Quantitative Recommendation of Phosphorus Fertilizer Based On The Correlation Between Phosphorus of Plant Organs and Soil Phosphorus In Washington Navel Oranges

Abdolkarim Ejraei (soilira@yahoo.com)
Islamic Azad University Jahrom Branch https://orcid.org/0000-0002-1826-8553

Research Article

Keywords: Soil Phosphorus, Regression Models, Washington Navel Orange, Fertilizer Recommendation, Integrated Plant and Soil System (IPSS)

Posted Date: May 13th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-512234/v1

Abstract

Aim

Many methods have been proposed to recommend plant nutrients, all of which are qualitative and based on the concentration of the element in the soil or leaves. But, in the "Integrated Plant and Soil System" (IPSS) method, there is a recommendation of fertilizer quantified and based on the correlation between concentration of elements in plant and soil organs.

Methods

In this study, 39 Washington Navel Oranges orchards were selected and in each orchard, three trees were chosen and sampled from roots, stems, leaves, fruit as well as the soil around the roots. Sampling was performed in late March and early May for two consecutive years and phosphorus was measured in the samples. After a correlation analysis between "soil properties and phosphorus of plant organs" with soil phosphorus, those factors that had a significant correlation with soil phosphorus were selected. And based on that, there was determined a regression model between them.

Results

Among all the studied factors, fruit phosphorus had the highest correlation with soil phosphorus. Based on that, two regression equations were obtained by which the required phosphorus can be calculated.

Discussions

Since the physicochemical properties of each element are different from the other, so the leaf alone cannot be a good indicator to determine the nutritional status of all elements. Therefore, it is more logical that the fertilizer recommendation of each element is based on the correlation between the element in that organ of the plant that has the highest correlation with that element in the soil.

Introduction

Nowadays, without regard to the nutrient elements of the soil, increasing production of crops in any region of the developing world will not be possible. One of the ways to improve the status of soil nutrient elements is application of fertilizers. These compounds, in addition to increasing the production and improving the quality of agricultural products, should not cause pollution of the environment and the accumulation of contaminants in the plant organs (Lu et al. 2013; Bujnovsky et al. 2016; Su et al. 2017). Phosphorus (P) as an essential nutrition element plays an important role in the physiological and biochemical processes of plants (Vance et al. 2003; Zambrosi et al. 2013; Ceulemans et al. 2017; Li et al. 2020). Among the essential nutrients, P has the greatest impact on the development and progress of reproductive organs, and as long as the P deficiency is not corrected, many products do not respond to nitrogen uptake (Sanchez 2007; Ford et al. 2016; Xiao et al. 2019; Pantigoso et al. 2020). In recent decade, much attention has been paid to the role and effect of excessive applied of P fertilizer on soil quality, crop quantity and the environment changes in around the world (Halitligil et al. 2002; Malhi and Lemke 2007; Halajnia et al. 2009; Ma et al. 2009; Valkama et al. 2009; Ferrise et al. 2010; Liang et al. 2011). Many studies have shown that excessive fertilizer uses by farmers who tend to produce more often does not always contribute to increase yields, but excessive apply causes the waste of fertilizer and its negative effects on the environment (Ju et al. 2009). Contamination of groundwater and surface (Le et al. 2010), greenhouse gas emissions (Zheng et al. 2004), accumulation of nutrient elements (Chen et al. 2006) and nutrient leaching (Zhang et al. 2005). So increasing the use of fertilizers will cause more and more problems for the environment in the world in future. Therefore, it is necessary to find a suitable fertilizer recommendation system that can not only improve the nutrient requirements for more production, but also helps maintain environmental sustainability (Xu et al. 2014). So far, various methods have been proposed to determine the status of nutrients in soil and plants, including morphological symptoms, soil test and plant analysis (Sajjadi 1992; Mourao Filho 2004; Robinson 2005). Also, Data results of soil and plant analysis in order to interpret and recommend fertilizer are evaluated by different methods, such as Critical Nutrient Concentration, sufficiency Range, Cate and Nelson diagram, Deviation from optimal percentage (DOP), Diagnosis and Recommendation Integrated System (DRIS (Cate and Nelson 1965; Beufils 1973; Dow and Roberts 1982). Although DRIS and DOP methods are more common than other methods, they also have weaknesses. The DOP method is not widely used due to lack of reference numbers for most plants (Lucena 1997). This method requires the collection of a series of data such as climate, topography, soil test, plant species, etc. If the accuracy of each factor is reduced, will be affected on the norm of each element. Also, the amount of the element in the soil or plant is not quantitatively and expressed with terms such as positive and negative (Ciesielska et al. 2002; Garcia-Escudero et al. 2013). In the DRID system, unlike other methods, the interpretation of leaf analysis results does not depend on the physiological age and site of sampling and in this method, the leaf is considered to be the most important place for plant analysis (Beufils 1973; Beverly et al. 1984; Sumner 1977). Efficiency of the DRIS method is when all the nutrients in the plant are examined together, so the limitation of this method is when only one or two elements of the plant are to be examined. Another weakness is the complexity of the method, which results in errors in the interpretation of the results and the recommendation of fertilizer, as well as deficiency or excessive amount of the element in the soil or plant is not expressed quantitatively and instead of that are used terms such as low, high or sufficient. As indicated the fertilizer recommendation is often based on the concentration of the element in the soil or plant, and there is less method in which the advice is based on the concentration of the element in the plant and soil (Vasileios et al. 2013). Also, in all available methods, the leaf is considered as the main organ of the plant to study the status of all nutrients, while the method of absorption, transfer, accumulation and role of each element in each organ is different from the other element in a plant. Therefore, it does not seem logical, leaves as an organ to determine the status of all the nutritional elements. Considering the above, and given that citrus fruits are evergreen and require more water and nutrients than deciduous plants, so to recommend fertilizer, there is necessary to use a quantitative method that not only provides plant nutrients but also does not pollute the environment. IPSS method can be a good system for fertilizer management and environmental protection. For these reasons the purpose of this research; 1) Determine the organ that the phosphorus content has the highest correlation with the phosphorus content of the soil. 2) Determine the model in which the fertilization recommendation is based on the relationship between the concentration of the element in the soil and the plant organs which is termed "integrated plant and soil system"(IPSS).

Material And Methods

Study area

The study was conducted in Jahrom (N 35, 32; E 28, 29) from March 2019 to June 2020, which is one of the most important citrus cultivation areas in Iran. The climate is arid to the semi-arid, the annual rainfall does not exceed 250 mm, and the average annual air temperature fluctuates around 21.24 centigrade. Agriculture, especially citrus and palm farming constitute the main economic activity of the local people.

Sampling and experimental analysis

In this research, 39 Washington Navel Orange (WNO) orchards were selected each from 8 to 10 hectares, and the average age of orchards in different areas of Jahrom was from 8 to 10 years. According to the previous years, yield and applied fertilizers were classified into three categories of low, medium and high yield gardens. Of these, 18 orchards were classified in a high yield group while more fertilizers were used (gardens in which 220-280 kg of ammonium sulfate and super triple phosphate, 250- 300 kg potassium sulfate, and 40-70 kg Magnesium sulfate were consumed in hectare per year and yields of 60 to 70-ton ha $^{-1}$). Meantime 10 orchards were used as the moderate group (in which 100-130 kg of ammonium sulfate and super triple phosphate, 20-40 kg of Magnesium sulfate were consumed in hectare per year and high yield of 30 to 40-ton ha^{-1}), And 11 orchards as low yields and low fertilizer consumption (with less than 80-100 kg of ammonium sulfate and super triple phosphate per hectare and yield of 10-20 tons per hectare in a year). In two consecutive years (2019, 2020), sampling was performed twice a year, the first sampling in late March and the second in the early May. Since 39 orchards were surveyed and three Washington Navel orange trees were chosen in each orchard and each tree was sampled four times in two consecutive years, thus totally 468 trees were sampled. It is very important that the two executive sample have time period correspondence (Estefan et al. 2013). Samples were taken from each side of the trees and from the roots, stems, old and young leaves, fruits and soil around the roots. Samples were packed in paper bags and transported to the laboratory (Carter 1993). Plant specimens were disinfected in 5% sodium hypochlorite, washed with distilled water and exposed to air to be dried (Campbell and Plank 1998; Jones 1998). Samples were Oven dried at 60 ° C, ground and kept in paper bags (Burton and David 1991; Fageria et al. 1991). After transferring soil samples to the laboratory, to reduce the activity of microorganisms, soil samples were kept at a temperature 1 - 2 ° C, and soil extract was prepared (Estefan et al. 2013; Brady and Weil 1999). Also, some physio-chemical properties of soil orchard samples were measured (Estefan et al. 2013; Bouyucos 1962), pH (Ryan et al. 1977; Ryan 2000), CEC (Sonmez et al.,2008; He et al. 2012), Organic matter (Walkley 1947; FAO 1974). The Olsen method was used to measure the content of soil and plant P (Olsen and Sommers 1982; Estefan et al. 2013). The range of changes in some physicochemical properties of the studied soils is shown in Table 1.

Table (1) Amplitude of changes in some Physicochemical properties of soil orchards.

Texture	pH	EC_e dSm^{-1}	$CaCo_3$%	OM%	CEC $Cmol^+$ Kg^{-1}
SL-CL	7.3-8.20	655-1420	34-40	1.15 -2.7	15.8-35.7

Data analysis

First, a correlation matrix was performed between each soil characteristic (pH, EC, OM, CEC), and P of plant organs (roots, stems, young and old leaves, fruit) with soil P (Table 2). Variables that had a significant correlation with soil P were selected and the correlation between those variables and soil phosphorus was investigated using multivariate regression analysis.

Table (2) Correlation coefficients of soil properties, soil available phosphorus and P in the plant organs in four sampling stages in all orchards.

	SAP[1]	OM	pH	EC	CEC	root	stem	Old leaf	Young leaf	fruit
SAP[1]	1	0.083*	-0.035 ns	0.075 *	0.064 ns	0.180**	-0.210**	0.894**	0.888**	0.916**
OM	0.083*	1	0.091	0.074*	0.795**	0.054 ns	0.047 ns	0.084*	0.088*	0.076*
pH	-0.035 ns	0.091 ns	1	0.081*	0.789**	-0.010 ns	-0.052 ns	-0.012 ns	-0.041 ns	-0.061 ns
EC	0.075 *	0.074 *	0.081*	1	0.031 ns	-0.036 ns	-0.013 ns	-0.011 ns	-0.081*	-0.079*
CEC	0.064 ns	0.795**	0.789**	0.031 ns	1	0.037 ns	0.041*	0.013*	0.015*	0.014*
root	0.180**	0.054 ns	-0.010 ns	-0.036 ns	0.037 ns	1	-0.071*	0.198**	0.206**	0.219**
stem	-0.210**	0.047 ns	-0.052 ns	-0.013 ns	0.041 ns	-0.071*	1	-0.233**	-0.225**	-0.213**
Old leaf	0.894**	0.084*	-0.012 ns	-0.011 ns	0.013 ns	0.198**	-0.233**	1	0.998**	0.987**
Young leaf	0.888**	0.088*	-0.041 ns	-0.081*	0.015 ns	0.206**	-0.225**	0.998**	1	0.993**
fruit	0.916**	0.076*	-0.061 ns	-0.079*	0.014 ns	0.219**	-0.213**	0.987**	0.993**	1

*' **'ns at the level of 5% and 1%, respectively, have a significant difference, not significant. 1- Soil Available Phosphorus

From these calculations, two regression equations were obtained, one for high-yield orchards and the other for all orchards. Which according to these two regression equations, the quantitative amount of P fertilizer required can be calculated (In the result, the calculation steps are shown with an example). Data analysis was performed by SPSS statistical software.

Results And Discussion

The correlation coefficients of soil properties, plant organs phosphorus with soil available phosphorus in all orchards and all four sampling showed a positive correlation between the soil phosphorus content and that in fruit (0.916**), young leaves (0.888**), old leaves (0.894**), root (0.180**) and a negative correlation with stem (0.210**). Phosphorus of all plant organs showed a positive significant correlation with each other (Table 2).

Regression model

As indicated in Table 2, in all 468 samples, among soil properties and plant variables, only plant P of organs (old and young leaves, roots, stems and fruits) showed a significant correlation with soil P. Using the Enter method, a significant model was obtained in which (R^2_{adj} = 0.962, N = 468, P <0.001) (Table 3).

Table (3) Analysis of variance between soil phosphorus and plant organs in four sampling stages in all orchards.

Model	Sum of Squares	df	Mean Square	F	Sig.	Adjusted R Square
Regression	475078.188	5	95015.638	2.3303	0.000[a]	
Residual	18796.335	462	40.773			0.962
Total	493874.524	467				

a. Predictors: (Constant), P fruit, P stem, P root, P old Leaf, P young leaf

Table (4) Regression coefficients of soil phosphorus and plant organs in four sampling stages in all orchards.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	- 96.4673	23.65421		-3.140	0.009
P root	-0.007515	0.003513	-0.020082	-2.139	0.033
P stem	-0.001826	0.002473	-0.006950	-0.738	0.461
P old Leaf	0.600533	0.018521	5.278000	32.425	0.000
P young Leaf	-0.759433	0.020242	-8.144850	-37.519	0.000

Although P of the stem had a significant correlation with the soil available P in the bivariate regression, but in the multivariate regression equation did not indicate a significant correlation (Tables 2 and 4). According to Table 4, the non-standardized regression coefficient (B) in the model for estimating the soil available P can be as follows:

$Y_1 = -96.4673 + 0.600533X_1 + 0.438697X_2 - 0.759433X_3 - 0.007515X_4$

Where: Y_1= soil available phosphorus, X_1= phosphorous concentration in old leaves, X_2= phosphorous concentration in fruits, X_3= phosphorous concentration in young leaves, X_4= phosphorous concentration in roots.

Considering that there is a significant correlation between P of plant organs, and there is a strong correlation between P of plant organs and also the highest correlation between P of fruit and P of other plant organs (Table 2). The mentioned multivariate regression equation can be simplified. For this purpose, on the right side of the equation, instead of the average P of plant organs (X_i), the ratio between the average P of that organ and fruit P (X_1) is set (Table 5). Therefore, the multivariate equation becomes a bivariate equation, and instead of measuring P in all plant organs, only fruit P is measured. As a result, above-mentioned model was more simplified while keeping its precision and effectiveness.

Table 5: Phosphorus amount in soil and plant organs in four sampling stages in all orchards.

	SAP*	Root	Stem	Old Leaf	Young Leaf	Fruit
Average Concentration (mg Kg^{-1})	29.249	268.949	365.648	1088.77	1309.29	1058.02

*Soil Available Phosphorus

$\frac{root}{Fruit} = 0.25420$ $\frac{Old\ Leaf}{Fruit} = 1.02906$ $\frac{Young\ Leaf}{Fruit} = 1.23749$

Y_1= – 96.4673 + (0.600533) (1.02906) X_1 + (0.438697) X_1 – (0.754933) (1.23749) X_1 – (0.007515) (0.25420) X_1

With arithmetic summation of X1 in the both side of the model:

Y_1= – 96.4673 + 0.120549X_1 (Formula A)

Y_1= soil available phosphorus (mg Kg^{-1}), X1= P concentration in the fruits (mg Kg^{-1})

Regression model in high yield orchard

In high-yield orchards (n = 216), as in other orchards, there was a significant correlation between soil P and P of plant organs, and the highest correlation was among fruit P with soil P and plant organs P. Therefore, a multivariate regression equation was written between soil P and plant organs P. Then, using the Enter method, a significant model was obtained (R^2_{adj} = 0.982, 216 = N, 0.001> P) (Table 7).

Table (6) Analysis of variance between soil phosphorus and plant organs in four sampling stages in high yield orchards.

Model	Sum of Squares	df	Mean Square	F	Sig.	Adjusted R Square
Regression	115726.700	4	28931.675	564.102	0.000[a]	
Residual	10821.763	211	51.288			0.982
Total	126548.463	215				

a. Predictors: (Constant), P fruit, P stem, P root, P old Leaf, P young leaf

Table (7) Regression coefficients of soil phosphorus and plant organs in four sampling stages in high yield orchards.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	-121.3799	26.065		-4.657	0.000
P old Leaf	0.61211	0.030	5.123	20.691	0.000
P young Leaf	-0.78920	0.031	-8.256	-25.486	0.000
P root	0.005455	0.000537	0.09566	10.866	0.006
P fruit	0.47110	0.015	3.966	30.736	0.000

In this regression model, β coefficient for fruits, root and old leaves P variables were positive predictive, and for young leaves it was a negative predictive effect. Although, steam P had a significant correlation with soil available P in bivariate regression, but in the multivariate regression equation, there was no significant correlation with soil available P (Table 6 and 7). Regarding unstandardized regression coefficients (B), The resulted model can be displayed as follows (Table 7).

Y_2= - 121.3799 + 0.005455X_1 + 0.47110X $_2$ + 0.61211X X_3 – 0.78920X_4

Which: Y_2= soil available phosphorus, X_1= phosphorous concentration in root, X_2= phosphorous concentration in fruits, X_3= phosphorous concentration in old leaves, X_4= phosphorous concentration in young leaves.

Since P of plant organs had a significant correlation, and the highest correlation was between soil available P and fruit. The mentioned multivariate regression equation can be simplified. For this purpose, according to the table 8, on the right side of the equation, instead of the average P of plant organs (X_i), the ratio between the average P of that organ and fruit P (X_2) is set. Therefore, the multivariate equation becomes a bivariate equation, and instead of measuring P in all plant organs, only fruit P is measured (Formula B):

Table (8) Phosphorus amount in soil and plant organs in four sampling stages in high yield orchards.

	SAP*	Root	Stem	Old Leaf	Young Leaf	Fruit
[illegible] (mg Kg^{-1})	37.989	293.240	330.311	1310.940	1576.450	1273.899

*soil available phosphorus

$\frac{Root}{Fruit} = 0.23019$ $\frac{Old\ leaf}{Fruit} = 1.02908$ $\frac{Young\ Leaf}{Fruit} = 1.2375$

$Y_2 = -\ 121.3799 + (0.005455)\ (0.23019)\ X_2 + (0.47110)\ X_2 + (0.61211)\ (1.02908)\ X_1 - (0.78920)\ (1.2375)\ X_2$

With arithmetic summation of X1 in the both side of the model:

$Y_2 = -\ 121.3799 + 0.1256308X_2$ (**Formula B)**

Y_2= soil available phosphorus (mg Kg^{-1}), X2= P concentration in the fruits (mg Kg^{-1})

The regression model obtained from four sampling stages of all orchards as well as high-yield orchards showed that there is a significant correlation between soil phosphorus and phosphorus of Washington Navel Orange organs. As mentioned, the result of this research is two formulas. Formula A, which shows the correlation between fruit P (X_1) and soil P (Y_1) in all orchards. The second formula (B), shows the correlation between fruit P (X_2) and soil phosphorus in high-yield orchards (Y_2). If in Formula (B) instead of X_2, the average P concentration of the fruit is replaced from Table 8, the amount of soil P (Y_2) will be obtained in high-yield orchards. Which is the norm of soil P in this region for orange plants. Also in which orchard probably has P deficiency, in formula (A) instead of X_1 is put the fruit P of that orchard, and the soil P of this orchard (Y_1) will be calculated. Therefore, by Subtracting Y_1 from Y_2, the required P is calculated quantitatively. The following example shows the application of this method and its formulas in fertilizer recommendation:

Suppose the concentration of fruit P in one of the citrus orchards of Jahrom is 975 mg kg^{-1} dry matter, if the distance from one tree to another is 4 meters, the average root depth is 80 - 120 cm, the average root expansion radius is 1.2 meters. To supply P, use triple superphosphate fertilizer (30% P) and the efficiency of fertilizer is 78%. To reach the desired level of P, how much of this fertilizer is required in a ten-hectare orchard?

At First, put the amount of fruit phosphorus in formula (A) to obtain the concentration of soil available P (21.068 mg kg^{-1}). On the other hand, the average fruit P in high yield orchards is 1273.899 mg kg^{-1} (table 8), by putting this amount in Formula B, the norm concentration of P in the soils of this region for oranges will be 38.661 mg kg^{-1}. Therefore, if subtract the amount of soil P from the norm concentration of the area, the amount of P required for that orchard will be 17.593 mg kg^{-1} soil.

$Y_2 - Y_1$ => 38.661 - 21.068 = 17.593 mg P kg^{-1} soil   Average P required per kg of soil

Average soil weight around the roots of each plant:

$M = B_d * h * A \Rightarrow W = Bd * h * \Pi r^2$

$M = 1350 * (1.20 - 0.80) * 3.14*(1.2)^2 = 2441.66$ Kg

M= soil weight (Kg), A = Root spread area (m^2), h= Average root depth (m), B_d = Bulk Density (Kg m^{-3}), r = Radius of root expansion (m)

Since the area occupied by each tree is 16 m^2 and the orchard area is 10 hectares (10 * 10,000= $1*10^5$ m^2), so the number of trees in this orchard is:

$N = 1*10^5 : 16 = 6250$ Number of orchard trees

Therefore, the amount of soil at the average depth of tree roots in this orchard is:

$W = M * N \Rightarrow 2441.66 * 6250 = 15260375$ Kg

W= Average soil weight around the roots of all trees in this orchard.

As calculated, the amount of P required for each kilogram of soil is 17.593 mg. It is also assumed that superphosphate fertilizer has 30% P and its efficiency in soil is 78%, therefore, P fertilizer require per each hectare is:

$F = 1526037.5 * (17.593 * 10^{-6}) * (100: 30) * (100: 78) = 118.73$ Kg ha^{-1}

F= Phosphorus fertilizer require (Kg ha^{-1})

Discussion

As shown in all 468 samples, there is a significant correlation between soil P and P of plant organs, and the highest correlation is between soil phosphorus and fruit P (0.916**). On the other hand, P of all plant organs has a significant positive correlation with each other and the highest level of correlation is between the P of each organ with the P of the fruit. This may be due to the role of P in the growth and development of plant reproductive organs (Lihong Wei and Qiuxi Zhai 2010; Zhu et al. 2014; Kiminori Yoshikawa et al. 2015; Zhang Zhihong et al. 2017; Santos et al. 2018; Wei Feng et al. 2020). According to the results, it seems that fruit P is a more suitable indicator for examining the status of P in this plant than soil P or P of other plant organs. Therefore, it seems more logical that fertilizer recommendation should be based on the intensity of the correlation between the concentration of element (P) in the soil and plant organs, not just the concentration of element (P) in the soil or a specific plant organ such as leaves (Slavich and Petterson 1993; Shaw 1994; Zhang et al. 2005; Sonmez et al. 2008; Ejraei et al. 2018, 2019). While almost all fertilizer recommendation methods are qualitative and are not able to determine quantitatively of fertilizer required. In some of the most popular methods, such as DRIS, the ratio between the elements is examined instead of the concentration of the elements (Beufils 1973; Hundal et al. 2005; Nayak et al. 2011; Raghupathi and Srinivas 2014; Gott et al. 2017). In CNC and CNR methods, the status of nutrients in the soil or plant is expressed in terms of Low, High and Medium (Venkatesh et al. 2014; Beranger et al. 2015). Also in DOP method, the concentration of elements in the plant is shown with Positive and Negative terms (Montañes et al. 1993; Lucena 1997; Sanz 1999; Ignacio et al. 2016). And in none of them the amount of element required is not calculated quantities. The method used in this study is called Integrated Plant and Soil System (IPSS). In this system contrary to the methods mentioned, the recommended fertilizer is based on the correlation between each divisive element in the soil and plant organs. This method (IPSS) is quantitative and fertilizer required for each element is precisely measurable. On the other hand, in most fertilizer recommendation methods, the leaf is an indicator for determining the nutritional status of all the elements and the basis for their fertilizer recommendation. While, the chemical properties and the role of each element in each of the plant organs is different from other elements. Therefore, it is more logical that fertilizer recommend is based on the relationship between the concentration of the element in the soil and that plant organ, which has the highest correlation with the concentration of that element in the soil, not merely based on the concentration of phosphorus (element) in the soil or plant leaves. The method used in this study is called Integrated Plant and Soil System (IPSS). In this system contrary to the methods mentioned, fertilizer recommendation is based on the correlation between the element in the soil and plant organs. This method (IPSS) is quantitative and fertilizer required for each element is precisely measurable. On the other hand, in most fertilizer recommendation methods, the leaf is an indicator for determining the nutritional status of all the elements and the basis for their fertilizer recommendation. While, the chemical properties and the role of each element in each of the plant organs is different from other elements. Also in recent years, many agricultural researchers have proven the correlation between soil nutrients and plant organs (Sharpley et al. 1989; Samira et al. 2003; Kiminori Yoshikawa et al. 2015). Another important point to note is that the behavior of elements such as P in the soil is very complex and therefore there are different methods with various extractors to measure P in the soil. But the amount of phosphorus measured in a soil is not the same in any of them (Bray and Kurtz 1945; Lindsay 1979; Mehlich 1984; Soltanpour and Schwab 1977). In IPSS, the amount of soil P is accurately measured only once to determine the Norm concentration of phosphorus in pilot studies. By measuring plant P and correlation between soil P and plant phosphorus can determine the amount of P fertilizer required. Which is another advantage over conventional methods.

Abbreviations

Integrated Plant and Soil System (IPSS), Phosphorus (P), Washington Navel Orange (WNO).

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