Determination of the Critical Phosphorus Concentration for Corn (*Zea mays* L.) Using the EBB and Flow System

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Abstract

An experiment was conducted to evaluate and assess the suitability of ebb and flow system in determining the critical concentration of phosphorus in plant tissue. There were five treatments consisting of different levels of P added in the form of $NaH_2PO_4*H_2O$ arranged in a Completely Randomized Design. Parameters such as plant dry matter yield and biomass were gathered at the end of the experiment. Results showed that the critical P concentration of corn at the early stage of growth using the ebb and flow hydroponic system was 0.29 % wherein the dry matter yield highly correlates with the P concentration of corn (r = 0.98). The result was nearly within the range of critical P levels obtained using different methods. It is concluded that ebb and flow hydroponic system is very useful for plant nutrition studies and the use of the method is highly recommended in any studies involving plant CNC determination.

Keywords: Critical P concentration, corn, ebb and flow system

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INTRODUCTION

Critical nutrient concentration (CNC) refers to the nutrient concentration where plant growth first begins to decrease. It is located at the boundary between the deficiency and adequacy zone (Alsaeedi and Elprince, 2000). Determination of CNC serves as basis for fertilizer recommendation in any crops. Critical nutrient levels of plants differ from maturity plant part. As the plant matures, nutrient composition in different parts changes. In CNC determination, the plant part to be selected for the analysis must have the following characteristics: it should be comparable for all plants at all sample dates; it must have a sharp transition zone between deficiency and adequacy zone; should have a broad range of nutrient concentrations between the deficiency and abundance; and must contain constant critical concentration and should be easy to sample (Alsaeedi and Elprince, 2000).

Phosphorus (P), which is present in plant tissue in small amount, is one of the macro nutrients needed by the plants for proper growth and development. It highly influences plant metabolism through its role in respiration and in making food for plants (Rosen, et al., 2014). It is a part of amino acids and the main component of ATP which is the energy carrier in the plant. Deficiency of P in the plant tissue may result to purple coloration due to anthocyanin production. Crops which are deficient with P delay maturity and develop stems that are slender affecting the overall performance of crops. Plants required P at high amount during early stage of growth. Unlike N and K, the concentration of P in the plant tissue is relatively lower.

Ebb and Flow or the Flood and Drain system is a form of soilless system in growing crops. The system consists of a nutrient solution, submersible pump, container for both solution and plant, timer, tubes and a growing medium enough to anchor the plant. In the process, the solution from the container is being pumped up into the plant roots through tubes connecting the system. The solution is allowed to stay for a specified time before it is drained back into the reservoir. The pumping and draining of solution work with a timer for a specific period of time which allows the solution to be aerated and the nutrients to be continuously supplied for the plant (Niekerk, 2015). In the case of corn, information on its critical phosphorus concentration is already available, hence this study is to evaluate and assess the suitability of ebb and flow system in determining the critical concentration of phosphorus in plant tissue.

MATERIALS and METHODS

Preparation of Nutrient Solution

Nutrient solution was prepared using Hoagland culture solution as described by Taiz And Zeiger (2002). Slight modification on the composition was made (Table 1). Phosphorus application was varied for each treatment.

Table 1. Composition of a Modified Hoagland Nutrient Solution*

Salts	Stock solution (g 100 ml^{-1})	Volume of stock solution (ml L^{-1})
Macronutrient		
KNO_3	10.10	6
$Ca(NO_3)_2 \cdot 4H_2O$	23.62	4
$MgSO_4 \cdot 7H_2O$	24.65	2
Micronutrient	**(g 20 ml^{-1})**	
H_3BO_3	0.286	1
$MnCl_2 * 4H_2O$	0.181	
$ZnSO_4 * 5H_2O$	0.022	
$(NH_4)_2MoO_4 * 4H_2O$	0.080	
$CuSO_4 * 5H_2O$	0.002	
$FeCl_2 * 4H_2O$	0.178	10
Na_2EDTA	0.373	

* Source of P = ($NaH_2PO_4 * H_2O$)

Nutrient Solution Management and Plant Set-up

Carefully selected two-week old corn seedlings were grown hydroponically in a soilless medium employing the flood and drain (ebb and flow) system. Plant roots were flooded every after 3 hours during the day (5 hours during the night) with nutrient solution from the reservoir using a submersible pump. The solution was allowed to drain from the roots by gravity every after 15 minutes of submergence. The nutrient solution was kept aerated until harvest. For the application, 8 liters of nutrient solution was placed for each container. The level of solution in the container was maintained up until harvest (weekly addition of nutrient solution was made).

Experimental Design and Pot Layout

The experiment was conducted at the screenhouse of the National Abaca Research Center (NARC), Visca, Baybay City, Leyte. It was carried out in a Completely Randomized Design (CRD) with 5 nutrient solution containers containing different levels of P as treatments having 4 pots each as replicates. The different treatments were designated as follows:

T_1 = 0 mg P L^{-1} solution
T_2 = 8 mg P L^{-1} solution
T_3 = 16 mg P L^{-1} solution
T_4 = 24 mg P L^{-1} solution
T_5 = 32 mg P L^{-1} solution

Biomass Determination

Dry matter yield (g plant^{-1}) – This was determined by weighing the fresh plant parts composed of roots and shoots. Samples were oven-dried at 70 ^{o}C until constant weight was attained. The dry matter yield was calculated as follows:

Dry matter yield (g plant^{-1}) = Total dry weight of leaves + Total dry weight of stalk + Total dry weight of roots

Plant Tissue Analysis

At the end of the experimental period, plant samples were thoroughly cleaned with distilled water along with drying for the determination of total P (%) content. Tissue samples were mixed and a replicate was gathered out of the composite sample and was used for the analysis. After that, plant materials (leaves) were placed in a properly labeled paper bags and were placed in a forced draft oven set at 70 ^{o}C until constant weight was attained. The oven-dried samples were weighed and were ground to a particle size of 1.0 mm using a stainless Wiley Mill grinder. The ground samples were stored in a properly labeled coin-envelops until analysis of nutrient was done.

Total P was analyzed by dry ashing. For each sample, a 0.5 g oven-dried sample was placed in a crucible and was transferred into a muffle furnace at 550 ^{o}C for 6-8 hours. The white ash for each sample was soaked in a concentrated HCl solution, filtered and was used for the analysis of total P. The result was quantified using spectrophotometer with ascorbic acid as reducing agent (Murphy and Riley, 1962) and the absorbance was measured using the spectrophotomer.

Data Analysis

The data gathered was analyzed using the STAR software version 2.0.1. Analysis of variance (ANOVA) was used to test the significant effects among treatments and was separated following the Duncan's Multiple Range Test at 5 % level of significance.

RESULTS and DISCUSSION

Dry Matter Production

Total plant dry matter, which is the result of the integration of all plant processes, is the most important parameter in the study of plant canopies. Mineral elements which include phosphorus (P) affect growth and development and subsequently dry matter accumulation of plants if altered (Lauron, 2002). In the study, varying levels of P applied did not significantly affect the dry matter production of corn seedlings (Table 2). Highest dry matter yield (19.06 g plant^{-1}) was obtained from the control group, the one without P application. On the otherhand, lowest dry matter yield (14.00 g plant^{-1}) was obtained from seedlings treated with 32 mg P L^{-1}. The result did not conform on the findings of Li et al., 2010; Temegne et al., 2015 that increased P application significantly increased total dry biomass of celery and a decrease P concentration significantly decreased the total biomass of three voandzou varieties studied, respectively. Under P deficient environment there is a preferential allocation of plant biomass into the roots causing it to expand and enlarge. Plants react to P deficiency by allocating more resources on the production of roots up to the point that increased above ground biomass is suppressed (Temegne et al., 2015).

Figure 1. Two week old corn seedlings hydroponically grown using ebb and flow system with varying levels of P (*levels were 24, 32, 8, 0 and 16 ppm arranged from right to left*)

Table 2. Average dry matter yield (g plant^{-1}) of corn hydroponically grown using ebb and flow system with varying levels of P (mg L^{-1}) at early stage of growth

P levels	Dry matter yield
T_1 – 0	9.53
T_2 – 8	7.19
T_3 – 16	8.60
T_4 – 24	8.12
T_5 – 32	7.00
LSD Value	
CV (%)	23.10

P Uptake of Corn Seedlings

Essential elements are nutrients required by the plants for proper growth and development. The uptake rate of these nutrients is dependent on the rate of plant growth (Marschner, 2012). Roy, 2006 added that the nutrient uptake of plant is low at early stage which increases rapidly until maximum dry matter is attained and declines towards crop maturity. In the study, control group has the lowest uptake (16.06 mg P plant^{-1}) among treatments involved. The highest value (36.56 mg P plant^{-1}) was observed in the samples treated with 16 mg P L^{-1}. P uptake of corn seedlings increased as the concentration of P in the solution was increased (0-16 mg P L^{-1}) and falls down as P concentration was further increased (16-32 mg P L^{-1}). However, statistical analysis revealed that varying levels of P applied did not significantly influenced the P uptake of corn seedlings at early stage of growth (Table 3). The result was in contrast on the findings of others that P application has a significant effect on P uptake of plants. According to Bargaz et al., 2012, low P application has significantly reduced the P uptake and subsequently the growth of *Phaseolus vulgaris*, regardless of its genotype.

Table 3. P uptake (mg P plant^{-1}) of corn hydroponically grown using ebb and flow system with varying levels of P (mg L^{-1}) at early stage of growth*

P levels	P uptake
T_1 – 0	16.06
T_2 – 8	19.36
T_3 – 16	36.56
T_4 – 24	32.46
T_5 – 32	27.59
LSD Value	
CV (%)	25.71

***** mean values from different treatments

Critical Phosphorus Concentration

Critical nutrient concentration (CNC) is defined as the concentration of which the plant needs to produce near maximal growth. It is the concentration at which plant weight is reduced to 90% of the maximum (Burns, 1992). It is based on the relationship between the nutrient concentration and the plant yield which changes with the age of plant (Bates, 1970). In the study, it was found out that the critical P of corn at early stage of growth was 0.29 % (Figure 2).

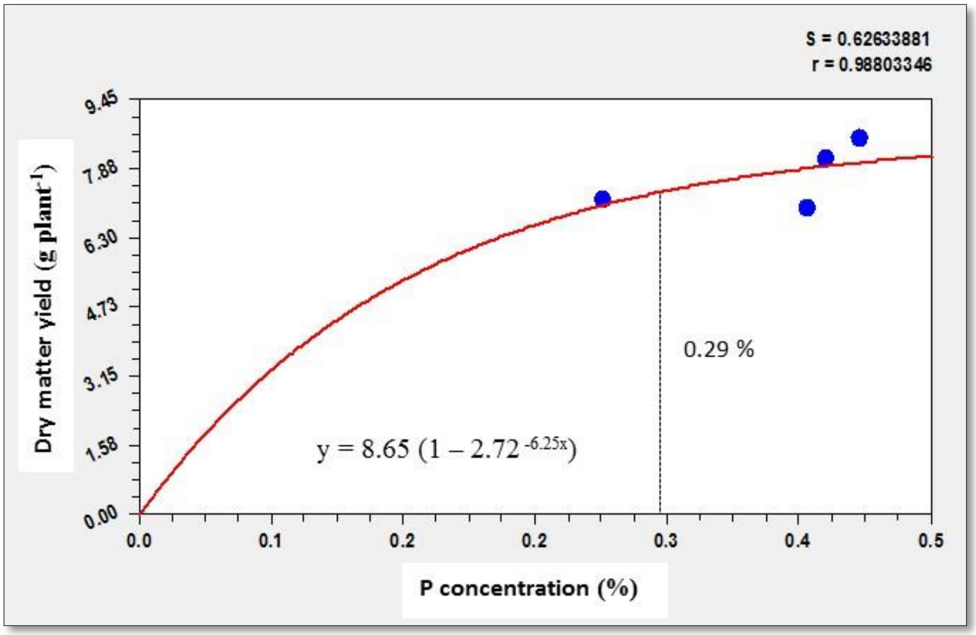

Figure 2. Critical P concentration of corn at early stage of growth

Percent P levels in the tissue highly correlates with the dry matter production of corn with a very high r value of 0.98 (i.e. exponential association). According to Cox and Barnes (2006), the critical P concentration of corn was 23 %.

Regardless of the flaws in the analysis and the actual conduct of the study, the result was nearly within the range from several studies employing different techniques in the determination process.

CONCLUSIONS and RECOMMENDATIONS

Based on the result, it can be concluded that P affects growth of plants however, variations greatly depends on the kind of environment they were in. The study revealed that the critical P concentration of corn which is 0.29 % is nearly within the range of levels obtained using other methods. This implies the suitability and the usefulness of the ebb and flow hydroponic system in CNC determination of plants. For further improvement, similar studies should be conducted to verify the results obtained from the experiment. It would be better if studies related to CNC will be conducted in a tight or highly controlled environment to avoid unnecessary deviations from the expected results. Moreover, responses of the varying P levels applied on the growth parameters (i.e. plant height, leaf width, length and area, base diameter and root length) should be included to support possible results on the biomass and uptake of plant samples. Based on the result, the use of flood and drain hydroponic system is highly recommended in any plant nutrition studies focusing on plant CNC determination.

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