND METHODS

The research was conducted in March-May 2012 for earlier fruit production and from March to May 2013 for later production in center of pummelo citrus in the District of Ma'rang, Labakkang and Segeri, Regency of Pangkep, Province of South Sulawesi, Indonesia. The altitude is around 17-35 m above sea level. Chemical analysis was performed in Soil Laboratory of South Sulawesi Assessment Institute for Agricultural Technology.

The research materials include 50 productive citrus trees that were 5-8 years old and managed relatively similar. Research tools include paper bags, scissors, compass, camera, altimeter and stairs. The sample was collected from the top third of the plant branches, each on the finish trubus (3rd-4th) and past trubus (5th-6th) that physiologically perfect. Leaves collected from individuals plant after harvesting, take one leaf from the West, East, North and South direction, in good weather conditions and between 8.00 to 12.00 am.

Analysis of N, P and K leaf concentration begins by cleaning the leaves and then dried in oven at temperature of 65°C. Then, the leaves blended and then sieved with 0.5 mm size hole. Determination of total N is using semi micro Kjeldahl. P and K content were measured using dry ash method. P concentration measured using Spectrophotometer UV-VIS and K with Flamephotometer. Production (yield) is measured on the number of fruit per tree. Data from the three locations were analyzed with simple linear regression.

Data analysis for determination of critical limits of nutrient adequacy: Age calibration was performed for earlier fruit production and leaf nutrient concentrations. Age varies while production is as a function of age, where the production will be compared each other as dependent variable, therefore production must be adjusted to the age. The calibration method is as follows:

$Y = f(t)$
Y = Estimated production due to age
T = Age (Year)
$Y_{adjusted} = \ddot{Y}+(Y_i-Y_i)$
$Y_{adjusted}$ = Adjusted production
Y_i = Actual production for ith age
$\ddot{Y}$ = Average
Y_i = Estimated production for ith age

Model to determine nutrient adequacy criteria: The obtained data were analyzed to determine the threshold criteria of nutrient adequacy. Critical limit of nutrient adequacy will be prepared based on nutrients concentration in the leaf tissue. Distribution of this data will be related to marketable or relative production.

Method to determine limits is boundary line as Walworth *et al.* (1986) such as follow:

- Scatter diagram of the relationship between adjusted production and plant's age is wrapped with boundary line where the line demarcate field actual data, so very little chance the data will be found outside the lines
- The line is related to an increase or decrease in production that corresponding to assessed nutrient concentrations in leaf tissue
- Limit of production decline from maximum production to nutrient adequacy already unfavorable or waste
- The intersection between boundary line and the estimated production level is the threshold criteria of nutrient adequacy

RESULT

Model of relationship between earlier and later fruit production with plant age: The variability between plant age and production, where there is different age in field, so that production component must be adjusted with age. While the production as a function of age, where the production will be compared each other, namely as the dependent variable. Adjusted production obtained by multiplying the nutrient content of N, P and K with relatively fruit production both earlier and later production.

This figure shows that earlier and later fruit production has relationship with age with coefficient of determination R^2 is high for earlier production and low for the later, which means a tendency of fruit production is strongly influenced by age. By using the equation $y = 10.66x^2-117.4x+324.8$ on earlier production, the adjusted value will be obtained according to formula a follow: $Y_{ti} = 17.88+(Yi-(10.66x^2-117.4x+324.8)$. By using the $y = -4.081x^2+59.79x-182.1$ on later production, the adjusted value will be obtained according to formula a follow $Y_{ti} = 30.89+(Yi-(-4.081x^2+59.79x-182.1)$.

Concentration of N, P and K with the age of plant showed very weak relationship, this means that the level of nutrient concentrations in plants especially pummelo showed no significant effect (Fig. 1). This is caused by environmental factors in which the plants grow very varied, so that diversity is not only influenced by the age.

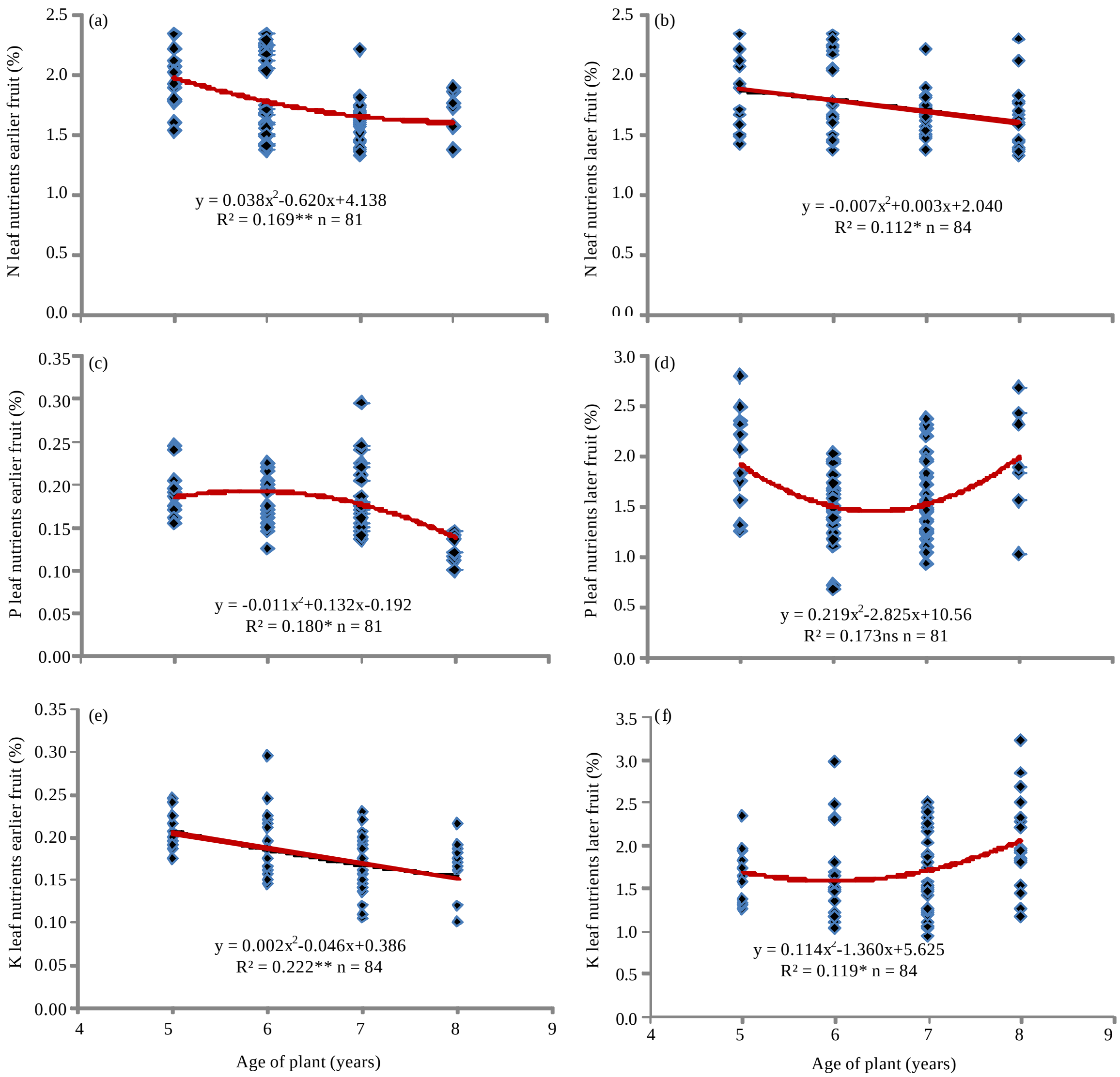

Fig. 1(a-f): Relationship between plant age and the percentage of N, P and K leaf concentration in (a, c, e) Earlier and (b, d, f) Later fruit production

Model of relationship between earlier and later fruit production with concentration of nitrogen, phosphorus and potassium: To determine leaf nutrient concentrations required for fertilization feasibility, the boundary line can be determined for relative yield that divided into low, moderate and high. Walworth *et al.* (1986) has been developed such a model to identify and measure factors related to crop production. If a unique relationship between a single growth factor to yield or quality can be determined, then with optimal factor the yield will get much better. However, most of the relationship with critical value determination for the purpose of diagnosis is often in similiar condition that only one factor is varied whiles other factors being equal. Therefore, the determination of critical value is not universal to be applied. Efforts to resolve the issue is use yield percentage (relative yield), because the combination of different lands or places demonstrate the complexity of the relationship between plant growth with environmental factors. If a variety of growth factors that can be arranged in many places, then the varies data set can be generated. Boundary Line is a line that limits a case. This line will be very useful in diagnosing the possibility to acquire the maximum production that is consistent with any value of a particular growth factor that can be determined. It is a simple matter to place the peak of the lines which correspond to the optimum levels of growth factors that being assessed (Sutandi and Barus, 2007).

The relationship between earlier and later relative yield with the concentration of N, P and K in third-fourth leaves and fifth-sixth leaves are depicted in Fig. 2-4, respectively. The figure show

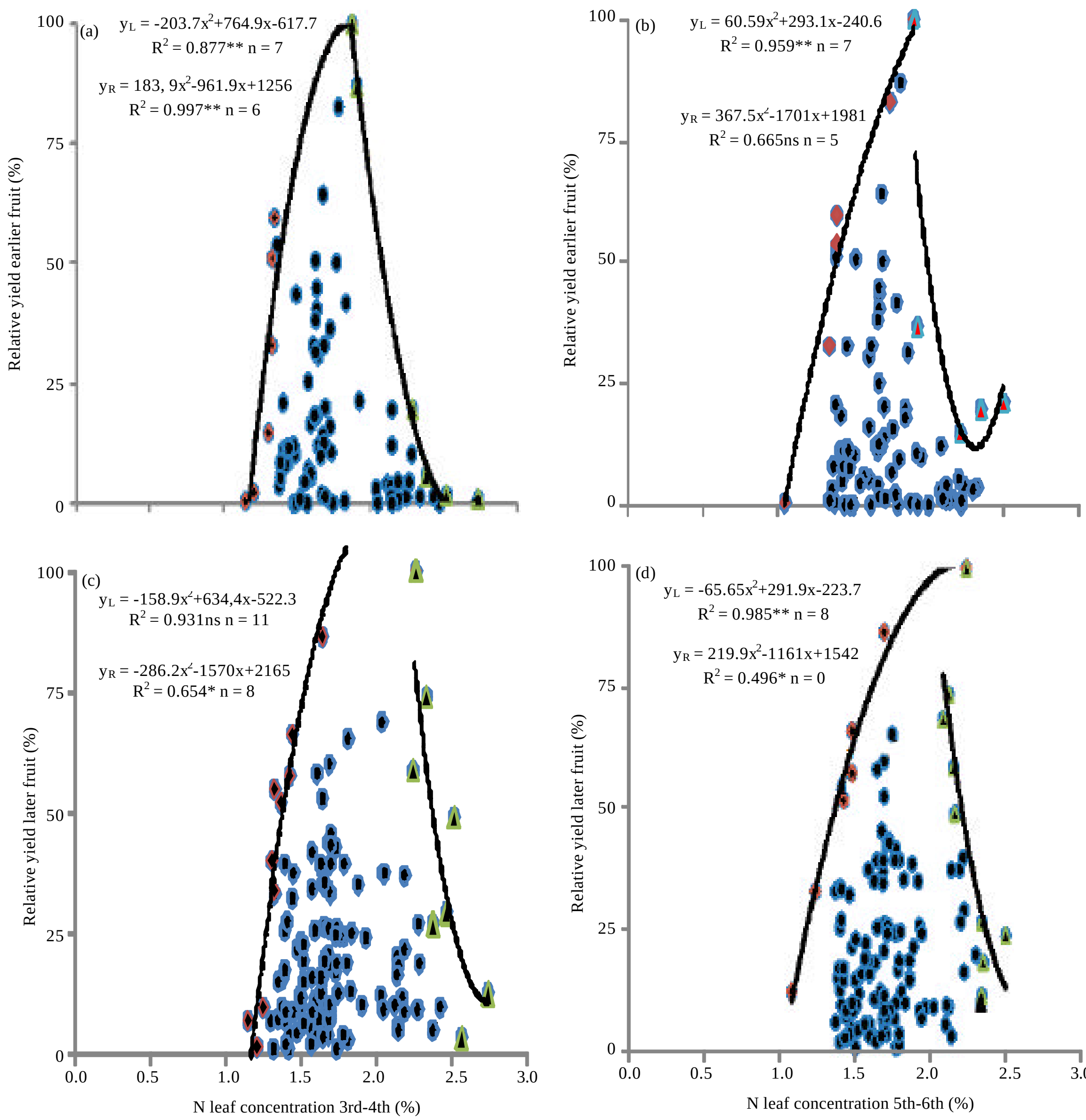

Fig. 2(a-d): Relationship between earlier and later relative yield with concentration of N leaf. 3-4 = Leaf at the finish trubus and 5-6 = Leaf at the earlier trubus

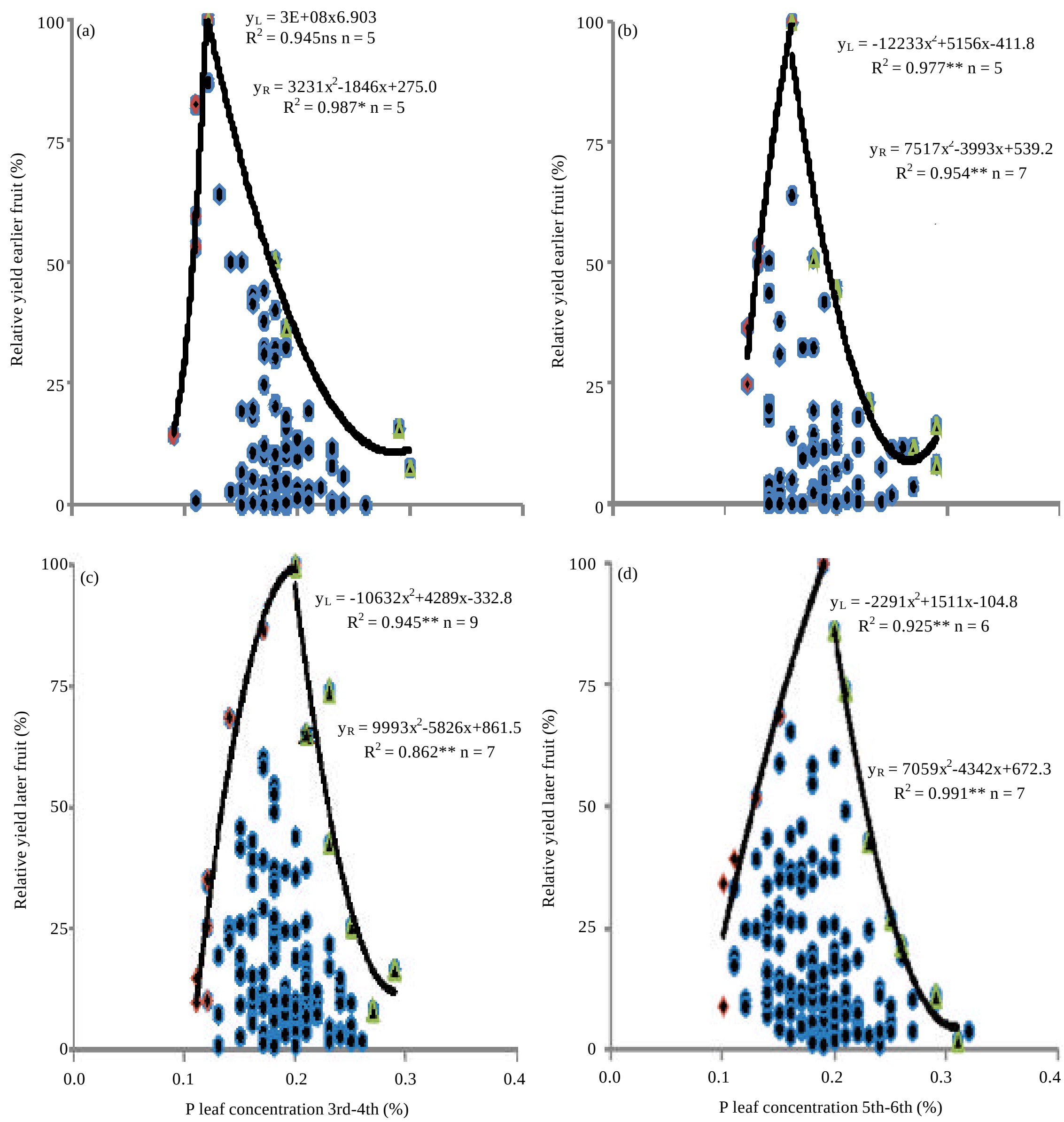

Fig. 3(a-d): Relationship between earlier and later relative yield with concentration of P leaf. 3-4 = Leaf at the finish trubus, 5-6 = Leaf at the earlier trubus

that relative yield of citrus related to leaf nutrient concentration, the lower the nutrient concentrations of leaves, the lower relative yield. However, high leaf nutrient concentration were also able to produce low yield because other factors affect the yield.

The calculation results to obtain boundary line for earlier and later relative yield for nutrient concentrations of nitrogen at 3rd-4th leaves are low (<1.38%), moderate (1.38-2.15%) high (>2.15%) and low (<1.48%), medium (1.48-2.00%), high (>2.00%). The calculation for 5th-6th leaves are low (<1.36%), moderate (1.36-2.22%), high (>2.22%) and low (<1.58%), moderate (1.58-2.11%) high (>2.11%). Criteria of nitrogen nutrient concentrations in 3rd-4th and 5th-6th

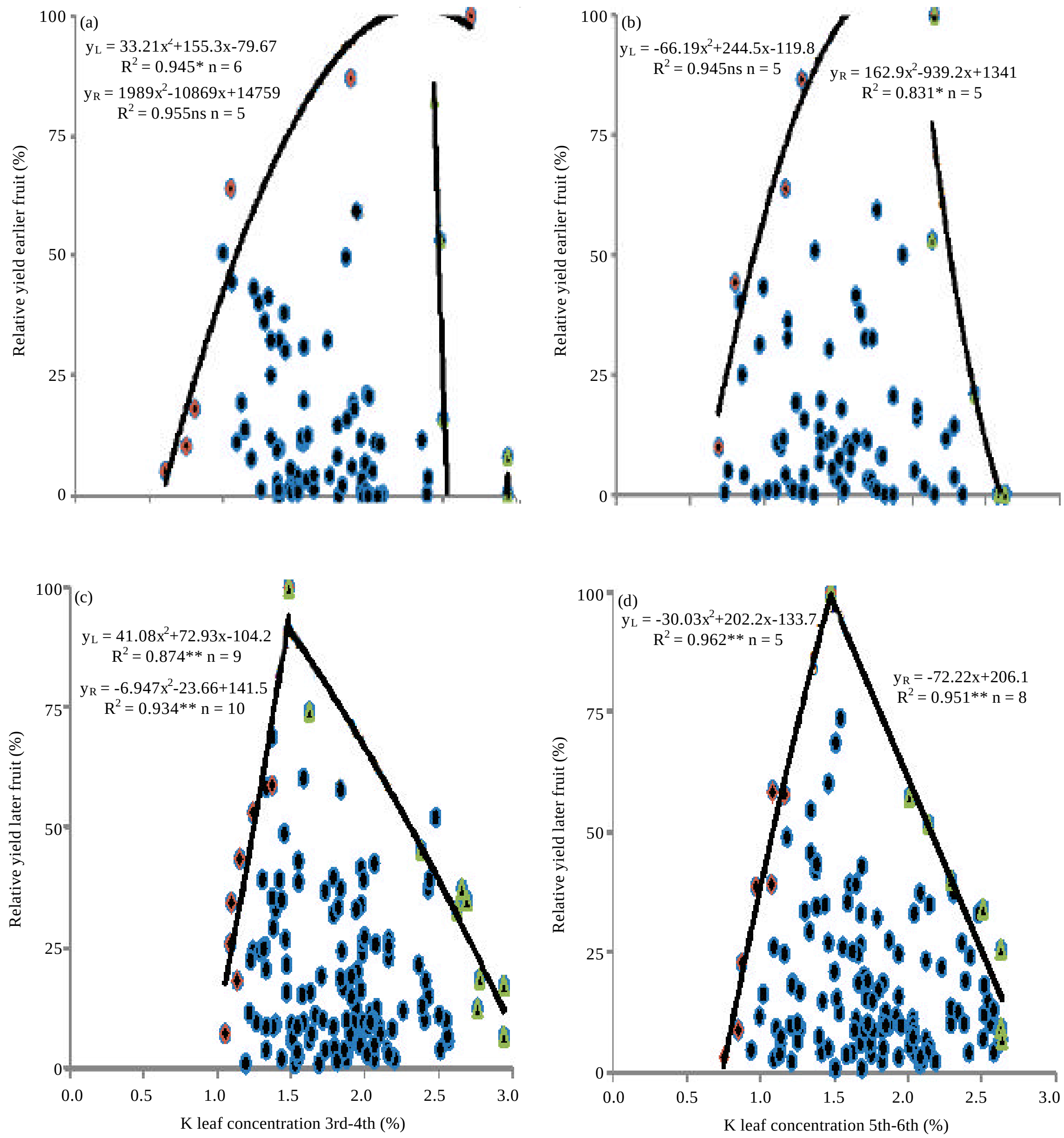

Fig. 4(a-d): Relationship between earlier and later relative yield with concentration of K leaf. 3-4 = leaf at the finish trubus, 5-6= leaf at the earlier trubus

leaves has two lines at the left and right sides. The higher concentration of nitrogen in 3rd-4th and 5th-6th leaves, the higher relative production and tend to lower by the higher concentration of nitrogen in 3rd-4th and 5th-6th leaves.

By substituting the production boundary line for earlier and later production on the two boundary lines, the nitrogen concentration in 3rd-4th leaves is around 1.38-2.15 and 1.48-2.00%, whereas nitrogen concentration in 5th-6th leaves is around 1.36-2.22 and 1.58-2.11% . By projecting the intersection of relative yield boundary line of earlier and later production on the X axis (nutrient concentration), then the best suitability of relationships in earlier relative yield is 85% and later 75% with nutrient concentrations in 3rd-4th leaves are 1.77 and 1.69% and 5th-6th leaves are1.79 and 1.87%.

The calculation results of earlier and later boundary line of production for phosphor nutrient concentrations (Fig. 3) is as follow: The 3rd-4th leaves are low (<0.11%), moderate (0.11-0.20%), high (>0.20%) and low (<0.15%), moderate (0.15-12.21%), high (>0.21%), respectively. The 5th-6th leaf is low (<0.13%), moderate (0.13-0.22%), high (>0.22%) and low (<0.16%), moderate (0.16-12.21%), high (>0.21%), respectively. Criteria of phosphor nutrient concentrations in 3rd-4th and 5th-6th leaves has two lines at the left and right sides. The higher concentration of phosphor in 3rd-4th and 5th-6th leaves, the higher relative production and tend to lower by the higher concentration of phosphor in 3rd-4th and 5th-6th leaves.

By substituting the production boundary line for earlier and later production on the two boundary lines, the phosphor concentration in 3rd-4th leaves are 0.11-0.20% and 0.15-0.21%, whereas, phosphor concentration in 5th-6th leaves are 0.13-0.22% and 0.16-0.21%. By projecting the intersection of relative yield boundary line of earlier and later production on the X axis (nutrient concentration), then the best suitability of relationships in earlier relative yield is 85% and later 75% with nutrient concentrations in 3rd-4th leaves are 0.16% and 0.19 and 5th-6th leaves are 0.18 and 0.19%.

The calculation results of earlier and later boundary line of production for Potassium concentrations (Fig. 4) is as follow: The 3rd-4th leaves are low (<1.02%), moderate (1.02-2.31%), high (>2.31%) and low (<1.43%), moderate (1.43-1.79%), high (>1.79%), respectively. 5th-6th leaf is low (<0.97%), moderate (0.97-2.04%) high (>2.04%) and low (<1.49%), moderate (1.49-1.53%), high (>1.53%), respectively. Criteria of potassium nutrient concentrations in 3rd-4th and 5th-6th leaves has two lines at the left and right sides. The higher concentration of potassium in 3rd-4th and 5th-6th leaves, the higher relative production and tend to lower by the higher concentration of potassium in 3rd-4th and 5th-6th leaves.

By substituting the production boundary line for earlier and later production on the two boundary lines, the potassium concentration in 3rd-4th leaves are 1.02-2.31 and 1.43-1.79%, whereas phosphor concentration in 5th-6th leaves are 0.97-2.04 and 1.49-1.53%. By projecting the intersection of relative yield boundary line of earlier and later production on the X-axis (nutrient concentration), then the best suitability of relationships in earlier relative yield is 85% and later 75% with nutrient concentrations in 3rd-4th leaves are 1.67 and 1.55% and 5th-6th leaves is 1.51%.

DISCUSSION

On average, 3rd-4th leaves from five years old trees showed higher concentration of N, P and K than 6, 7 and 8 years old while the 5th-6th leaves tend to have unstable N, P and K concentrations by age (Fig. 1). The similar results were reported by Liferdi (2011) on mangosteen which showed a decrease in the concentration of N , P and K with increasing of age. The same was found in alfalfa (Rominger *et al*., 1975) and the potato tissue (Dow and Roberts, 1982) in which N concentration decreased significantly with increasing of age. The pattern of nutrients changes, especially N, tends to decrease with increasing of age, although Ca and Mg increased in maize and soybean (Munson and Nelson, 1973). In addition to age, nutrient concentrations are also influenced by leaves position. Sumner (1977) reported that concentrations of N, P and K in soybean decreases with age, whereas concentration of N, P and K increased when the position closer to the leaf buds.

The results of correlation analysis between leaf nitrogen and yield show diverse closeness of the relationship. Overall, results of relationship between leaf nitrogen concentration with yield has associations with plant age as indicated by very low correlation coefficient. On average, 3rd-4th and 5th-6th leaf with five years old plant have the highest correlation coefficient compared with other plant age, although have a weak correlation coefficient.

The results of correlation analysis between leaf phosphorus and yield show diverse closeness of the relationship. Overall, relationship between leaf phosphorus concentrations with yield has associations with plant age as indicated by very low correlation coefficient. On average, 3rd-4th leaf with 8 years old plant have the highest correlation coefficient compared with other plant age while 5th-6th leaf have the highest correlation coefficient with 7 year old plant, although have a weak correlation coefficient.

The results of correlation analysis between leaf potassium and yield show diverse closeness of the relationship. Overall, relationship between leaf potassium concentrations with yield has associations with plant age as indicated by very low correlation coefficient. On average, 3rd-4th leaf with 7 years old plant have the highest correlation coefficient compared with other plant age while 5th-6th leaf have the highest correlation coefficient with five year old plant, although have a weak correlation coefficient.

Correlation coefficient of N, P and K leaf with pummelo citrus production show no close relationship between plant age with leaf position, but on average overall 3rd-4th leaf have higher concentrations, therefore more appropriate to be used as sample to determine the nutrient status. Due to physiological properties, these leaves has mature and serve as source as well as its availability is higher than 5th-6th leaves which are often not available or fall. The relationship between growth variables (age) and physiological condition of the trees have not shown a strong relationship to nutrient concentrations of pummelo citrus. The same has been reported by Srivastava (2011), that plant age, diameter and canopy position did not have a strong impact on growth and production.

Concentrations of N , P and K in 3rd-4th and 5th-6th leaf based on earlier and later relative yield shows differ average of N, P and K concentrations. The 3rd-4th leaf is higher than 5th-6th (as shown in Fig. 2-4). This difference may be caused by fruit loads per tree in which on average the earlier yield higher than the later. It is more due to the production nature namely alternative bearing that sometimes have higher and lower yield in a given year and even alternate bearing cultivars do not form flower in the following year after fruiting. This phenomenon is influenced by environmental factors, especially microclimate and plant endogenous factors (Embleton *et al*., 1973). Moreover, it also caused by depletion of carbohydrate reserves in all plant organs (Goldschmidt and Golomb, 1982). Sutopo *et al*. (2005) reported that for 100 kg of harvested fruits, many nutrients will be transported namely 0.52 kg N, 0.27 kg P_2O_5 and 1.06 kg K_2O. For mandarin orange, the values is 1.532 g N, 376 g P_2O_5 dan 2.465 g K_2O and sweet orange is 1.773 g N, 506 g P_2O_5 and 2.465 g K_2O (Srivastava, 2011).

Huang *et al*. (2012) reported that an additional adjustment of N and K on citrus fruit with a high burden through fertigation required ensuring fruit development, although high levels of fertigation is not always good. Research on persimmon tree (Choi *et al*., 2011) and apple (Neilsen *et al*., 2010) show that high fruit load need higher N and K element than others (Pedrero *et al*., 2012). Hernita *et al*. (2012) found that concentrations of N, P and K in the third leaf of duku with leaf position without fruit showed the best correlation with the yield. In mango, the best sample can be taken from the fifth leaf from the bottom at the time of flush after harvest

(Pushparajah, 1994). Menzel *et al.* (1992) on Lychee found that the best leaf can be derived from a flowering branch 1-2 weeks after panicel emergence. It is confirmed by the study of Jones *et al.* (1991), that the nutrient of N, P and K is mobile from leaves to the fruit.

CONCLUSION

The 3rd-4th leaf is the most appropriate to diagnose the status of N, P and K and has the best correlation with earlier fruit production than 5th-6th leaf and later fruit production in Pangkep pummelo citrus.

Concentrations of N, P and K in earlier fruit production with 3rd-4th leaf are low (<1.38; <0.11; <1.13%), moderate (1.38-2.15, 0.11-0.20, 1.02-2.31%) and high (>2.22; >0.20; >2.31%), respectively. The optimum concentration with 85% relative production are 1.77, 0.16, 1.67%, respectively.

Concentrations of N, P and K in later fruit production with 3rd-4th leaf are low (<1.48; <0.15; <1.43%), moderate (1.48-2.00, 0.15-0.21, 1.43-1.79%) and high (>2.00; >0.21; >1.79%), respectively. While the optimum concentration by projecting the target relative yield 75% are 1.69, 0.19, 1.55%, respectively.

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