EFFECT OF CHICKEN MANURE BIOCHAR INCORPORATED WITH POTASSIUM TO THE GROWTH, YIELD AND EATING QUALITY OF GLUTINOUS MAIZE PLANTED ON SILABUKAN SOIL

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

CROP PRODUCTION PROGRAMME

FACULTY OF SUSTAINABLE AGRICULTURE

UNIVERSITI MALAYSIA SABAH

2017

PUMS 99:1

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN TESIS

JUDUL: EFFECT OF CHICKEN MANURE BIOCHAR AND POTASSIUM TO THE GROWTH, YIELD AND EATING QUALITY OF GLUTINOUS MAIZE PLANTED ON SILABUKAN SOIL.

IJAZAH: DEGREE OF BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS (CROP PRODUCTION)

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ACKNOWLEDGEMENT

I would like to take this opportunity to thank my supervisor, Prof. Madya Datuk Hj. Mohd Dandan @ Ame Hj. Alidin and Dr. Jupikely James Silip, my co-supervisor, for helping me, guiding me and for giving me the chance to gain a new knowledge and a precious experience while I'm doing my final year project 1 and 2. I am really thankful for their support, their guidance and their time in making sure this project ended with a success. I also want to express my gratitude to Dr. Mohamadu Boyie Jalloh for helping me in doing data analysis using SAS, for helping in providing materials and also for his guidance in making soil analysis test.

I also want to express my gratitude to the laboratory assistant, Puan Nurul Syakina binti Marli, and also to the field staffs for their help and effort especially in preparing all the materials such as fertilizers, machine and tools and equipments needed while doing this final year project.

Next, I want to express my gratitude to all my friends especially under the same supervision for their teamwork, help and tolerance to help each other and their support until the end of this project.

I also want to thank both of my parents, Julius Kolis Jinivon and Rosetina Richard Raji and to all my family members for their help, guidance and for giving me moral support while I'm doing this project. Last but not least, I also want to express my gratitude to everyone who have involved directly or indirectly has helped me during the progress of finishing this project.

ABSTRACT

This study was carried out at Faculty of Sustainable Agriculture, Universiti Malaysia Sabah (UMS) Sandakan campus from April to September 2016 to determine the effect of chicken manure biochar (20 tonnes ha^{-1}, 40 tonnes ha^{-1} and 60 tonnes ha^{-1}) incorporated with potassium (90:60:60 kg ha^{-1}, 90:60:90 kg ha^{-1} and 90:60:120 kg ha^{-1}) on the growth, yield and eating quality of glutinous maize planted on Silabukan soil. The best rate of potassium and chicken manure biochar for yellow reddish glutinous maize was determined. The treatments that were involved in this experiment were control, three different rates of chicken manure biochar and three different rates of potassium fertilizer. For control treatment, NPK rate of 90:60:60 were applied without incorporating with chicken manure biochar. These treatments were arranged using completely randomized design (CRD) with three replications. The data collected were analysed using one-way ANOVA at 5% significant level. For vegetative growth results, treatment P3M2 (potassium 120 kg ha^{-1}, chicken manure biochar 40 tonnes ha^{-1}) gave the tallest maize (303.73 cm). Treatment P1M2 (potassium 60 kg ha^{-1}, chicken manure biochar 40 tonnes ha^{-1}) and treatment P3M1 (potassium 120 kg ha^{-1}, chicken manure biochar 20 tonnes ha^{-1}) produced the highest number of leaves (13). Treatment P2M3 (potassium 90 kg ha^{-1}, chicken manure biochar 60 tonnes ha^{-1}) gave the longest maize girth circumference (7.1 cm) and also recorded the highest first cob height from the soil surface (158.13 cm). For yield components results, treatment P2M2 (potassium 90 kg ha^{-1}, chicken manure biochar 40 tonnes ha^{-1}) had the longest mean length of cob (13.4 cm) while treatment P2M3 (potassium 90 kg ha^{-1}, chicken manure biochar 60 tonnes ha^{-1}) recorded the highest mean fresh weight of cob (75.426 g). For diameter and circumference of cob (cm), treatment P3M2 (potassium 120 kg ha^{-1}, chicken manure biochar 40 tonnes ha^{-1}) had the highest mean (2.2 cm) and (6.91 cm) respectively. Treatment P2M3 (potassium 90 kg ha^{-1}, chicken manure biochar 60 tonnes ha^{-1}) had the highest mean number of grains which (186.33) grains while treatment P2M1 (potassium 90 kg ha^{-1}, chicken manure biochar 20 tonnes ha^{-1}) showed the highest mean weight of 100 grains (14.66 g). For the total soluble solid content, treatment P1M2 (potassium 60 kg ha^{-1}, chicken manure biochar 40 tonnes ha^{-1}) had the highest mean brix reading (16.966 %). For soil analysis test, treatment P1M3 (potassium 60 kg ha^{-1}, chicken manure biochar 60 tonnes ha^{-1}) showed the highest pH value (6.04), compared to the initial value (4.07). For nitrogen test, treatment P2M3 (potassium 90 kg ha^{-1}, chicken manure biochar 60 tonnes ha^{-1}) had increased the nitrogen content of Silabukan soil from 2.1% to 2.26% while treatment P3M2 (potassium 120 kg ha^{-1}, chicken manure biochar 40 tonnes ha^{-1}) had increased the phosphorus content from 0.105 ppm to 1.912 ppm. For fresh cob extrapolated yield and root dry matter content, treatment P2M3 (potassium 90 kg ha^{-1}, chicken manure biochar 60 tonnes ha^{-1}) produced 6.44 tonnes ha^{-1} and 14.66 g respectively. Therefore, the best treatment that can be recommended to the farmers is P2M3 (potassium 90 kg ha^{-1}, chicken manure biochar 60 tonnes ha^{-1}) as it produced more grains and had the highest mean fresh weight of cob, highest nitrogen content and had pH of 5.99 and also had the highest fresh cob extrapolated yield.

KESAN BAJA BIOCHAR NAJIS AYAM DISEBATIKAN DENGAN BAJA KALIUM TERHADAP PERTUMBUHAN, HASIL DAN KUALITI PEMAKANAN JAGUNG PULUT YANG DITANAM PADA TANAH SILABUKAN.

ABSTRAK

Kajian ini telah dijalankan di Fakulti Pertanian Lestari, Universiti Malaysia Sabah (UMS) kampus Sandakan bermula pada April sehingga September 2016 untuk mengkaji kesan baja biochar najis ayam (20 tan ha^{-1}, 40 tan ha^{-1} and 60 tan ha^{-1}) dan baja kalium (90:60:60 kg ha^{-1}, 90:60:90 kg ha^{-1} and 90:60:120 kg ha^{-1}) kepada pertumbuhan, hasil dan kualiti pemakanan jagung pulut yang ditanam pada tanah Silabukan. Kadar terbaik kalium dan baja biochar najis ayam untuk jagung pulut akan ditentukan selepas kajian ini. Rawatan yang telah digunakan dalam kajian ini adalah rawatan kawalan, tiga kadar yang berbeza bagi baja biochar najis ayam dan tiga kadar yang berbeza bagi baja kalium. Untuk rawatan kawalan, kadar baja NPK yang telah digunakan ialah 90:60:60 tanpa disebatikan dengan baja biochar najis ayam. Setiap rawatan mempunyai tiga replikasi dan disusun menggunakan rekabentuk rawak lengkap (CRD). Data yang telah dikumpulkan dianalisis menggunakan ANOVA sehala pada keertian 5%. Keputusan untuk pertumbuhan vegetatif menunjukkan rawatan P3M2 (kalium 120 kg ha^{-1}, baja biochar najis ayam 40 tan ha^{-1}) mempunyai ketinggian pokok yang tertinggi (307.43 cm). Rawatan P1M2 (kalium 60 kg ha^{-1}, baja biochar najis ayam 40 tan ha^{-1}) dan rawatan P3M1 (kalium 120 kg ha^{-1}, baja biochar najis ayam 20 tan ha^{-1}) mempunyai bilangan daun yang terbanyak, iaitu (13) daun. Rawatan P2M3 (kalium 90 kg ha^{-1}, baja biochar najis ayam 60 tan ha^{-1}) mempunyai ukur lilit pokok yang tertinggi (7.1 cm) dan mempunyai ukuran tinggi tongkol pertama dari permukaan tanah yang tertinggi (158.13 cm). Keputusan untuk komponen hasil menunjukkan bahawa rawatan P2M2 (kalium 90 kg ha^{-1}, baja biochar najis ayam 40 tan ha^{-1}) mempunyai tongkol yang terpanjang (13.4 cm) dan rawatan P2M3 (kalium 90 kg ha^{-1}, baja biochar najis ayam 60 tan ha^{-1}) mempunyai tongkol yang paling berat (75.426 g). Bagi diameter dan ukur lilit tongkol, rawatan P3M2 (kalium 120 kg ha^{-1}, baja biochar najis ayam 40 tan ha^{-1}) masing-masing mempunyai hasil yang tertinggi iaitu 2.2 cm dan 6.91 cm. Rawatan P2M3 (kalium 90 kg ha^{-1}, baja biochar najis ayam 60 tan ha^{-1}) mempunyai bilangan biji yang tertinggi (186.33) biji manakala rawatan P2M1 (kalium 90 kg ha^{-1}, baja biochar najis ayam 20 tan ha^{-1}) mempunyai berat 100 biji yang tertinggi (14.66 g). Bagi kandungan pepejal terlarut, rawatan P1M2 (kalium 60 kg ha^{-1}, baja biochar najis ayam 40 tan ha^{-1}) mencatatkan bacaan brix yang tertinggi (16.966 %). Untuk analisis tanah, rawatan P1M3 (kalium 60 kg ha^{-1}, baja biochar najis ayam 60 tan ha^{-1}) menunjukkan peningkatan pH tanah yang tertinggi (6.04), berbanding dengan nilai pH tanah sebelum rawatan (4.07). Bagi analisis nitrogen, rawatan P2M3 (kalium 90 kg ha^{-1}, baja biochar najis ayam 60 tan ha^{-1}) telah menunjukkan peningkatan kandungan nitrogen tanah Silabukan dari 2.1 % kepada 2.26 %, manakala untuk analisis fosforus, rawatan P3M2 (kalium 120 kg ha^{-1}, baja biochar najis ayam 40 tan ha^{-1}) telah menunjukkan peningkatan kandungan phosphorus tanah Silabukan iaitu dari 0.105 ppm kepada 1.912 ppm. Bagi unjuran hasil tongkol dan berat kering akar, rawatan P2M3 (kalium 90 kg ha^{-1}, baja biochar najis ayam 60 tan ha^{-1}) masing-masing mempunyai bacaan yang tertinggi iaitu 6.44 tan ha^{-1} dan 14.66 g. Oleh itu, rawatan yang boleh disyorkan kepada petani ialah rawatan P2M3 (kalium 90 kg ha^{-1}, baja biochar najis ayam 60 tan ha^{-1}) kerana menghasilkan biji yang lebih banyak, menghasilkan tongkol yang paling berat, menunjukkan peningkatan kandungan nitrogen yang tertinggi terhadap tanah Silabukan, mempunyai pH 5.99, dan mempunyai unjuran hasil tongkol yang tertinggi.

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%	percentage
ANOVA	Analysis of variance
cm	centimetre
g	gram
ha	hectare
kg	kilogram
ml	millilitre
ppm	parts per million
SAS	Statistical Analysis System
UMS	Universiti Malaysia Sabah

CHAPTER 1

INTRODUCTION

1.1 Background

Maize, or corn (*Zea mays*) is a cereal crop that can produced grain annually than any other grain and can grow in a range of agro-ecological environments throughout the world. Other than wheat and rice, maize is also the most important crop and become the staple food for more than 1.2 billion of world's human population and are known for their grains which are rich in vitamins A, C and E, rich in carbohydrates, essential minerals and contain about 9% protein in their grain. Other than that, the maize grain also rich in dietary fibre and calories which are known for a good source of energy.

All parts of the maize can be used both for food and non-food production. For industrial purposes, maize can be use as a livestock feed and as a raw material for industrial products. The production of maize worldwide is 785 million tonnes with United States producing the largest amount of maize which are 42%. Another country producing maize, such as Africa, produces 6.5% of maize and imports 28% of the required maize from the other country. A heavy reliance on maize in the diet will cause malnutrition and vitamin deficiency diseases.

One of the objectives of maize breeders is to produce maize that contain favourable sweetness with a high sugar content in its endosperm. Glutinous maize (*Zea mays* var. *ceratina)* has become increasingly important in local market around Asia such as Thailand, China, Vietnam, Laos, Korea and Taiwan (Thongnarin *et al.,* 2008; Kesornkeaw *et al.,* 2009). Thailand has exports glutinous maize hybrid seeds and frozen glutinous maize and clearly it has a promising trend for market expansion both at local and international market. The carbohydrates characters of the kernels include sugar in forms of sucrose, glucose and fructose, phytoglycogen and starch (Creech, 1965) are important factors to determine the table quality of the glutinous maize. The sugar content will determine the sweetness, glycogen will determined the tenderness and starch in the form of amylopectin determines the waxy taste of glutinous maize (Azanza *et al.*, 1996). The balance combination of these components has creates a unique taste of the glutinous maize that has not been found in any other variety of maize. All forms of carbohydrates will accumulate in the kernel after pollination and the rate and patterns of accumulation will vary among glutinous maize.

Potassium has been known for their supply of sugar, fibre, vitamin C, beta-carotene to maize. Potassium is also known for their two main functions in plant. One of the functions are to activate the enzymes in metabolism processes that responsible for the formation of sugar and protein, thus will increase the sweetness in a crop plant, such as in glutinous maize. Potassium will maintain the turgidity of the cells and maintain the level of water in which, both factors are important in controlling the movement of nutrient inside the plant and the transportation of sugar that has been formed by photosynthesis process for the storage organ such as cereals, bit root, and fruits (International Potash Institute, 2013). Other than that, potassium also will increase the absorption of nitrogen, stimulates the movement of amino acid and forming protein that will enhance the quality. Application of potassium in maize will increase their starch content (International Potash Institute, 2013).

The application of organic fertilizer is important in enhancing the quality of a crop without harming the environment as it will not contain inorganic fertilizer and it is also rich in macronutrient and micronutrient. The growth and yield of maize from the application of enriched organic fertilizer has shown positive results compared with inorganic fertilizer NPK (Ayoola and Makinde, 2009). Organic fertilizer that will be used in this study are chicken manure biochar, and it can help to increase the growth and yield of maize (Ezeibekwe *et al.,* 2009) and also can improve the soil fertility and quality compared to the application of inorganic fertilizer, NPK (Obi and Ebo, 1995).

1.2 Justification

Glutinous maize are one type of maize that has a unique taste as it has the combination of components such as sugar and glycogen and has a high amount of starch in its kernel. Glutinous maize, along with sweet maize is commonly being cultivated as a 'green crop' production. The demand for glutinous maize is quite high as it can be used in many other ways apart from as a source of food, such as for adhesive industries.

However, the low production and a low quality of glutinous maize compared to sweet maize had caused the demand for the glutinous maize cannot be fulfilled by the farmers. Therefore, this study will enable me to do a research regarding the best rate of potassium, which is known to have the ability to increase the total soluble solid in a crop, incorporated with the best rate of organic fertilizer application that can produce a good quality of maize, both in the production and the eating quality of yellow reddish glutinous maize.

Other than that, this study will use Silabukan soil, which is known as low quality of soil as it contain a high amount of clay in its structure. Therefore, this study will determine the best rate of potassium to be incorporated with chicken manure that are able to improve the quality of Silabukan soil so that farmers will not facing a problem while using the Silabukan soil.

1.3 Significance of the Study

This study will help farmers cultivating yellow reddish glutinous maize to increase the crop growth performance and eating quality of the crop by using an organic and inorganic fertilizer incorporated together. The incorporation of these fertilizers at optimum rate will bring economical benefits to the farmers as organic fertilizers are easily available and also easily prepared.

Potassium is known to be able to increase the total soluble solid content in a crop. The total soluble solid will determine the sweetness of the crop. Therefore, if the sweetness of glutinous maize can be improved by this study, it will have competitive advantages over the hybrid maize, thus, this study can give a better market for glutinous maize.

Other than that, this study will use Silabukan soil which is known for its low fertility and a poor soil to be used in agriculture for crop production. Therefore, by using potassium and chicken manure biochar, it will help to determine an optimum rate to be applied to Silabukan soil so the quality and fertility of this soil can be improved for crop production, especially for glutinous maize cultivation.

Therefore, from this study, it is hope that it can give a big impact to the farmers that are cultivating glutinous maize and facing a problem with Silabukan soil so that they are able to increase the production and quality of yellow reddish glutinous maize while reducing the input costs by using both organic and inorganic fertilizer at an optimum rate and also can avoid the wastage of fertilizers.

1.4 Objectives

The objectives of this study were;

1. To determine the effect of potassium and chicken manure biochar on the growth, yield and eating quality of glutinous maize planted on Silabukan soil.

2. To investigate the effect of potassium and chicken manure biochar on the quality of Silabukan soil.

1.5 Hypothesis

1. H_0 : There is no significant difference on the growth, yield and eating quality of glutinous maize planted on Silabukan soil with the application of potassium and chicken manure biochar.

   H_a : There is a significant difference on the growth, yield and eating quality of glutinous maize planted on Silabukan soil with the application of potassium and chicken manure biochar.

2. H_o : There is no significant difference on the application of potassium and chicken manure biochar to the quality of Silabukan soil.

H_a : There is significant difference on the application of potassium and chicken manure biochar to the quality of Silabukan soil.

CHAPTER 2

LITERATURE REVIEW

2.1 Maize

Maize or also known as corn (*Zea mays*) is one of the popular grain other than paddy and wheat and is grown widely throughout the world in a range of agro-ecological environments. Maize is produced more than any other grain annually. There are many types of maize such as sweet corn, flint corn, dent corn, pod corn and also glutinous maize. All types of maize exists in a different colours, textures, grain shapes and also different in size. Most common colour type is white, yellow and red (IITA, 2009). The grains of maize has many nutrient that are beneficial for humans such as vitamin A, vitamin C, vitamin E, essential minerals, carbohydrates, 9% protein and are also rich in dietary fibre and calories which are known as a good source of energy. It is also contain low fat and sodium. Figure 2.1 below shows the maize plant parts.

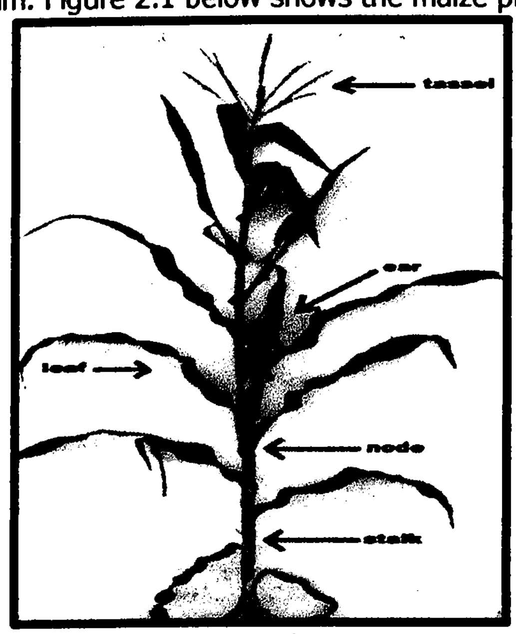

Figure 2.1 : Maize plant parts

Source : Plant & Soil Science eLibrary

Maize is usually used fresh for human consumption. Though it is a cereal crop, it is often consumed as a vegetable. Maize can be dried and grounded into flour for another usage. The grain of maize contains oil that can be used in cooking and also in industrial uses. Other than consumed as a food for human consumption, the whole maize plant also can be a livestock animal sources of food as it can be used for forage and silage. Maize has also become an important bio fuel, both in the form of oil and ethanol and because of that, the maize production has increased by 42% worldwide over the past decades as the demands of maize to be used for bio fuel also has increased.

Glutinous maize, or also known as waxy maize (*Zea mays* L. var. *ceratina*) is one type of maize that are different from the other type of maize. This is due to that glutinous maize has nearly 100% of amylopectin in its endosperm and less or almost none amylose, which makes it different from the other type of maize. However, glutinous maize, along with sweet corn are the most common variety that grown for "green corn production" because these variety has short growing period and are more nutritious and delicious in taste compared with other varieties (Bacanto, 2004). Glutinous maize has grain that is rounded and plump. The grain shows no roughened exterior due to shrinkage during the maturity of the maize. The endosperm of glutinous maize shows a dull and smooth fracture though it is hard like that of flint corn. Glutinous maize is popular to consume as it is tender, lightly sweet, fitting ear and has a short harvesting time which is 55 to70 days only.

Glutinous maize was originally found in China in 1908. However, nowadays, it can be found in many other places in Asia. Glutinous maize is mainly being consumed as a fresh vegetable in many Asian countries such as Japan, Korea and Phillippines. Other than being consumed as food, glutinous maize also can be used as a raw material in many industries such as food industries, textiles, adhesives and also in paper industries.

2.2 Growth Stages of Maize

The growth stages of maize can be divided into vegetative growth and reproductive growth stages. Vegetative growth of maize starts with the emergence of the maize until the formation of tassel.

2.2.1 Emergence Stage

Emergence stage refers to the emergence of first coleoptiles from below the soil through the soil surface (Abendroth *et al.*, 2011). Coleoptiles are also known as the first leave. Basically, the seed needs a moist soil to germinate. A hard or clumpy soil should be avoided for planting the seed as it will make the plumule to unable to emerge and failed to grow upwards, thus will cause a failed germination of the seed.

The elevation of the coleoptiles through the soil surface will be done by the elongation of mesocotyl. Mesocotyl is technically known as the first internode of the stem. It has a tubular, white and stem like tissue that connects the seed to the base of the coleoptiles. The exposure of red light wavelengths of solar radiation during when the coleoptiles nears the soil surface will cause a changes in the supply of growth hormones from coleoptiles to the tissue of mesocotyl. This will cause the elongation of mesocotyl becomes to a halt (Vanderhoef and Briggs, 1978). The leaves inside the coleoptiles will continuously expand, thus causing the coleoptiles tip eventually ruptures. This will allow the first true leaf to emerge. The success of the emergence of first true leaves above the soil surface will be determined by whether the elongation of mesocotyl has elevated the coleoptiles successfully or not.

2.2.2 Leaf Stage

Leaf stage is the development of leaves with a visible collar. It is always numerated as Vn, where n is the number of leaves with visible collars and V represents vegetative growth. For example, at V3, there will be 3 leaves that are fully extended with a visible collar. The nodal roots become active and the growing point is below the ground. At V6, there will be 6 leaves with visible collars and at this point, the tassel and ears will start to develop. Further development, 12 leaves with visible collars will fully expand, however, the bottom leaf will be gone. At V12, the ear size, kernel size and number will be determined. Sufficient water and nutrients should be applied to the plant as the limits of water and nutrients will cause a reduction in yields. At V15, potential kernel number will be set, the upper two ears will be similar in size, however the uppermost will be dominant (Abendroth *et al.*, 2011).

2.2.3 Taselling Stage

Tassels (male) and ear (female) developed by the abortion of the female components of the male flowers, gynoecia and the male components of the female flowers, stamens, respectively. The tassels portion could be visible before the maize plants reaches the last final visible leaf collar occurred. Literally, the teaselling stage occurs when the tassel's last branch emerges from the whorl (Richie *et al.*, 1993).

During or after the tasselling growth stages, the maize plant will reach its maximum height as the final stalk internodes complete their elongation. At this stage, all of the maize leaves are exposed, causing it to be more vulnerable to hail damage. A completely loss of leaf at this growth stage will cause a completely loss of yield by harvest. Though the fertilization of ovules are successful through pollination, most of ear shoots will eventually dies as there are less leaves that remains to make photosynthesis that can produce carbohydrates for completing the filling of maize grain.

The tasselling, silking and pollination stages of maize growth are extremely critical as during these stages, the kernel number and yield components cannot be increased by the plant and the size of the kernel is being determined (Lauer, 1999).

After vegetative growth is the reproductive growth. A successful pollination and initiation of kernel development will initiate the grain fill period. The yield potential of the maize plant can be achieved if there are no stress during the period of grain fill while having a stress condition during the period can cause kernel abortion, lightweight grain and stalk rot development. Hanway (1971) and Abendroth *et al.,* (2011) has described that the kernel development has a several relatively distinct stages starting with silking stage.

2.2.4 Silking Stage

Silking stage occurs 3 days after the stage of taselling. Every potential kernel will develops its own silk. Silk is the functional stigma of the female flower. After the 12 leaves with visible collars occurs, the silk will begin to elongate starting with ovules nearer the base of the cob. It will then continuouslyelongates up the cob, with the tip of the ovules silking last. Turgor pressure can enhance the elongation of silk while drought can caused a delayed in silk elongation and emergence from the husk leaves. The silks will continuously elongates until there are pollen grains captured or until they deteriorate themselves with ages. The pollen captured by the silk will germinates quickly and a pollen tubes will developed to penetrate the silk tissue and elongate to the ovule in about 24 hours. After the fertilization of male gametes to the ovule, the silk will eventually deteriorates at the base and drops away. Therefore, fertilization can be considered as successful or not by visibly checking the silk before any visible kernel development occurs (Nielsen, 2012).

2.2.5 Kernel Blister Stage

This stage will begin about 10 to 14 days after silking. At this stage, the kernel that is developing will contain abundant clear fluid. The silks will mostly become brown and rapidly dried and the starch will begin to accumulate at the endosperm. At this stage, the kernels should be free from stress, as the presence of stress will cause the abortion of kernels at pre blister and blister stages. The kernel moisture content is approximately 85% at this stage.

2.2.6 Kernel Milk Stage

The kernels of the maize will become mostly yellow and contain a milky fluid about 18 to 22 days after the silking stage. The endosperm cell division is almost completed and continuously growth because of the expansion of cell and the accumulation of starch. The stress effect still can abort the kernels, however, the effect are lesser than at the blister stage. The kernel moisture content reduced to 80% at this stage.

2.2.7 Kernel Dough Stage

As the starch accumulation continues, the kernels now will have a "doughy" consistency about 24 to 28 days after silking stage. At this stage, the kernels have reached about 50% of their mature dry weight. The abortion of kernel at this stage is less likely to occur, however, presence of stress can still affect the yield by reducing the kernel weight. The kernel moisture content is reduced 70%.

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