EFFECT OF POTASSIUM COMBINED WITH ORGANIC FERTILIZERS ON GROWTH, YIELD AND SWEETNESS OF CORN PLANTED ON BRIS SOIL

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS

CROP PRODUCTION PROGRAM
FACULTY OF SUSTAINABLE AGRICULTURE
UNIVERSITI MALAYSIA SABAH
2018

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL: EFFECT OF POTASSIUM COMBINED WITH ORGANIC FERTILIZERS ON GROWTH, YIELD AND SWEETNESS OF CORN PLANTED ON BRIS SOIL

IJAZAH: SARJANA MUDA SAINS PERTANIAN DENGAN KEPUJIAN

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ACKNOWLEDGEMENT

I would like to express my deepest gratitude to the Almighty and all the people who have helped me to complete this research project. I am greatly indebted to my parents, Mr. Amran bin Ahmad and Madam Alizah binti Abdullah, who willingly sacrificed everything to provide me the best education despite their own limited education.

My appreciation to my supervisor, Assoc. Prof. Datuk Hj. Mohd Dandan@Ame bin Hj. Alidin and to my co-supervisor, Assoc. Prof. Dr. Mohamadu Boyie Jalloh for all the advice, monitoring, encouragement, continued patience and guidance. Without their guidance, I would not have completed my research project. Not forgetting the lecturers that helped in this study, Mr Borhan Haya@Yahya, Assoc. Prof. Dr. Nur Hardy bin Abu Daud and Prof. Muhammad bin Mohd Lassim for giving advice and thoughtful comments on my research project.

My special gratitude to the laboratory assistance and field staff who helped provide the equipment and places for analysis purposes, which include Madam Ahjia binti Jekan, Madam Nurul Syakina binti Marli, Madam Amirah binti Yusof, Mr.Mattunjan Upin@Ipin, Mr. Frederick Florentius @ Mr. Firdaus, Madam Dg. Sitti Aminah binti Kennedy and Madam Anika @ Flora Bulangou.

Not to forget, important people that lend a hand during the early preparation of this experiment; Mr. Ibnu, Mr. Rahman and Madam Athirah that help in collecting BRIS soil in Kg. Tembalang. Miss Christine Gustin, Miss Safiza Mohd. Salim, Miss Evelyn Koay Shin Rou, Miss Nur Aishah binti Mohd Anuar were among my friends that I would give credit to as they helped in this research project. Not forgetting my colleagues under the supervisor of Assoc. Prof. Datuk Tn. Hj. Mohd Dandan; Mr. Ng Ji Feng, Mr. Byron Clifford Blantocas, Miss Thien Ying Qing, Miss Faradila Fathin Eddie and Miss Ng Hooi Chin who were always there to help me throughout my final year project.

Finally, I would like to express my gratitude to the faculty and UMS for all the support and allowing me to finish my research project.

ABSTRACT

This study was conducted to determine the effect of potassium combined with organic fertilizers on the growth, yield and sweetness of reddish waxy corn. The experiment was arranged on Completely Randomized Design (CRD) covering a span of three months. The treatments were: control or 60 kg ha^{-1} of potassium (T1), 30 kg ha^{-1} potassium + 20 tons ha^{-1} chicken manure biochar + 1.5 tons ha^{-1} of bokashi (T2), 90 kg ha^{-1} potassium + 20 tons ha^{-1} chicken manure biochar + 1.5 tons ha^{-1} of bokashi (T3) and 120 kg ha^{-1} potassium + 20 tons ha^{-1} chicken manure biochar + 1.5 tons ha^{-1} of bokashi (T4). Each treatment was replicated six times. Stem girth, number of leaves, height of first cob, fresh weight of first cob, 100 grains weight, cob girth, cob length and sweetness of Brix reading was analysed using ANOVA at 5% significant levels. Least Significant Different (LSD) was used to compare the means for significantly different results. Significant differences on growth was obtained at ($p<0.05$) in waxy corn for the number of leaves, height of first cob, length of cob and girth of between the control and all treatments. However, no significant difference was obtained for sweetness of waxy corn for all treatments. Mean total for growth parameters; number of leaves, stem girth and height of first cob from soil surfaces and mean total for yield parameters; cob girth, length of cob, fresh weight of cob, 100 grains weight and number of kernels was significantly higher for all treatments of T2, T3 and T4 compared to control treatment of T1. Results of the study showed no significant different on the sweetness of waxy corn with increasing potassium application resulting in increased total soluble content. Similar studies for different rate of organic fertilizers and soil analysis can be done to further ascertain the effects on growth, yield and sweetness parameters of reddish waxy corn with selected soil properties.

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AAS	Atomic Absorption Spectrophotometer
ANOVA	Analysis of Variance
BRIS	Beach Ridges Interspersed with Swales
CRD	Completely Randomized Design
CEC	Cation Exchange Capacity
DAS	Day after sowing
FSA	Faculty of Sustainable Agriculture
LSD	Least Significant Difference
pH	Potential of Hydrogen
SAS	Statistical Analysis Software

CHAPTER 1

INTRODUCTION

1.1 Background

Corn (*Zea mays* L.) or Indian corn had been planted in the majority area across the globe (Purwono *et al.*, 2008), placed in third rank after wheat and rice for the world's cereal crops planted. Malaysia is a tropical country located in the equator, with hot and humid climate spreading over 336, 745 km^2 (Peng *et al.*, 1998). In Malaysia, there are 21,112 hectares in 2015 allocated to grow crops such as corn, groundnut, cassava, sweet potatoes and aroids (Jabatan Pertanian Putrajaya, 2015). In 2015 also, the production of corn reached 99,640 metric tonnes, with Selangor, Johor and Sarawak being the main producing states (Unit Perangkaan, 2015).

Corn is known to have a broad morphological variability. It was planted worldwide as corn is among the cross-pollinated crops and could be artificially characterized based on its kernel endosperm. Kernel endosperm refer to the tissue, which surrounds the embryo that provides food for the seed's growth, which is in close relation to its food uses. Maize variety types include *Zea mays* var *amylaceae* (floury corn), *Zea mays* var *tunicata* (pod corn) or *Zea mays* var *ceratina* (waxy corn) (Purwono *et al.*, 2008).

In Sabah, specifically Kota Marudu, the location where the seeds were obtained for the planting material for this research, the farmers and locals prefer to grow, sell and consume waxy corn instead of growing grain corn due to several factors such as the local demands and for human consumption (The Star, 2006). Waxy corn differ from regular corn based on the starch formation in its structure. The composition in waxy corn is mostly amylopectin whereas the other types of non-waxy corn have 25% amylose and 75% amylopectin in their composition.

Several studies showed that the application of potassium with the rate of 60 and 90 kg ha^{-1} will significantly produce bigger cobs and increase in 100 grain weight (Brar *et al.*, 2012), greater number of leaves that aids in photosynthesis process and resulted in substantial increase in total soluble solid content (Kumar, 2006).

BRIS (Beach Ridges Interspersed with Swales) soil is considered as problematic soil that constituent an amount of 200,000 hectares throughout Malaysia with 40,400 hectares in Sabah. This type of soil is included as idle land totalling 119,273 hectares within Malaysia (Unit Perangkaan, 2015; Peng *et al.,* 1998). This BRIS soil commonly found in coastal area in Sabah was once planted with paddy but this agricultural activity is being halted due to several factors mainly due to the salinity of the soil (Mohd Hashim, 2003).

It was suggested that BRIS soil fertility has opportunities to be improved with the addition of organic fertilizers such as compost. Pasture plants respond to the treatment with nutrients phosphorus, potassium, calcium, copper, sulphur, boron, molybdenum and magnesium when planted in the BRIS soil area (Peng *et al.,* 1998) and other studies showed that organic fertilizer such as compost aids the increase of cation exchange capacity (CEC) thus, improving the fertility of the BRIS soil (Mohd Khairi *et al.*, 2011).

1.2 Justification

Sabah is a state in Malaysia surrounded with coastal area that is 1,800 km long. The coastal zones were extremely flat and low in elevation causing intrusion of the seawater, thus contributing to soil salinization. In a few parts of Sabah especially in the east coast and west coast, the BRIS soil areas were planted with paddy as a main activity but due to salinity, water sources and poor drainage issues, the planting was halted (Mohd Hashim, 2003). This contributed to the amount of idle agricultural land in Malaysia to increase up to 119,273 hectares (Unit Perangkaan, 2015).

As an additional crop, waxy corn became one of the options to be planted on BRIS soil other than watermelon, cucumber, papaya and banana (Appendix D, iii). Waxy corn was planted mainly in hilly areas of the west coast (north) of Sabah in the area of Kg. Menggaris Dua, Kota Marudu (Jabatan Tanah dan Ukur, 2017).

Waxy corn according to locals in that area had starchy textures, ranging from white, yellow to reddish in colour and easier to plant because it required less maintenance and fertilizer requirement as compared to sweet corn. Nevertheless, there is no significant study yet as evidence that waxy corn required less maintenance because waxy corn especially reddish waxy corn, which is considered as a local breed with unidentified origins in Malaysia.

In Tuaran area, activities to improve BRIS soil fertility by using organic amendments from chicken manure were applied by local farmers (Appendix D, iii). By using organic amendments to increase the fertility of the sandy soil and using silver shine to mulch the soil preventing weed growth, retain moisture and avoid fertilizer leaching, farmers managed to improve the soil fertility and successfully planted crops such as cucumber, papaya, pumpkin and hybrid corn and even banana.

Therefore, this study was initiated to improve the growth, yield and sweetness of waxy corn by using different rates of potassium in combination with chicken manure biochar and bokashi. Potassium is known to promote translocations of sugar in plants especially fruit or vegetables plants and assessed by total soluble solid (TSS) content. Sugar as assimilates are translocated from sources to sink in plant as potassium application increased. A study showed that potassium influences the sweetness of papaya by increasing the TSS content (Kumar *et al.*, 2006).

This study aimed to increase the sweetness of the reddish waxy corn that is rather milky and less sweet in taste compared to sweet corn because of the chemical composition of the corn. With different amounts of potassium fertilizer on the total soluble content being studied, which refer to the sweetness of the corn and upon obtaining results from this study, we can determine the best amount of potassium needed to be applied in order to increase the total soluble content of waxy corn. By improving the eating quality, reddish waxy corn has potential as a local breed corn to be commercialized and complement sweet corn whose seeds are imported from Thailand. This will increase the marketability of Malaysian products.

1.3 Objectives

i. To evaluate the effect of potassium rates combined with organic fertilizers on the growth and yield of reddish waxy corn planted on BRIS soil.

ii. To evaluate the effect of potassium rates combined with organic fertilizers on the sweetness of reddish waxy corn planted on BRIS soil.

1.4 Research Hypotheses

H_{A1}: There is no significant difference on the effect of potassium rates combined with organic fertilizers on the growth and yield of reddish waxy corn planted on BRIS soil.

H_{O1}: There is significant difference on the effect of potassium rates combined with organic fertilizers on the growth and yield of reddish waxy corn planted on BRIS soil.

H_{A2}: There is no significant difference on the effect of potassium rates combined with organic fertilizers on the sweetness of reddish waxy corn planted on BRIS soil.

H_{O2}: There is significant difference on the effect of potassium rates combined with organic fertilizers on the sweetness of reddish waxy corn planted on BRIS soil.

CHAPTER 2

LITERATURE REVIEW

2.1 Corn

Corn (*Zea mays* L.) or Indian corn had been planted in almost every region in the world (Purwono *et al.*, 2008) and is ranked third after wheat and rice for world's cereal crops planted. It was planted originally in American region where it was consumed as primary food in the Indians' diets. In an expedition by the year 1492, Christopher Columbus was an explorer who disseminated corn to other countries that he visited (Nuni, 2008). Corn was known as "Queen of Cereals' due to its high productivity. Among the cereals, corn had the highest average yields which was grown mainly for human consumption in the form of grains, next was for animal consumption in the form of fodder and lastly as raw materials functioning in diversified products as well as industrial processes (Panda, 2009).

In the early 18^{th} century, the Portuguese introduced corn in Malaysia before 1957 and was known as "Tanah Malaya" and had a good acceptance among farmers. Along the way, corn turned into an important agriculture commodity in Malaysia thus making corn the second major crop planted after paddy (Nuni, 2008). The production of corn also revolved around planting for human consumption due to the sweetness of its flesh, as fodder as well as products in the industry (Purwono *et al.*, 2008).

2.1.1 Types of Corn

Corn is known to have a broad morphological variability that was planted worldwide because it was a cross pollinated species and could be artificially characterized based on its kernel endosperm (tissue surrounding embryo that provides food for the seed's growth) composition, which is closely related to its food uses. One or more inherited genes controlled the trait that resulted in distinguished properties based on the endosperm properties for dent, flint, flour, sweet, pop and pod corn.

Composition of the kernel endosperm is not indicative of natural genetic relationship with the exception for pod corn, other types of corn contain divisions based on the quality, quantity and pattern of their endosperm (Figure 2.1). In breeding special-purpose types of corn, alteration of even one single gene may contribute changes to the physical, chemical characteristicsor both in plant appearance in the case of floury (*fl*) versus flint (*Fl*), sugary (*su*) versus starchy (*Su*), waxy (*wx*) versus non-waxy (*Wx*) and other single recessive traits (Brown and Darrah, 1985; Salvador, 1997; Dickerson, 2008).

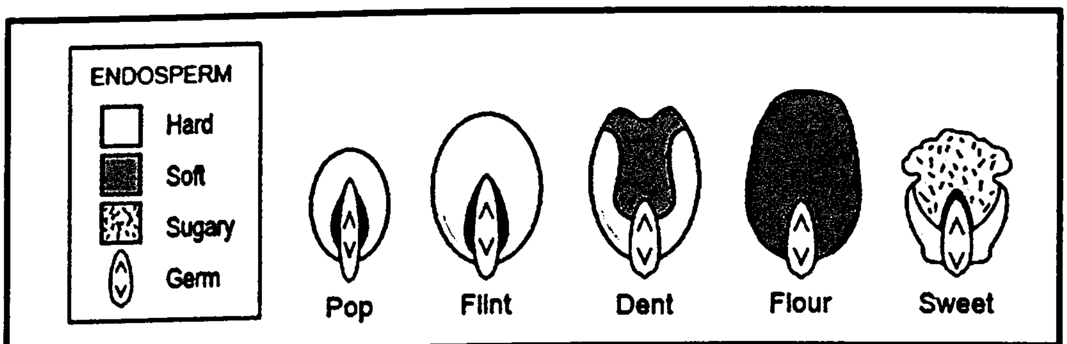

Figure 2.1: Endosperm distribution in five types of corn kernels
Source: Dickerson, 2008.

Moreover, other classification of corn uses variety but also based on the kernel composition. There were *Zea mays* var *amylaceae* (floury corn), *Zea mays* var *tunicata* (pod corn) or *Zea mays* var *ceratina* (waxy corn) (Purwono *et al.*, 2008).

2.2 Waxy Corn

There are two different pathways to differentiate the starch formation in corn, which are 25% amylose and 75% amylopectin in non-waxy corn whereas in waxy corn, the starch formation was mainly from amylopectin composition with lesser amount of amylose as compared to the non-waxy corn.

Amylose refers to straight-chain polysaccharide of starch formation and amylopectin refers to branched-chain polysaccharide from a common substrate (Fan *et al.*, 2009). Studies showed that Chinese waxy corn was mutated from flint corn after the latter was introduced about 1 600 A.D. in China. By using Zea genus sample in sequencing partial waxy gene, discovery on the percentage of the origin of the waxy corn had a constituent of major Chinese flint corn with 30%, genetic diversity of American corn and genetic diversity in *Z. mays* subsp. *Parviglunis* with 22% and 14% respectively.

Meanwhile, ethnographic studies suggest that some province in Southwest China such as Yunnan, Guizhou and Guangxi were the "centre of genetic diversity" when it comes to the waxy corn cultivation in upland areas, showing the significance of waxy corn planting to these area in terms of their economics and culture (Tian *et al.*, 2009).

Waxy corn become a marketable product in Sabah specifically Kota Marudu area instead of Suwan corn of grain corn for animal feed. Based on the farmers preferences for waxy corn, this type of corn has a better potential in the market because it is more popular compared to Suwan corn that is harder in texture and more suitable for animal feed and not for human consumption. Moreover, waxy corn has a better selling price and have a place in the market, either raw or cooked (The Star, 2006).

2.3 Corn Botany

2.3.1 Root System

Corn has a deep and profusely branched root system. It consist of three seminal or temporary roots, crown or coronal roots and brace, prop or aerial roots. Seminal roots consist of radicle and a number of lateral roots arise above the scutellar node.

Crown roots refer to the stem basal portion and aerial roots refer to formation of roots from the second, third or sometimes fourth nodes above ground, which the roots exist in or outside the soil surface. In early germination, seminal roots form and emerge after the formation of the first root from the planted seeds. Along the developmental stages, seminal roots were substituted with adventitious roots that were permanent roots, originating from the crown present at the end of the mesocotyl.

Roots would develop, spread and penetrate deeply in the soil depending on the soil moisture status (Panda, 2009) with four to six adventitious roots formed per band (Plessis, 2003). In addition, there is formation of 'prop' or 'brace' roots, which are adventitious in nature, produced in the first two or three nodes of the plants above the soil level, and aids in anchoring the corn firmly in the soil (Panda, 2009).

2.3.2 Leaves

Leaves are arranged spirally on the stem in alternate positions with typical grass leaf shape; with ligules, auricles and a blade. A prominent mid-rib supports the leaf's entire length, providing support to the structure. The leaf blade is long, narrow, undulating and tapers towards the tip; globrous to hairy (Plessis, 2003). The sheath is located at the longitudinal dimensions into the leaf's basal part whereas the blade is located at the top portion, between them exist a boundary known as ligular region with a green auricle and ligule that appears to diffuse together (Figure 2.2).

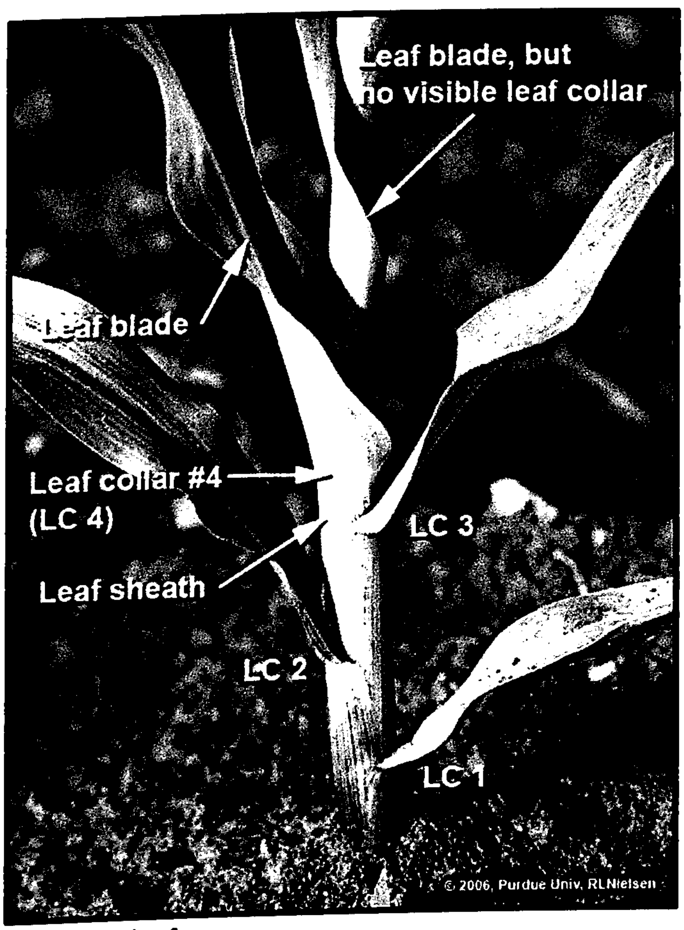

Figure 2.2: Parts of a corn leaf
Source: Nielsen, 2014

2.3.3 Stem

Depending upon the variety, corn could reach a height between 1.5 m to 3.0 m, cylindrical, solid and clearly divided into 12 -18 alternating nodes or internodes filled with pith (Panda, 2009). Internodes below the sixth, seventh and eight leaves elongates to approximately 25, 50 and 90 mm whereas there is no lengthening in size for those below the first four leaves with bearing tillers (Plessis, 2003). On the leaves sheath, internodes grooved or flattened at the side next to leaf sheath when either bud or branch form at the nodes and leaves attach to the nodes (Panda, 2009).

2.4 Life Cycle

Imbibing of water during germination under favourable conditions of air, moisture and temperature swells the corn kernel, thus increasing its weight. A 30% accumulation of corn kernel dry weight happens before enzymatic activity in the embryo begins. Within 2 – 3 days, under stimulation of favourable conditions, enzyme activities continue with radicle elongation and emergence from the seed coat. This process continued with plumule elongation with additional leaves emergence later on.

Soft leaves development are enclosed in a coleoptile, a specialized leaf structure where these leaves will continue developing and growing upward, through the abrasive soil above ground. Radicle formation develop first followed by several other seminal roots which function as corn anchoring and structure for water and nutrient uptake from the soil. Within the early 14 days, seminal roots continue growing until permanent roots form at the crown of corn roots.

Mesocotyl is a structure developed between the point of kernel attachment and the crown with tubular, white stem like parts that is sometimes referred to as the first internode. As the coleoptile breaks through the soil layers, moving towards the surface of the soil, elongation of both mesocotyl and coleoptile occurs and upon exposure to sunlight, the coleoptile stops growing and the first leaves break through the coleoptile. After exposure to sunlight, the coleoptile tip will release chemical signals to modify the depth of the crown, commonly 2 – 3 cm below the soil surface.

Naturally, the mesocotyl depth is equal to approximately half of the planting depth but this factor may vary according to planting depth. Deeper mesocotyl causes the mesocotyl to elongate longer (O'Keefe and Schipp, 2009). The most common system used to define corn growth stages is by dividing the growth cycles into two parts, which are vegetative growth and reproductive development.

2.5 Fertilizer Requirement

Corn requires essential nutrients elements such as nitrogen, phosphorus and potassium. It also requires at least 10 minor or trace elements for normal plant growth and development. Fewer differences have been observed across corn systems in five regions with respect to the application of chemical fertilizers. In addition to the base fertilizer applied at planting by all farmers, most farmers also apply a topdressing (usually nitrogen) at least once (and sometimes twice). If fertilizer is applied only once, application takes place at the booting stage (ear development). The second application, if it occurs, is at the elongation stage. Farmers opt for one application to reduce chemical costs and labour use, and to shorten the interval between base fertilizer application and fertilization at elongation. Macroelements that corn needed include nitrogen, potassium and phosphorus where deficiency in these macroelements will result in adverse effects. However, trace elements are needed in minute amounts (Brewbaker, 2003). The recommended rate of fertilizers by Jabatan Pulau Pinang (2013) are shown in Table 2.1.

Table 2.1: Recommended fertilizer application rates

Types of fertilizer	Time of fertilizing	Rates
Organic matter	A day before planting	5 tons ha^{-1}
N:P:K ; 12:12:17: 2 + TE	A day after planting	500 kg ha^{-1}
Urea	20 days after planting	130 kg ha^{-1}
Urea	40 days after planting	130 kg ha^{-1}

Source: Jabatan Negeri Pulau Pulau Pinang, 2013

2.5.1 Nitrogen

The demand for nitrogen increases dramatically about 40 days after seedling emergence. Before this, the plants take about 18% to 20% of their total nitrogen requirement. However, by the end of silking, they should have 75% of their total requirement (O'Keefe and Schipp, 2009). In order to get maximum amount of corn production and high quality, nitrogen plays a significant role.

Throughout the life cycle of corn, nitrogen uptake stimulates the growth of plants, increases protein content of grain and stover, corn ears are increase in size and numbers and intensifies green colour. Through fertilizer application, various nitrogen sources can be obtained such as from free ammonia, urea or salts of ammonium or nitrate with anhydrous ammonia when applied to the soil under normal atmospheric pressure.

During the growing season, nitrogen is made available to plants by the action of soil bacteria that turns the nitrogen into available nitrates but this nitrate encounter problems to stay long inside the soil because it is prone to leaching and denitrification. Without adequate supply of nitrogen, corn may encounter problems such as light green or yellowish colour on lower leaves, premature dying along leaf midribs and at the leaf tip, stunted plants that slows flowering process and short ears, which area often poorly filled (Brewbaker, 2003).

2.5.2 Phosphorus

A large proportion of the nitrogen and phosphorus taken up by the plant is removed in the grain at harvest (O'Keefe and Schipp, 2009). Two major roles of phosphorus in corn growth are they are major blocks for cellular compounds and aid in the transfer of adenosine triphosphate (ATP), an energy molecule responsible in cellular process. Under high metabolic activity and in young tissues, phosphorus is required the most. Phosphorus is required in the critical stage of early plant development due to inability of root systems to forage for soil phosphorus where the mycorrhizae soil fungi in symbiosis process helps root to uptake phosphorus, which colonize roots and extend the root system. In direct relationship to dry matter accumulation, corn accumulate phosphorus throughout the growing season.

Phosphorus is immobile in soil and the movement of phosphorus is greater in sandy soils than in clay soils. However, even though the movement of phosphorus is greater in sandy soils,it may move less than an inch in the point of placement. Phosphorus requirement in ample amount at the early stage of corn production because only extra phosphorus become available for root uptake only after sufficient phosphorus addition to satisfy the phosphorus adsorption. Deficient in supply of phosphorus will cause purplish leaves, stunted growth, delayed flowering, poorly developed roots and reduced kernel size and number (Brewbaker, 2003).

2.5.3 Potassium

Like other monocotyledon plants, corn takes up potassium in large amounts. Potassium is essential for vigorous growth, but it is not a part of organic compounds or proteins in the plant. Potassium is less available for plant uptake even though it is abundant in soils because its immobility is higher than nitrate and leaching losses are generally not important except on sandy soils. When corn has inadequate amount of potassium, it may show symptoms such as yellow to brown discolouration of lower leaves, scorching of the leaf edges when plants are small, greater tendency of plants to lodge and small ears that fail to fill out fully at the tip (Brewbaker, 2003).

By the end of flowering, the plant takes up more than 90% of its potassium requirement. Uptake of potassium is complete soon after silking, but uptake of other essential nutrients such as nitrogen and phosphorus continues until near maturity. Most of the potassium taken up is returned to the soil in the leaves, stalks and other plant residues (O'Keefe and Schipp, 2009).

2.5.3.1 Importance of Potassium for Corn Growth and Yield

Potassium is needed in plant for overall metabolic and enzymatic activities especially in photosynthesis (Nedamaya *et al.*, 2016). Research has shown that higher level of potassium will produce greater number of leaves (Kumar *et al.*, 2006) and bigger stem girth at 60 kg ha^{-1} of potassium (Brar *et al.*, 2012). Previous study shown that with the application of 60 kg ha^{-1} of potassium, gave significantly bigger gobs, with more length and girth (Brar *et al.*, 2012) and increased grain yield and weight of 100 cobs (Nedamaya *et al.*, 2016; Brar *et al.*, 2012).

2.5.3.2 Importance of Potassium for Sweetness

Potassium is known to promote translocations of sugar in plants especially fruit or vegetables plants and assessed by total soluble solid (TSS) content. Studies have shown that potassium influences the sweetness of papaya by increasing the TSS content. Acidity content significantly decreased with increased in potassium supply (Kumar *et al.*, 2006). In a study using sweet sorghum, application of only 50 kg potassium sulphate per hectare increased the total sugar content by 10.50% as well as total fresh weight by 25.44% (Abas *et al.*, 2008).

A study using tomato variety showed that potassium treatment in increasing levels also improved the yield and yield attribute characters where 75 kg K per hectare produced highest numbers of fruits per plant with highest total soluble solute of 6.25 °Brix (Manoj *et al.,* 2013). Therefore, it is expected that total soluble solid of waxy corn in this study will increase as the potassium fertilizer applied is increased.

2.5.4 Microelements

Calcium is significant to corn as it will neutralize cellular acids and important in the plant cell wall formation. Calcium is abundant in soils but under acidic soils, high amounts of elements such as manganese, iron and aluminium becomes the limiting factor for calcium but the calcium deficiency is quite rare in corn where its identification is complicated by side effects. To correct the acidity of the soils, lime is an option to do so, thus correcting calcium deficiency. Most phosphorus fertilizer usually contain some amount of calcium.

Magnesium has a principal function in chlorophyll formation. Magnesium deficiency will lead to yellow leaf streaking and purpling of the leaf tips and edges with suitable measures taken to correct the soil by using dolomitic limestone or Epsom salts. Sulphur has many functions in the plant, among them the formation of the essential amino acids in proteins—cysteine, cystine, and methionine. Correction in deficient soils is done by applying sulphate-containing fertilizers like calcium sulphate (gypsum) and ammonium sulphate. These elements are used in minute amounts, but deficiency of any of them can cause plant injury. Manure applications can have a very favourable effect on soil micronutrient levels. It rarely pays to apply special micronutrient supplements to corn fields, although boron deficiency is reported on heavily fertilized coastal soils (Brewbaker, 2003).