Determination of Critical Potassium Concentration of Corn (*Zea Maize L.)* at Early Stage of Growth Using Flood and Drain Technique

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Abstract

Critical nutrient concentration is defined as the level that results in 90% of maximum yield or growth which can also be used as a basis in formulating recommendations. An experiment using hydroponically grown corn to determine the critical potassium concentration at its early stage of growth and to assess the suitability of the flood and drain technique. Five (5) treatments used in the experiment which consist of different levels of potassium using KCl arranged in a Completely Randomized Design. There was no significant difference observed in biomass and potassium content of the plant tissue. On the other hand, critical potassium concentration was observed in 2.1% which correlates to the plant biomass and has an r-value of 0.99. This finding suggests that the flood and drain technique is suitable in determining the critical potassium concentration of corn and also this could be useful to an experiment that also involves CNC determination.

Keywords: Critical K concentration, corn, flood and drain technique/ ebb and flow system

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INTRODUCTION

Corn (*Zea maize* L.) locally known “mais” is next to rice as the staple food for the most Filipinos, which is also considered as an important source of energy. About 20.8 % of the total population in the country eat corn, especially in the Visayas region (Boda, 1965). According to Successful Farming (1996), corn is the most highly valued of all cereal grains for it is multifarious uses of human food, as an important raw material and a vital ingredient for a variety of industries such as paper, beverages, corn starch, corn oil, plastics, high valued feeds, industrial chemicals, medical products, pharmaceuticals, ethanol and many more. Approximately 26% of the country’s area are devoted to corn production or approximately 3,432,700 hectares of agricultural land (PCARR, 1975). However, it is important to increase food production to be able to meet the food demand of the continuing population of the country.

Plants require 17 essential elements for growth; carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), potassium (K), Sulphur (S), calcium (Ca), magnesium (Mg), boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), and zinc (Z). These essential elements are also called nutrients. The first group is the three macronutrients that plants can obtain from water, air or both (C, H, & O) the soil does not need to provide these nutrients, so they are sold as fertilizers. The other 14 essential elements are split into two groups- soil-derived macronutrients and soil-derived micronutrients. The split is based on the actual amount of nutrients required for adequate plant growth. One of the examples of soil-derived macronutrients is potassium (K), potassium (K) is needed by plants in a considerably large amount together with nitrogen (N), and phosphorus (P).

Potassium has many different roles in plants, in fact according to Min Wang et. al, (2013) potassium (K) is an essential nutrient that affects most of the biochemical and physiological processes that influence plant growth and metabolism. Potassium is also important for water and energy relationships and has been linked to improved cold hardiness. Since potassium is mobile in plants, deficiencies can be diagnosed by looking at the older plant tissue/leaves. Deficiencies appear along the outer margins of older leave as streak or spots of yellow (mild deficiencies) or brown (severe deficiencies).

Correct fertilization is necessary to maximize net returns from field crop production. Critical nutrient concentration or CNC is a term both common in soil and plant analysis. In plant analysis, it is defined as the level that results in 90% of the maximum yield or growth (Lal, 2017). Determining the CNC for every crop could also serves as a basis in formulating fertilizer recommendations.

Flood and drain technique by ebb and flow is a popular hydroponics, a method of growing plants in water rather than in soil. Drain system uses soilless media, the container that contains nutrient solutions will be pumped into the plants using an aerator for a specified time. In the case of corn, information on the critical potassium concentration of corn is available, hence this study is conducted. Hence, this particular research study was conducted to reassess the critical potassium (K) content of corn and to evaluate the suitability of the ebb and flow system in determining the critical concentration of potassium at the early stage of growth.

MATERIALS and METHODS

Preparation of Nutrient Solution

Eight (8L) modified Hoagland's solution as described by Taiz and Zeiger (2002) was prepared in the study. The modification was made in the composition of the solution (Table 1). Potassium application was varied for each treatment.

Table 1. Composition of a Modified Hoagland Nutrient Solution*

Salts	Stock solution ($g\ 500\ ml^{-1}$)	Volume of stock solution ($ml\ L^{-1}$)
Macronutrient		
$Ca(NO_3)_2 \cdot 4H_2O$	118	4
$Na(NO_3)$	42.5	6
$MgSO_4 \cdot 7H_2O$	123	2
$NH_4H_2PO_4 \cdot H_2O$	66	1
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	
$FeCl_2 * 4H_2O$	0.89	10
Na_2EDTA	1.865	

* Source of K = $KCl * H_2O$

Nutrient Solution Management and Plant Set-up

Each container was transplanted with corn seedlings of almost the same size and vigor was grown hydroponically in a soilless medium employing the flood and drain (ebb and flow) system. Plant roots were flooded every after 2 hours daily 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.

Experimental Design and Pot Layout

The experiment was conducted at the screen house 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 N as treatments having 4 pots each as replicates. The different treatments were designated as follows:

T_0 = 0 mg K L^{-1} solution
T_1 = 30 mg K L^{-1} solution
T_2 = 60 mg K L^{-1} solution
T_3 = 90 mg K L^{-1} solution
T_4 = 120 mg K L^{-1} solution

Maintenance and Pest Control

The plants were kept pest free until harvest. If infested by pests and diseases, a suitable pesticide was applied not unless the damage reaches the critical threshold level.

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 is attained. The dry matter yield was calculated as follows:

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

Preparation and Analysis of Tissue Samples

Plant samples taken from the harvested leaves were used for nutrient analysis. These were washed with distilled water to remove any adhering soil particles. The samples were oven dried and ground in a tissue grinder ready for analysis.

A 0.2 g sample of both shoots and leaves was dry-ashed separately in a furnace at 500°C for 5 hours. The white ash in the crucible was added with 0.1N HCl solution and transferred into the volumetric flask up to 100 ml mark. The solution was filtered and the filtrate was analyzed. The total potassium in the extract was quantified using AAS (atomic absorption spectroscopy) in DOST-Philippine Nuclear Research Institute.

Critical Potassium Concentration Determination

Determination for the value of the critical K was determined using CurveExpert ver. 1.4. And by following the formula:

CNC= highest value of the computed Y – 10% of the highest value of the computed Y

Statistical Analysis

Statistical analysis of all data gathered obtained was done using the statistical tool available (STAR ver.2.0.1). Analysis of variance (ANOVA) will be used to test the significant effects among treatments and will be separated following the Duncan's Multiple Range Test at 5 % level of significance

RESULTS and DISCUSSION

General Observation

A week after the set-up, transplanted corn with different levels of potassium concentrations showed uniform growth. The majority of the treatments are showing interveinal chlorosis for 2 weeks after transplanting, but the plants recovered in the following weeks until harvest.

There were problems tackled during the conduct of the experiment such as uneven distribution of sunlight through the different treatments. The presence of leakage in each hose and hose malfunction makes the solution to run out in every container which was rehabilitated immediately.

Generally, corn grown hydroponically in treatment 4 (120 mg K L^{-1} solution) were taller (no presented data) but showing a thin stem which needed a stake to support the corn compared to other treatments.

Figure 1. Two-week-old corn seedlings hydroponically grown using ebb and flow system with varying levels of K (*levels were 0, 30, 60, 90, and 120 ppm*)

Growth Characteristics, Biomass Content and Potassium Uptake of Corn

The nutrients have a specific role in the various biochemical processes in the plant system specifically on the production of photosynthesis which is an essential component for dry matter production. The symptom of having a potassium deficiency could appear along the outer margins of older leave as streak or spots of yellow (mild deficiencies) or brown (severe deficiencies). In this particular study, both total K uptake and biomass were not significant. Transplanted corn showed uniform growth during the early stage of research (2 weeks). However, in the succeeding weeks, it was further observed that there was a change in variation to most of the growing plants. It was observed (no data presented) that corn grown hydroponically with 120 mg K L^{-1} solution (figure 2) were taller throughout the duration of the study. Amanullah et. al, (2016) demonstrated that increasing the rate of K (under a certain level) will improve growth and maize productivity of corn under certain conditions.

Figure 2. Comparative growth characteristics of corn flow system with varying levels of K (*levels were 0 T1 (30), T2 (60), T3 (90), and T4 (120 ppm*) upon harvest

Even though there was no significant difference in the different nutrient solutions used, it is worth mentioning that most corn with 120 mg K L^{-1} solution has higher K content and plant biomass.

Critical Potassium Concentration

According to Alsaeedi and Elprince (2000), CNC refers to the boundary between deficiency and adequacy zone, it could also refer to the nutrient concentration where plant growth first begins to decrease. In this particular study, the critical potassium concentration of corn at its early stage of growth is at 2.1 % K (figure 3) which correlates to biomass production and having an r value of 0.99. Cox and Barnes (2006) determined that the critical potassium concentration for corn grown in a goldsbro soil is 1.02%. The result may vary depending on the medium used in the experiment.

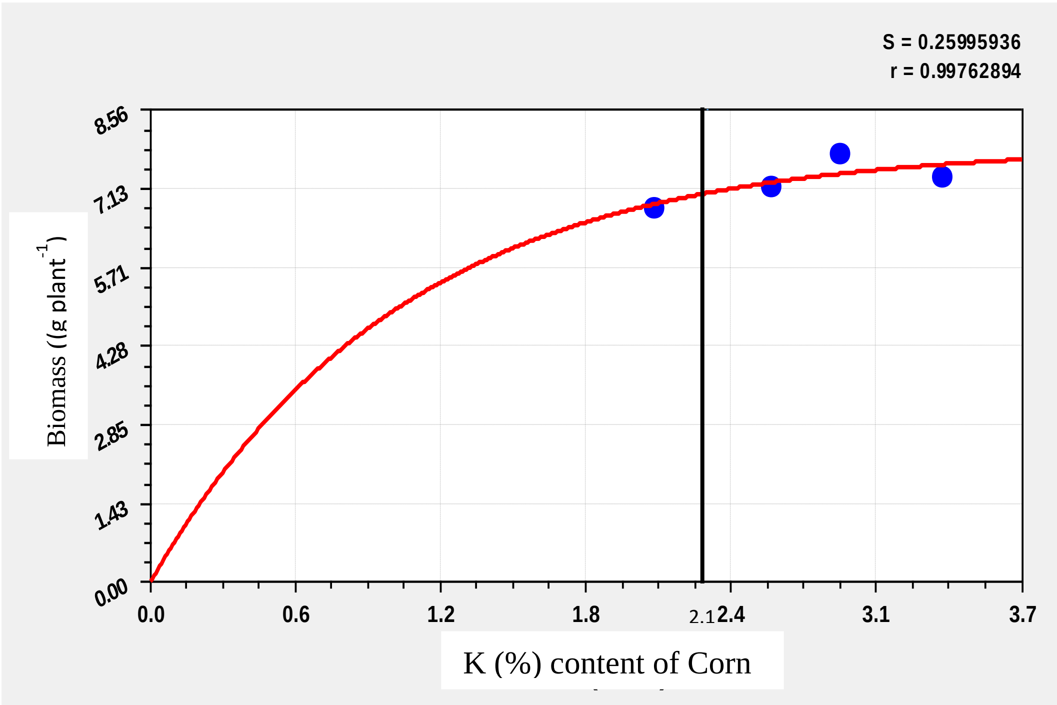

Figure 3. Critical potassium concentration of corn at early stage of growth (regression equation: $y=7.90E+00\ (1-e^{-(9.51E-01\ X)})$

CONCLUSION

Transplanted corn were grown hydroponically using flood and drain or ebb and flow system with the different treatments; T_0 = 0 mg K L^{-1} solution, T_1 = 30 mg K L^{-1} solution, T_2 = 60 mg K L^{-1} solution, T_3 = 90 mg K L^{-1} solution, & T_4 = 120 mg K L^{-1} solution. The plants were harvested after 4 weeks after transplanting.

There was no significant difference observed in both potassium content and biomass production of the corn. Treatment 4 (120 mg K L^{-1} solution) was observed be the tallest among the treatments.

Based on the results of the study, critical potassium level was determined at 2.1% for corn at its early stage of growth, and Ebb and Flow or the flood and drain system suits perfectly in determining the critical concentration of potassium of corn at its early stage of growth.

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