EFFECTS OF POTASSIUM AND RICE HUSK BIOCHAR ON THE GROWTH, YIELD, AND EATING QUALITY OF GLUTINUOUS MAIZE (*Zea mays* L.)

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ABSTRACT

This study was carried out at the Faculty of Sustainable Agriculture (FSA), Universiti Malaysia Sabah, Sandakan, Sabah (5°55'4" N 118°0'8" E) to know the effects of different rates of potassium incorporated with rice husk biochar on the growth, yield, and eating quality of glutinous maize planted on Silabukan soil. The first objective of this study was to determine the optimum rate of potassium needed for growth, yield, and eating quality of glutinous maize. The second objective of this study was to investigate the differences in soil pH, nitrogen, phosphorus, and potassium content before and after the experiment was carried out. This study was conducted from April 2016 until October 2016. The experimental design that was used in this experiment was complete randomized design (CRD). There are 7 treatments involved in this study and each treatment carried a different rate of potassium incorporated with 20 tonne ha^{-1} rice husk biochar, between 40 tonne ha^{-1} to 90 tonne ha^{-1}. Each treatment had three replications. Data collected was analyzed using one-way ANOVA at 5% significance level. The results shown for vegetative growth of glutinous maize showed that treatment 6 produced the highest plant height with 235.57 cm while treatment 4 produced the highest average number of leaves with 14.7. In terms of yield components of glutinous maize, treatment 5 recorded the highest average number and dry weight of cobs with 2.33 and 8.02 g respectively. Treatment 3 resulted the highest average of first cob height and weight of cob, with 127.33 cm and 70.69 g respectively. Treatment 4 also recorded the longest average length of cob with 10.5 cm. Treatment 2 recorded the highest average of cob diameter with 4.15 cm. Treatment 7 showed the highest average number of grains with 274 grains. Furthermore, in term of eating quality of glutinous maize, treatment 6 showed the highest average of total soluble solids with 17.3°. Additionally, based on the results obtained for soil analysis of Silabukan soil, treatment 2 and treatment 4 shared the same record showing the highest average soil pH at 4.31 while, treatment 5 recorded the highest nitrogen content with 2.088%. Based on the results obtained, there are a few recommendations made which are treatment 3 is the most recommended practice to the farmers since it helps in producing better glutinous maize yield as they recorded highest production of cob, weight of cob, number of grains and extrapolated yield with 2.0, 70.69 g, 222.67 and 3.39 tonne per ha respectively. It also produced higher plants height with 230.13 cm. The rate of potassium applied on Silabukan soil was 50 tonne ha^{-1} incorporated with 20 tonne ha^{-1} of rice husk biochar. Treatment 4 is the second most recommended practice to the farmers. These maize plants produced the highest number of leaves with a mean of 14.67. In terms of yield component, this treatment resulted in longer cobs as compared to the other treatments, with an average of 10.5 cm. For soil analysis, treatment 4 also showed the highest soil pH value even though it may not have reached the required level with 4.31.

KESAN DARIPADA KADAR KALIUM BERBEZA DAN BIOCHAR SEKAM PADI KEATAS PERTUMBUHAN, HASIL, DAN KUALITI MAKANAN JAGUNG PULUT (*Zea mays* L.)

ABSTRAK

Kajian ini telah dijalankan di Fakulti Pertanian Lestari, Universiti Malaysia Sabah, Sandakan, Sabah (5°55′4″ N 118°0′8″ E) bertujuan untuk mengkaji kesan daripada perbezaan kadar kalium yang dicampurkan bersama biochar sekam padi ke atas pertumbuhan, hasil, dan kualiti makanan jagung pulut yang ditanam menggunakan tanah Silabukan. Objektif utama kajian ini adalah untuk menentukan kadar optimum baja kalium yang dicampurkan bersama biochar yang diperlukan bagi pertumbuhan, penghasilan, dan kualiti makanan jagung pulut. Objektif kedua kajian ini adalah untuk mengetahui kandungan pH tanah, nitrogen, phosphorus, dan kalium sebelum dan selepas kajian dilakukan. Kajian ini telah dijalankan sejak April 2016 hingga Oktober 2016. Terdapat 7 rawatan yang terlibat di dalam kajian ini dan setiap rawatan mempunyai kadar kalium yang berbeza yang dicampurkan bersama 20 tan ha^{-1} biochar sekam padi dalam lingkungan 40 tan ha^{-1} hingga 90 tan ha^{-1}. Setiap rawatan mempunyai 3 replikasi. Rawatan disusun mengikut rekabentuk rawak lengkap (CRD). Data yang telah direkod dianalisis dengan menggunakan ANOVA satu-hala atas keertian 5%. Berdasarkan keputusan yang diperolehi bagi pertumbuhan vegetatif jagung pulut, rawatan 6 telah menghasilkan pokok tertinggi dengan 235.57 sm manakala rawatan 4 telah menghasilkan purata bilangan daun terbanyak dengan 14.7. Bagi komponen hasil jagung pulut, rawatan 5 telah menghasilkan purata bilangan tongkol dan berat bersih tertinggi dengan 2.33 dan 8.02 g. Rawatan 3 telah menghasilkan purata ketinggian tongkol pertama tertinggi dengan 127.33 sm dan 70.69 g. Rawatan 4 juga telah menghasilkan purata panjang tongkol tertinggi dengan 10.5 sm. Bagi diameter jagung pulut, rawatan 2 menunjukkan hasil tertinggi dengan purata sebanyak 4.15 sm. Seterusnya, rawatan 7 juga menunjukkan purata bilangan butiran sebanyak 274 biji. Bagi kualiti makanan jagung pulut, rawatan 6 telah menghasilkan purata kemanisan tertinggi iaitu sebanyak 17.3°. Selain itu, untuk analisa tanah Silabukan, rawatan 2 dan rawatan 4 telah mencatat pH tanah tertinggi dengan 4.31 manakala, rawatan 5 mencatat kandungan nitrogen dalam tanah Silabukan tertinggi dengan 2.088%. Dari segi kandungan fosforus dalam tanah pula, rawatan 4 telah mencatat kandungan fosforus tertinggi dalam tanah dengan 0.135 ppm. Berdasarkan keputusan yang diperolehi, terdapat beberapa cadangan telah dibuat di mana rawatan 3 adalah aplikasi yang terbaik untuk dipraktikkan oleh para petani memandangkan ia dapat menghasilkan komponen hasil terbaik seperti penghasilan tongkol tertinggi, berat tongkol tertinggi, butir jagung terbanyak dan unjuran hasil tertinggi dengan 2.0, 70.69 g, 222.67 and 3.39 tan ha^{-1}. Ia juga menghasilkan ketinggian pokok kedua tertinggi iaitu 230.13 sm. Kadar kalium rawatan 3 merupakan 50 tan ha^{-1} dicampurkan bersama 20 tan ha^{-1} biochar sekam padi. Kadar kedua terbaik yang dicadangkan kepada petani ialah rawatan 4. Menurut kajian, pokok jagung yang dihasilkan memperoleh bilangan daun tertinggi sebanyak 14.67. Ia juga turut menghasilkan panjang tongkol tertinggi dan pH tanah tertinggi sebanyak 10.5 sm dan 4.31.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

=	Equal
%	Percentage
ANOVA	Analysis of Variance
ATP	Adenosine Triphosphate
CRD	Completely Randomized Design
FAO	Food and Agriculture Organization
FSA	Faculty of Sustainable Agriculture
ha	Hectare
K	Potassium
LSD	Least Significant Difference
MOP	Muriate of Potash
N	Nitrogen
P	Phosphorus
ppm	Parts per million
R	Replicate
T	Treatment
TSP	Triple Super Phosphate
TSS	Total Soluble Solids
UMS	Universiti Malaysia Sabah

CHAPTER 1

INTRODUCTION

1.1 Background

Maize is the third most important staple food and cereal crop grown in Malaysia after rice and potato due to the suitable climatic conditions in Malaysia which is hot but humid all year long. Maize also ranks third, following wheat and rice, in the world production of cereal crops (FAO, 2010). It is very high in demand globally as it is a source of daily food in certain countries which makes it a very valuable crop. The production of maize exported globally can help in generating income for the country. Maize is widely used for human consumption, poultry feed and as an industrial raw material in Malaysia, as well as in other countries. To meet these demands, farmers in Malaysia have been planting and improving their maize crop for optimum production with high quality. Currently, many technologies have been developed which makes the whole production process a lot easier than before. The technologies developed can be used for studies on improving the yield, growth and eating quality of the crop so that the food produced is enough, healthy and scrumptious.

Glutinous maize is scientifically known as *Zea mays* cv. *ceratina* Kulesh and is a member of the grass family which is Poaceae. Maize is a unique cereal crop as it is a monoecious plant in which the male and female inflorescences are separated on the same plant. Glutinous maize is dissimilar to regular sweet maize as it contains higher starch content and lower sugar content which is filling when eaten and its taste differs from the regular sweet maize. According to Ohio State University Extension in Rouf (2010), glutinous maize contains 100% amylopectin while regular maize contains 75% amylopectin and 25% amylose. The amylopectin content in glutinous maize has a number of uses for both food and other industrial uses. For example, the starch (amylopectin) can be made into a thickener and stabilizer in many food products. Glutinous maize usually appears white in color due to the high starch content but, if the maize contains a mix of yellow kernels, the plant might have undergone cross pollination with yellow sweet maize. It is also very sensitive to mildew disease (*Perenosclerospora maydis* L.), even though it can tolerate drought (Makkulawu *et al.*, 2012).

In Malaysia, glutinous maize is commonly found in the northern part of Sabah, specifically in some areas, such as Kota Marudu, Kota Belud and Kudat, and is usually consumed either as boiled maize or grilled maize. There is even a special annual celebration known as the Maize Festival to celebrate this prosperous staple and the industry that forms the backbone of the district. The Maize Festival is a two day celebration filled with corn-related activities such as corn industry exhibitions, corn competitions, traditional sports and the highlight of the event is the maize beauty queen pageant featuring local beauties decorated with corn-derived jewelry. In Peninsular Malaysia it is rare and the existence of glutinous maize crop there is the result of seeds imported from Sabah. Production of glutinous maize is less than optimal because of several factors such as improper management of glutinous maize as interval plants and also because it has relatively no commercial value and thus, the availability is limited. Glutinous maize has many advantages compared to regular sweet maize and it can be substituted for rice to support the national food security program with the ever increasing population in Malaysia.

The Silabukan soil is named after a place in Lahad Datu which is Silabukan (5.0169° N 118.5514° E). Silabukan soil is very poor quality soil which contains high percentage of clay. Clay soil can damage plant roots as the pores are too compact and there is not enough space for the roots to grow. As root growth is inhibited, the plant growth will also be stunted as the roots are too small and cannot take up enough nutrients to be supplied to the whole plant, as they cannot travel through the soil. Most land in Sabah are Silabukan in which the quality of the soils is quite low. The problem with such soils can be overcome by the alteration of the soils through findings of studies that have been done.

Biochar is a valuable soil amendment that helps to improve soil fertility which can increase productivity and crop yields. Biochar's vast surface area and complex pore structure can act as a habitat to the bacteria and fungi that plants need to absorb nutrients from the soil. So, biochar acts as a secure habitat for beneficial microbial activity that is important for crop production. As the ability of biochar is to enhance the availability of plant nutrients, soil nutrient retention is improved. This means that less fertilizer needs to be applied which reduces the cost of producing the crop. Moreover, soils that contains biochar have shown reduced runoff of phosphorus into surface waters and leaching of nitrogen into groundwater. So, pollution caused by fertilizer run-off into streams and rivers are prevented. Biochar can also be an important organic matter in providing good food security and food safety.

The cultivation of glutinous maize needs fertilizer as an essential mineral source which needs to be properly applied in order to produce glutinous maize optimally. However, according to Mutegi *et al.* (2012), the high price of fertilizers make farmers reluctant to use fertilizers as recommended. Fertilizers must be applied efficiently to be well dissolved and sufficient for plants, so that the cost for fertilizers can be minimized. NPK fertilizers consist of Nitrogen (N), Phosphorus (P), and Potassium (K) which are widely used in the agricultural industry in Malaysia. NPK fertilizer is a synthetic fertilizer that can provide essential nutrients to maize crops, and can be quite costly. So that is why it is important for us and the farmers to apply only adequate amounts of NPK fertilizer which can help produce high quality maize crops at minimal cost. Furthermore, excessive application of synthetic fertilizers can be toxic to the plant and causes soil pollution (Agno and Awu, 2005).

1.2 Justification

The purpose of this study is to increase the fertility of Silabukan soil as well as improve the vegetative growth, yield and eating quality of glutinous maize due to the low production and eating quality of glutinous maize in Sabah. As the production of glutinous maize is low, it is not widely distributed throughout Malaysia nor to other countries. Through research done through the internet and social media, it is seen that the demands for glutinous maize is quite high as many people are seeking glutinous maize. The glutinous maize is not widely produced perhaps due to the low yield, small size and low eating quality of the maize, which do not give optimum profit to the farmers as compared to regular sweet corn. So, this study will be able to contribute to the farmers to help them get greater returns, production and quality glutinous maize crop so that they are able to export globally and meet demand.

This study was also done to see the effects of the application of different rates of potassium incorporated with biochar on the poor quality and low soil fertility of Silabukan soil. Potassium is responsible for vegetative yield, growth and total soluble solids. Through this study, the optimum and adequate amount of potassium can be determined and applied on the maize plants to increase the growth, yield and total soluble solids of glutinous maize.

Furthermore, the application of rice husk biochar into the soil, is due to the character of biochar as a soil amendment which is able to alter the structure of the Silabukan soil into a less clayey soil which will help in increasing nutrient uptake as the porosity of the soil increases and make it easier for the nutrients to travel throughout the soil to be transported to the plant. Rice husk biochar is used to overcome the problems that most farmers in Sabah are going through. It is specifically chosen so that more definite information can be provided to the farmers as different types of biochar will have different qualities, which might affect the results.

1.3 Objectives

1. To evaluate the effects of different rates of potassium incorporated with rice husk biochar on the growth, yield and eating quality of glutinuous maize planted on Silabukan soil.

2. To evaluate the effects of different rates of potassium incorporated with rice husk biochar on soil pH, nitrogen and phosphorus content of Silabukan soil.

1.4 Hypothesis

i. H_o : There is no significant difference on the growth, yield and eating quality of glutinuous maize planted on Silabukan soil due to the application of different rates of potassium incorporated with rice husk biochar.

H_A : There is significant difference on the growth, yield and eating quality of glutinuous maize planted on Silabukan soil due to the application of different rates of potassium incorporated with rice husk biochar.

ii. H_o : There is no significant difference in soil pH, nitrogen and phosphorus content of Silabukan soil due to the application of different rates of potassium incorporated with rice husk biochar.

H_A : There is significant difference in soil pH, nitrogen and phosphorus content of Silabukan soil due to the application of different rates of potassium incorporated with rice husk biochar.

CHAPTER 2

LITERATURE REVIEW

2.1 Glutinous Maize

2.1.1 Centre of Origin

It is generally agreed that teosinte (*Z. mexicana*) is an ancestor of maize, although opinions vary as to whether maize is a domesticated version of teosinte (Galinat, 1988). The teosintes are wild grasses native to Mexico and Central America and have limited distribution (Mangelsdorf *et al.*, 1981). Teosinte species show little tendency to spread beyond their natural range and distribution is restricted to North, Central and South America. They are not reported to occur in Southeast Asia (Watson & Dallwitz, 1992). Due to differences in races, species and plant habits, taxonomic classification is still a matter of controversy. The annual teosintes are classified into two subspecies which are, *Z. mays* ssp. *mexicana* and *Z. mays* ssp. *Parviglumis* var. *parviglumis* (race Balsas) and var. *huehuetenangensis* (race Huehuetenango), and the species *Z. luxurians* (race Guatemala) (Doebley and Iltis *et al.*, 1980).

2.1.2 Taxonomy of Glutinous Maize

In certain areas, glutinous maize is known as waxy corn or waxy maize and scientifically, it is known as *Zea mays* var. *ceratina* Kulesh. The grains of glutinous maize usually appears white in colour that is similar to the colour of wax, as it contains higher starch content than normal maize. According to Ohio State University Extension (2010) in Rouf (2010), glutinous maize contains 100% amylopectin while regular maize contains 75% amylopectin and 25% amylose.

The genus *Zea* is an annual grass that belongs to the tribe Andropogoneae in the subfamily Panicoideae in the family Poaceae (USDA, 2005). Other grasses in this family include wheat, barley, rye, sugarcane, sorghum and rice. Currently there are 86 recognised genera within the Andropogoneae tribe (USDA, 2005). Table 1 shows the classification of glutinous maize;

Table 1. Classification of Glutinous Maize

Classifications	**Glutinous Maize**
Kingdom	Plantae
Division	Magnoliophyta
Sub-division	Panicoideae
Class	Liliopsida
Order	Poales
Family	Poaceae
Genus	Zea
Species	*Zea mays* L.
Variety	*Zea mays* var. *ceratina* Kulesh

Source : Ministry of Environment and Forests *et al.*, 2009

2.1.3 Botanical Features of Glutinous Maize

Maize is a tall, monecious annual grass, and determinate annual C_4 plant, varying in height from one to four meters, producing overlapping sheaths and broad conspicuously distichous blades. One main difference between maize and other cereals is that it bears cobs that are larger than any other grass family. Maize also produces higher yield of food per unit than any other grain. This productivity is one of the main contributing factors to maize's appeal to farmers.

a. Root

According to the Ministry of Environment and Forests *et al.* (2009), maize plants have three types of roots, which are seminal roots, adventitious roots and brace roots (Figure 1). Seminal roots develop from the radicle and tend to attain for a long period while adventitious roots develop from the lower nodes of stem below the ground level which act as the active roots of the maize plant, and lastly, the brace roots are produced by two lower nodes. The roots grow very rapidly and almost equally outwards and downwards to act as anchorage for the maize plant. Favorable soils may allow maize root growth up to 60 cm laterally and in depth.

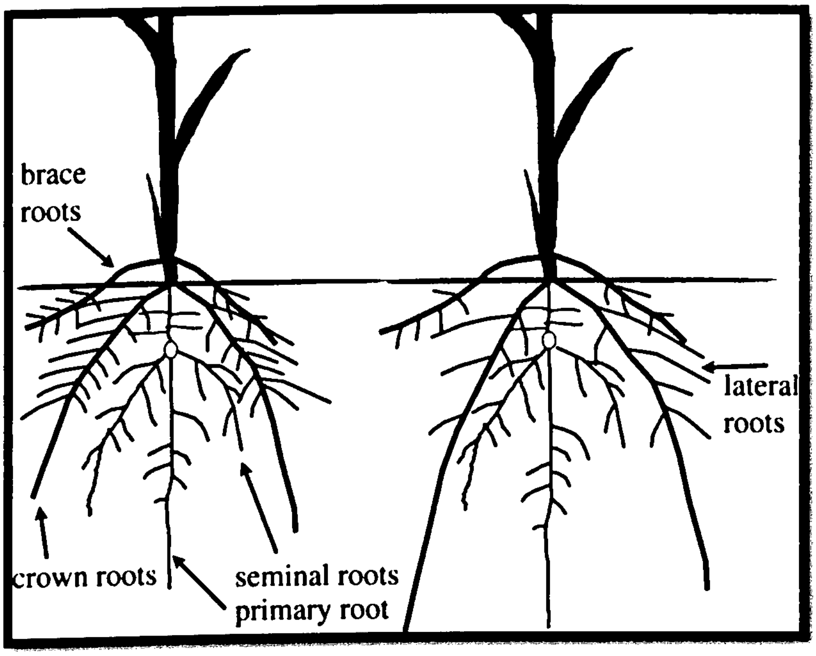

Figure 1 : Brace roots is the main root system of Maize plants

Source : The Royal Society, 2012

b. Stem

The stem generally attains a thickness of three to four centimeters. The internodes are short and fairly thick at the base of the plant but, become longer and thicker higher up the stem, and then taper again. The cob bearing internode is longitudinally grooved, to allow proper positioning of the cob. The upper leaves in corn are more responsible for light interception and are major contributors of photosynthate to grain (Ministry of Environment and Forests *et al.*, 2009).

c. Flower

According to the Ministry of Environment and Forest (2009), the apex of the stem ends at the tassel (male inflorescence flowers) and the cobs (female inflorescence) are borne at the apex of condensed, lateral branches known as shanks protruding from leaf axils. The male (staminate) inflorescence, a loose panicle, produces pairs of free spikelets each enclosing a fertile and a sterile floret. Plants have staminate spikelets in long spike-like racemes that form large spreading tassels and pistillate inflorescences in the leaf axils, in which the spikelets occur in 8 to 16 rows, approximately 30 long, on a thickened, almost woody axis (cob). The female (pistillate) inflorescence, a spike, produces pairs of spikelets on the surface of a highly condensed cob. The female flower is tightly covered over by several layers of leaves, and so closed in by them to the stem that they don't show themselves easily until emergence of the pale yellow silks from the leaf whorl at the end of the ear. The silks are the elongated stigmas that look like hair initially and later turn green or purple in color. The whole structure of cob is enclosed in numerous large foliaceous bracts and a mass of long styles (silks) protrude from the tip as a mass of silky threads (Hitchcock and Chase, 1971).

Figure 2 : Male Inflorescence, The Tassels

Source : Ministry of Environment and Forests *et al.*, 2009

Figure 3 : Female Inflorescence, The Silk

Source : Ministry of Environment and Forests *et al.*, 2009

d. Grain

The individual maize grain is botanically a caryopsis, a dry fruit containing a single seed fused to the inner tissues of the fruit case. The seed contains two sister structures, a germ which includes the plumule and radical from which a new plant will develop, and an endosperm which will provide nutrients for that germinating seedling until the seedling establishes sufficient leaf area to become autotrophy. The germ is the source of maize "vegetable oil" (total oil content of maize grain is 4% by weight). The endosperm occupies about two thirds of a maize kernel's volume and accounts for approximately 86% of its dry weight. The endosperm of maize kernels can be yellow or white. The primary component of endosperm is starch, together with 10% bound protein (gluten), and this stored starch is the basis of the maize kernel's nutritional uses (Ministry of Environment and Forests *et al.*, 2009).

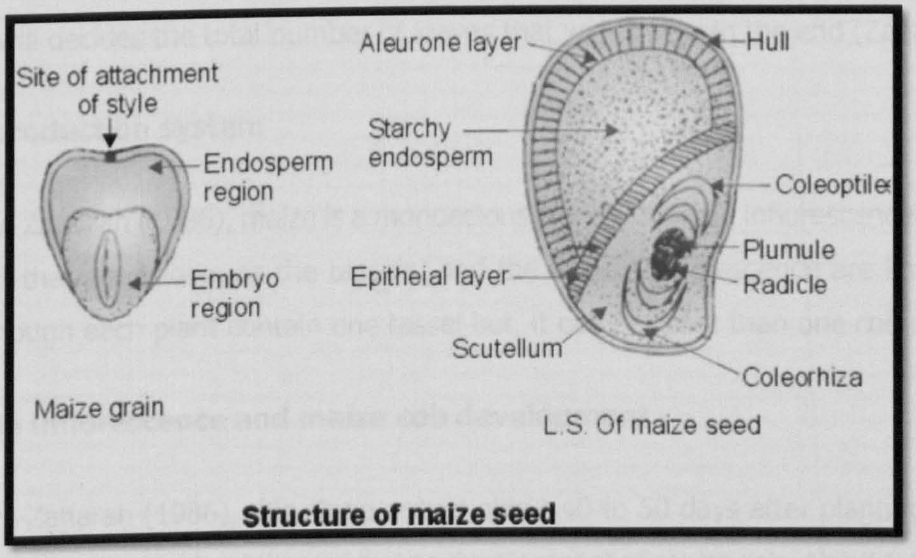

Figure 4 : Maize Seed Structure

Source : http://www.biologydiscussion.com/, 2013

2.1.4 Physiology of Maize Plant

According to Jabatan Pertanian Pulau Pinang (2016), the maize plants take about 68 to 72 days to complete their life cycle from germination stage until they reach physiological maturity stage. Following Zaharah (1986), growth and development stage of maize plant are as follows:

a) Germination process

In this stage, the maize seed need adequate amount of water from the soil moisture content to be supplied throughout the plants to start the germination process. Planting in a dry

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