KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY (KNUST), KUMASI, GHANA

STEM BORER INFESTATION ON MAIZE PLANTS TREATED WITH SALICYLIC ACID

By Ismaila Mbenga

Thesis submitted to the Faculty of Agriculture, Department of Crop and Soil Sciences in partial fulfillment of the requirements for the degree of

Masters of Science

in

Crop Protection

May, 2010

DECLARATION

I hereby declare that unless for the purpose of reference to other people‟s work which have been duly acknowledged, this thesis submitted to the Board of Postgraduate studies of Kwame Nkrumah University of Science and Technology, Kumasi, is the result of my own study and has not been presented for any other degree elsewhere.

……....

ISMAILA MBENGA

CANDIDATE

…… ……

DR. J.V.K AFUN DR. M. OWUSU -AKYAW

SUPERVISOR & HEAD OF DEPARTMENT CO-SUPERVISOR

ABSTRACT

Maize is cultivated under a broad range of climatic conditions in West Africa and Central Africa. Lepidopteran stem borers are a major pest of maize and losses they cause in maize vary between 10-70%. Salicylic acid (SA) is a colorless, crystalline organic acid which is widely known as a plant hormone. To determine the effect of salicylic acid on infestation and damage on maize by stem borers, different doses of salicylic acid (50g in 100L of H_2O /ha, 100g in 100L of H_2O/ha, 200g in 100L of H_2O /ha, 400g in 100L of H_2O /ha and 0g of SA as the control) were dissolved in water and sprayed on the leaves of maize plants for five times, at 10-day intervals, starting 10 days after germination until 60 days of the plant growth. The experiment was conducted in both the major and the minor seasons of the year 2009, with a split plot design; with fertilizer and without fertilizer, with four replications. The results indicated that salicylic acid appeared to have no effects on both the stem borer infestations levels and grain yield of the maize. *Busseola fusca* formed the majority of the stem borer larvae in the maize in both seasons, and the fertilized crops appeared to have attracted more stem borers than the unfertilized crops.

DEDICATION

I will like to dedicate this work to my late grandmother Aji Sainabou Kah, under whose guidance I was when I first enrolled to nursery school. She brought me up and impacted a positive influence on my life. Though she had gone, she would always be remembered at all times. Rest in Peace, Grandma.

ACKNOWLEDGEMENTS

First of all, I will like to thank the program of Strengthening Capacity for Agricultural Research and Development in Africa (SCARDA) for sponsoring this project work. My heartfelt thanks and gratitude to Dr. Babou Jobe, Dr. Mustapha Ceesay, Mr. Lamin Jobe, Dr. Sait Drammeh, Mr. Modoulamin Darboe, Mr. Mbye Jabang and all Heads at the National Agricultural Research Institute (NARI) of The Gambia for making sure that this programme of study was possible.

Many thanks goes to my Supervisor and Head of the Department of Crop and Soil sciences, Kwame Nkrumah University of Science and Technology, Dr. J.V.K. Afun for his guidance, assistance and tireless efforts which lead to the accomplishment of this work. Special thanks also go to my Co-supervisor at Crops Research Institute (Kwadaso) Dr. M. Owusu-Akyaw for his support throughout the study of this work.

Again, sincere gratitude also goes to Mr. Amaglo Newton for helping me in various aspect of this work. Special appreciation also goes to Danial Nyadanu for his assistance in the data analysis. I am also very grateful to my parents, Mr. Alhagie Ebrima O. Mbenga and Aja Binta Bah for their prayers, supports and encouragements throughout this course of study.

I am also expressing sincere gratitude to my other family members in The Gambia and elsewhere, not forgetting my friends and colleagues in Ghana, The Gambia and Nigeria for their relentless supports and words of inspiration.

Above all, many thanks and glory to Almighty Allah for He is responsible for being a great force behind this work.

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CHAPTER ONE: INTRODUCTION

Maize (*Zea Mays* L.) is an important stable cereal produced in all agro-ecologies of West and Central Africa, with a demonstrated high yield potential in the savanna zones (FAO, 2000). In Africa, maize is the main ingredient in several well-known national dishes. Its wide genetic diversity and multiple uses account for its cultivation in a large range of environments. Maize is the most important cereal crop in East Africa where it is a staple food for a large proportion of the population. In other countries of West and Eastern Africa, maize can be used to prepare several dishes. Examples are tuwon, masara and akamu in northern Nigeria, Koga in Cameroon, banku and kenkey in Ghana, injera in Ethiopia and ugali in Kenya. In West Africa, maize is an important component of the farming system and it is increasing in importance as it expands into the savannah zones. It is also used as animal feed and as raw material for brewing beer and for producing starch (Misra, 2009). However many factors limit maize production, insects and mites being among the most important (Bosque-Perez, 1995).

The major insects pest of maize include Lepidopteran stem borers, the predominant ones being the African stalk borer (*Busseola fusca* Fuller*)*, the spotted stem borer (*Chilo partellus* Swinhoe*)*, the pink stem borer (*Sesamia calamistis* Hampson*)* and the sugar cane borer (*Eldana saccharina* Walker). Stem borers interfere with the movement of water and metabolites through the plant's vascular system, which stunts its growth and development. Attacks during the first eight weeks after sowing result in “dead heart” and late damage (beyond eight weeks after sowing) leads to stem lodging. Both types of damage to the crop cause drastic loss in maize yield (Bosque-Perez, 1995).

It has been observed by Foidl (2009) that high doses **(**0.69 grams in 1 L H_2O / ha and 2.53 grams in 1 L H_20/ha) of Salicylic acid increased maize productivity through activation of genes which enabled the crop to mature fast and produce four to five cobs per plant (Foidl, 2009).

Maize is the most important cereal crop in sub-Saharan Africa. It is a staple food for an estimated 50% of the population (IITA, 2009). It is an important source of carbohydrate, protein, iron, vitamin B and minerals. Africans consume maize in many forms (e.g. for porridges, pastes and beer). Green maize fresh on the cob is eaten baked, roasted or boiled. Every part of the maize plant has economic value: the grain, leaves, stalk, tassel, and cob can all be used to produce a large variety of food and non-food products (IITA, 2009). In sub-Saharan Africa, maize is mostly grown by small-scale farmers, generally for subsistence as part of mixed agricultural systems. The systems often lack inputs such as fertilizer, improved seed, irrigation and, understanding and management of major pests and diseases. According to (FAO, 2000),

Africa produced 7% of the 598 million tonnes produced worldwide from 138 million hectares in 2000 (IITA, 2009).

In The Gambia, maize is ranked third to millet and rice (M‟ballo, 1998). Production is estimated at about 1.3 metric tonnes/ha (FAO, 2003). Production in The Gambia was concentrated before 1984 to the homestead gardens where house hold refuse was dumped. After 1984, production moved to the outer fields where a lot of inorganic fertilizer was required to increase yield. Maize production in these areas increased because of improved seeds and agronomic practices.

Production also increased because of expansion rather than intensification. However, shortened fallow period, high level of insect pest infestations and deminishing virgin lands have resulted in decreased yields (M‟ballo, 1998).

Yield reductions occur every year across sub-Saharan-Africa due to weed pressure, insect feeding, or stalk lodging (www.isatate.edu, 1995-2009). The potential yield of maize within an environment could be realized when pests are managed by scouting fields regularly and applying treatments when necessary (www.isatate.edu, 1995-2009).

Stemborers are among the most important insect pests of maize in sub-Saharan Africa (www.infornet-biovision, 2009). They cause yield loss that varies between 10-70% (www.infornet-biovision, 2009). Therefore, efforts should be made to manage the pests to increase production of the maize crop.

Maize stalk borers are difficult to control with insecticides (Vitale *et al.*, 2007), the reason presumably being that existing spray-based practices have been found ineffective against the internal feeders and they are costly and hazardous (Clieve, 2003). In the United States of America (USA), therefore, only 18% of the total maize area is sprayed against stem borers (Clieve, 2003). Pests are also increasingly developing resistance to conventional chemical insecticides (I.N.E.R.A, 1999) and outbreaks are expected to worsen through climate change. For instance, all the major global climate models forecast high temperatures that will promote high pest populations (Hulme, 2005). This, therefore, necessitates further research work to develop other methods of controlling maize stem borers more effectively.

Salicylic acid has been shown to have a positive effect on maize plants with regards to expression of dormant genes. However, no work has yet been done to assess the level of insect attacks on the maize plants treated with salicylic acid. Considering the fact that some substances in association with crops under particular conditions can induce the presence of both major and minor pests and diseases at different stages of development, the level of stemborer infestations on maize in association with salicylic acid under our prevalent conditions must be properly studied and understood.

The concept of integrated pest management has taken centre stage in pest and diseases management on a wide range of crops. This approach includes an integration of cultural, biological, chemical and host plant resistance methods in controlling pests. Therefore, finding out the effect of salicylic acid on the population level and damage of stem borers can help update the control strategy of lepidopteran stemborers on maize. Therefore the main objectives of this study were:

- To determine whether salicylic acid has a pull or push effect on lepidopteran maize stalk borers.
- To determine the application rate of salicylic acid for the management of maize stemborers.

CHAPTER TWO: LITERATURE REVIEW

2.1 Taxonomic classification of maize

Maize is an annual monocolyledonous diploid (2n=20) plant belonging to the family *Poacea* and sub-family *Panicoideae.* It is in the *Maydeae* tribe, which is sometimes referred to as *Anthropogoneae* of which eight different genera have been recognized by Taxonomists. *Tripsacum* which has numerous wild species and *Zea* are considered genera of the new origin (Norman *et al.,* 1995). However, Ristanovic (2001) included *Euclaena* among the new world genera while the rest of the *Tripsacum* wild species are considered to be Asiatic in distribution. The genus *Zea* has four species namely *Z. doploperemis, Z. peremis, Z. luxuria and Z. mays*. *Z. mays* has four sub species which are: *mexicana, parviglum, huehuetenangenis, and mays* (Norman *et al.*,1995). The closest relative of cultivated maize is the annual teosinite weed, *E. mexicana* which interbreed to yield fertile hybrids.

2.2 Origin and introduction of maize to other countries

Some researchers believe that maize evolved in Mexico in Central America about 6000 years back (Driscoll, 1990). The earliest archaeological evidence with regards to maize was from the Techucan valley in Mexico (The Food and Culture Encyclopedia, 2003). The second possible centre of origin could be Central America as reported by Martin *et al*. (1976).

After 1492, maize rapidly diffused into Europe, Africa and Asia, and, was successful largely because it did not directly compete with existing grain crops such as rice, wheat, oats, millet and barley. Linguistic evidence strongly suggests that maize penetrated the interior of tropical Africa from the coastal regions, but the timing and mode of its introduction cannot be established. The commonly repeated assertion that the Portuguese brought maize to tropical Africa from the New

World cannot be documented at this juncture, although they seem certainly to have had economic motives for doing so. Maize was probably introduced to tropical Africa at more than one point and at different times. Maize was widely grown along the coast from the River Gambia to Sao Tome, around the mouth of the River Congo, and possibly in Ethiopia, in the sixteenth century (Miracle, 1965).

There is reference to it in Zanzibar and around the mouth of the River Ruvuma in the seventeenth century. It was not only mentioned but described as an important foodstuff and a major provision for slave ships between Liberia and the Niger Delta during the same century (Miracle, 1965).

According to Ristanovic (2001), some data suggest that maize was present in Nigeria even before the famous Colombus voyage. Many researchers believe the introduction of maize to Africa is very recent compared to Europe and Latin America (Ristanovic, 2001).

2.3 Conditions for maize cultivation

Maize is a versatile crop; growing across a range of agro-ecological zones. It thrives best in a warm climate and is now grown in most of the countries that have suitable climatic conditions. In the temperate zones, its growth depends more on high summer temperatures than on a high mean temperature. It will ripen in a short hot summer and will withstand extreme heat (www.satake.co.uk, 2009). A large amount of water is needed during the growth of maize. Its average maturing period is relatively short and this makes it possible to grow at fairly high latitudes (www.satake.co.uk, 2009).

The crop is also suited to cultivation in otherwise poor growing conditions related to topography, soils, climates, and elevation. Significantly, maize does well in exceptionally wet climates unsuited to wheat or relatively arid regions unsuited to rice cultivation (The Food and Culture Encyclopedia, 2003).

2.4 Importance of maize

2.4.1 Nutritional composition

Maize seed is composed of the following substances expressed in grams (g) or milligrams (mg) per 100g weight that have nutritional value: 361 calories, 9.4 g protein ; 4.3 g fat; 74.4 g carbohydrate; 1.8 g fibre; 1.3 g ash; minerals (9 mg Calcium, 290 mg Phosphorus, 2.5 mg Iron) and vitamins (140 mg A, 0.43 mg Thiamine (B1), 0.1 mg Riboflavin (B2), 1.9 mg Niacin) (Duke and Ayensu, 1985).

2.4.2 Uses in human and animal feed

Currently, maize provides the world's most cost-effective and highest yield plant resource available for the production of livestock forage, fodder and feed, a staple food for an estimated 50% of the population in sub-Saharan Africa and a raw material for many industrial products including medicine (Duke and Ayensu 1985; Dowswell *et al*., 1996; IITA, 2009).

In northern Italy, maize is ground with water and eaten as a finely ground mash or porridge. This came to be known as "polenta" to the peoples of northern Italy, which has since been incorporated into European and American cuisines. A variety of toppings and additives, including cheese and

pasta, have diversified the ingredients of maize and transformed it into an international favorite (The Food and Culture Encyclopedia, 2003).

In Africa, maize is consumed in several ways. It is prepared as traditional food called *kpekple* in Ghana, *bidia* in Zaire, *sadza* in Zimbabwe, *putu* in Zululand, *mealie* in South Africa, *Nyeleng* and *chere* in The Gambia and *posho* or *ugali* in East Africa consumed by millions (The Food and Culture Encyclopedia, 2003). Again, in most African countries including The Gambia, fresh maize is roasted or boiled on the cob; the dry grains can be cooked in combination with some legumes or milled, boiled and prepared into balls and eaten with soup or stew or baked or fried into pancakes whilst some types can be popped and eaten as desert and others fermented and brewed into beer and syrup (M‟ballo, 1998).

2.4.3 Uses in medicine

Maize silk can be used to reduce blood sugar levels for the treatment of diabetes mellitus (Duke and Ayensu, 1985) as well as, gonorrhea and gout (Foster and Duke, 1990). The silks are harvested before pollination occurs and are best used when fresh because they tend to lose their diuretic effect when stored and also become a purgative (Launert, 1984). A decoction of the cob is used in the treatment of nose bleeds (Duke and Ayensu, 1985). The seed can also be used as diuretic, a mild stimulant and can be used in the treatments of ulcers, swellings and rheumatic pains (Grieve, 1930), as well as for the treatment of cancer, tumours and warts (Duke and Ayensu 1985). It contains the cell-proliferant and wound-healing substance, allantoin, which is widely used in herbal medicine (Foster and Duke, 1990).

2.5 Constraints to maize production

The average yield of maize in developed countries is about 8.6 tonnes per hectare but production per hectare is still very low in Africa (1.3 tonnes per hectare) (IITA, 2009). The low yields of maize in Africa results from the interaction of abiotic factors which include the volume and distribution of rainfall and soil fertility, and biotic factors comprising diseases and insect pests.

2.5.1 Abiotic factors

2.5.1.1 Water

Approximately 10 to 16 kg of maize grain are produced for every millimeter of water used (Plessis, 2003). Maize yield of 3152 kg/ha requires between 350 and 450 mm of rain per annum. At maturity, each plant will have used 250 mm of water; anything less normally results in moisture stress (Plessis, 2003).

2.5.1.2 Temperature

Maize is a warm weather crop and does not grow in areas where the mean daily temperature is less than 19^0C or where the mean in the summer months is less than 23^0C (Plessis, 2003). Although the minimum temperature for germination is 10^0C, germination will be faster and less variable at soil temperatures of 16 to 18 ^{0}C. At 20^0 C, maize should emerge within five to six days. The critical temperature detrimentally affecting yield is approximately 32^0C. Frost can damage maize at all growth stages and a frost free period of 120 to 140 days is required to prevent damage. Leaves of mature plants are easily damaged by frost and grain filling could be adversely affected (Plessis, 2003).

2.5.1.3 Soil requirements

The most suitable soil for maize production is one with a good effective depth, favourable morphological properties, good internal drainage, an optimal moisture regime, sufficient and balanced quantities of plant nutrients, favourable and chemical properties and a clay content of less than 10% (sandy soils) or in excess of 30% (clay and clay-loam soils) (Plessis, 2003).

2.5.2 Biotic factors

In Ghana, the bulk of maize is produced in the Guinea savanna and forest savanna-transition zones (Gounou *et al.,* 1993). In these agro-ecological zones, maize production is intensive but numerous diseases and insect pests particularly stem borers limit yields (Kwapong, 1990). In areas with a bimodal rainfall, e.g. the forest and forest savanna transition zones, stem borer populations generally reach climax during the minor cropping season where total crop loss due to stem borer attack is not uncommon (Adeyemi *et al.,* 1966).

2.5.2.1 Stemborers

Several species of maize stemborers have been reported worldwide. The most notorious ones are *Sesamia calamistis* (Lepidoptera:Noctuidae), *Eldana saccharina* (Lepidoptera: Pyralidae) and *Busseola fusca* Fuller (Lepidoptera: Noctuidae) (Abu, 1986). *Chilo partellus* (Lepidoptera: Pyralidae) is of Asian origin but it has been recently introduced into eastern Africa (BosquePerez, 1995). Significant reduction in yield due to stem borers has been reported in all the major producing areas in Ghana (Bowden, 1956, 1976; Girling, 1980). The larvae of stemborers usually cause the damage. Estimated yield losses caused by stem borers in West Africa range from 10-

100% (Usua, 1968). The story is not different from other parts of Africa where most peasant farmers do not plant the minor season maize because of stem borers attacks (Gounou *et al*., 1993).

Severity and nature of stem borer damage depends upon the borer species, the plant growth stage, the number of larvae feeding on the plant, and the plant's reaction to borer feeding. Almost all plant parts, leaves, stems, tassels and ears are attacked. Crop losses may result from death of the growing point (dead hearts), early leaf senescence, reduced translocation, lodging and direct damage to the ears. The incidence of stalk and ear rots is increased by larval feeding and lodging of the plants (Bosque-Perez, 1995).

2.5.2.1.1 African maize stemborer (*B. fusca*)

2.5.2.1.1.1 Geographic distribution

B. fusca is distributed widely throughout sub-Saharan Africa. Populations in eastern and southern Africa appear to be adapted to different environments from those in West Africa. In the eastern and southern parts of the continent, *B. fusca* is restricted to mid-and high elevations areas (>600m), whereas in West Africa, the same species is found at all elevations, but is most abundant in the savanna zone (Overholt *et al*., 2001). Counties in which *B. fusca* has been recorded include Angola, Benin, Botswana, Bukina faso, Cameroon, Ethiopia, Ghana, Guinea,

Cote d‟Ivoire, Kenya, Lesotho, Malawi, Mali, Mozambque, Nigeria, Rwanda, Sierra Leone, Somalia, South Africa, Swaziland, Tanzania, Uganda, Zaire, Zambia and Zimbabwe (Harris and Nwanze, 1992). The pest thrives on wide number of other cultivated and wild host plants, mostly of the grass family (Khan *et al*.,1997).

2.5.2.1.1.2. Biology and Economic importance of *B. fusca*

The female lays many eggs in batches of 30-50, inserted between the sheath and the stem. Incubation lasts about 1 week. After hatching, the larvae feed on the young blades of the leaf whorl and then, suspended from silk strands, spread to neighboring plants. They penetrate the stems by boring through the whorl base. Generally, they destroy the growing points and tunnel downward. After passing through six to eight stages (30-45 days), they chew an outlet for the adult and pupate in the tunnel. Pupation lasts 10-20 days. Up to four generations are produced per year. At the end of the rainy season, larvae of the last generation enter diapause in maize and sorghum stubble or in wild grasses. They pupate a few months later, just before the start of the following rainy season.

In the mid and high elevation areas of eastern and southern Africa, *B. fusca* is often the most important stem borer of maize. Yield losses have been estimated to be about 12% for every 10% of plants infested (Harris and Nwanze, 1992). In Sub-Saharan African countries, which include Ghana, *B. fusa* is considered the most important pest of maize, yield loss as high as 40% has been attributed to *B. fusca* infestations (www.maizedoctor.com, 2010). In Zaire for instance, *B. fusca* occasionally caused yield losses of 8-9% in early-planted maize, and 22-25% in lateplanted maize. In Cameroon, Cardwell *et al.* (1997) reported grain loss at 4.6g per borer in lowland fields and 8.7g per borer in highland fields.

2.5.2.1.2 Pink stemborer (*S. calamistis*)

2.5.2.1.2.1 Geographic distribution

S. *calamistis* occurs in most of tropical Africa. Country records include south Africa, Zimbabwe, Malawi, Uganda, Tanzania, Kenya, Zanzibar, Madagascar, Mauritius, Reunion, Angola, Nigeria, Cote d"Ivoire, Camaroon, Gambia, Ghana, (Tams and Bowden, 1953), Mozambique (Cugala *et al*., 1999), Ethiopia (Gebre-Amlak, 1985).

2.5.2.1.2.2 Host plants

The following plants were recorded as hosts of *Sesamia calamistis*; Maize, sorghum, finger millet, rice, sugarcane (Nye, 1960), *Andropogon* sp., *Cenchrus ciliarus, Coix larcryma-jobi, Echinochloa haploclada, Echinochloa, Echinoochloa pyramidalis, Hyparrhenia filipendula, Hyparrhenia rufa, Panicum maximum, Pennisetum purpuream, Phragmites sp., Setaria sphacelata, Sorghum arundinaceum, Sorghum vulgare var.Sudanense, Tripsacum laxum, Vossia* spp., *Cyperus distans, Cyperus immensis, Cyperus papyrus, Typha domingenis* (Khan *et.al*., 1997).

2.5.2.1.2.3 Biology and Economic importance of *S. calamistis*

In 3-5 days, the female lays up to 350 eggs, deposited in batches of 10-40. The eggs are arranged in two to four contiguous rows and inserted between the lower leaf sheaths and stem. Several hours after hatching, the larvae leave the oviposition site to penetrate the stems either directly or after feeding on the leaf sheath. During the larval stage, which lasts 30-60 days, depending on the climatic conditions, and usually involves five to six moults, larvae may successively attack a number of young stems or tillers. Pupation generally takes place in the stem, rarely between the sheath and stem. The pupal period lasts 10-12 days at 25^0C. Under tropical conditions five to six generations are completed in a year. *S. calamistis* breeds throughout the year without diapauses.

S. calamistis is considered to be a very damaging pest in West Africa, whereas in the eastern and southern Africa it is only of moderate importance (Bosque-Perez and Schulthess, 1998).

2.5.2.1.3 The African sugar cane borer (*E. saccharina*)

2.5.2.1.3.1 Geographic distribution

E. saccharina is widely distributed in sub-Saharan Africa including Burundi, Chad, Ghana, Kenya, Mozambique, Nigeria, Rwanda, Sierra Leone, Somalia, South Africa, Tanzania, Uganda and Zaire (Maes, 1998).

2.5.2.1.3.2 Host plants

The following plants were recorded as host of *Eldana saccharina:* Sugarcane, maize, rice, sorghum, *Panicum maximum, Pennisetum purpureum, Phragmites* sp., *Rottboellia cochinchinensis, Sorghum arundinaceum, Sorghum vesicolor, Sorghum vulgare* var.*sudanense, Cyperus distans, Cyperus immensis, Cyperus maculates and papyrus* (Khan *et al.*, 1997).

2.5.2.1.3.3 Biology and Economic importance of *E. Saccharina*

Atkinson (1980) published a detailed account of the biology, distribution and natural hosts of the species in Natal, South Africa, while Girling (1978) did the same in Uganda, and Sampson and Kumar (1985) studied this species in Ghana. Females lay batches of 50-100 eggs on dry leaves at the base of the plants, which may partly explain the tendency of *E. saccharina* to infest mature crops. Eggs hatch after about 6 days and the young larvae feed externally on epidermal tissue before penetrating the stems. The length of larval development is variable and may take up to 2

months. Larvae pupate within the stems. Up to six generations may occur in a year and there is no larval diapause.

In West Africa, *E. saccharina* is a pest of maize and sugarcane. Bosque-Perez and Mareck (1991) found that even though *E. saccharina* attacks maize plants late in the growing season damage can be as high as 20%. In Southern Africa, *E. saccharina* is considered to be a serious pest of sugarcane (Atkinson, 1980). In eastern Africa, *E. saccharina* attacks maize, but usually towards the end of the growing season, and is generally not considered a serious pest.

2.5.2.1.4 The spotted stalk borer (*C. partellus*)

2.5.2.1.4.1 Geographic distribution

C. partellus is native to Asia where it is considered to be a pest of maize and sorghum. It was reported in Africa in 1930 in Malawi, and has since spread to most countries in eastern and southern Africa, including Ethiopia, Kenya, Malawi, Mozambique, Somalia, South Africa, Sudan, Tanzania, Uganda (CAB,1977), Botswana, Swaziland, Zimbabwe (Sithole, 1990), Comoro Islands, Madagascar (Bleszynski, 1970; Delobel, 1975). Additionally, recent samplings conducted by ICIPE and/or national programmes have found *C. partellus* in Eritrea, Zambia, Zanzibar and Somalia (unpublished).

2.5.2.1.4.2 Host plants

The following plants were recorded as hosts of *C. partellus*: Maize, sorghum, rice, sugarcane, *Eleusine coracana, Hyparrhenia rufa, Panicum maximum, Pennisetum purpureum, Rottboellia*

compressa, Sorgham verticilliflorum, Vossia cuspidate (Bleszynki,1970), *Cenchrus ciliaris, Coix lacryma-jobi, Dactyloctenium bogdanni, Echinochloa haploclada, Echinochloa pyramidalis, Hyparrhenia filipendula, Hyparrhenia pilgerana, Hyparrhenia rufa, Panicaum deustum, Panicum maximum, Pennisetum purpureum, Pennisetum trachyphyllum, Pharagmites* sp.,*Rottboellia cochinchinesis, Setaria incrassate, Sorghum arundinaceum, Sorghum vesicolor, Sorghum vulgare* var.*sudanense, Sporobolus marginatus* (Khan *et al*,. 1997).

2.5.2.1.4.3 Biology and Economic importance of *C. partellus*

Adults emerge from the pupae in the late afternoon and early evening and are active at night. During the day they rest on plant debris. Females mate soon after emergence and oviposit for two to three subsequent nights, in batches of 10-80 overlapping eggs, on the upper and undersides of leaves, mainly near the midribs. Some eggs are also laid on the stem. Adults live for about 2-5 days and do not normally disperse far from emergence sites. Eggs hatch in the early morning (06:00-08:00 h), 4-8 days after being laid, and young larvae ascend plants to enter the leaf whorls, where they start to feed. Older larvae tunnel into stem tissue, and after feeding for 23 weeks, pupate in the stem for 5-12 days. Under favorable condition, the life cycle is completed in 25-50 days, and five or more successive generation may develop during a single maize growing season. In cold and/or dry conditions, larvae may enter a resting stage (diapauses) in stems, stubble and other crop residues, where they spend up to 6 months before pupating when favourable conditions occur in the next growing season. However, part of the stemborer population may remain active in wild grasses during the season (Overholt *et al*., 2001).

C. partellus is considered to be the most important stemborer in most low to medium elevation areas of eastern and southern Africa. Yield losses in maize of about 18% were attributed to *C.*

partellus and *C. orichalcociliellus* in the southern coastal area of Kenya (Warui and Kurai, 1983), and 50% in southern Mozambique (Sithole, 1990). Losses of 2-88% due to *C. partellus* have been reported in sorghum (Seshu-Reddy, 1998). Recent evidence suggests that *C. partellus* is increasingly becoming a pest in higher elevation areas as well (Kirl, 1997).

2.5.2.2 Damage symptoms of Stemborers

Stemborers damage plants by feeding on the leaves and in the stems and cobs. Early instars of *Chilo spp.* and *B. fusca* typically migrate from the oviposition site to the whorl where they feed for the first two or three instars on the young succulent leaf tissue. This type of feeding is characterized by „pin holes" and „window panes". Pin holes are a linear series of small holes created when larvae chew horizontally through developing leaves in the whorl. The damage becomes quite evident as the leaves mature and expand out of the leaf sheath. Window panes refer to early larval feeding in which the larvae do not completely chew through the leaf but leave a thin layer of transparent leaf epidermis.

Early instar feeding by *Sesamia spp.* and *E. saccharina* is not usually in the whorl. *Sesamia spp.* feed for a few days in the leaf sheath (between the leaf and the stem) and then tunnel into the stem. *E. saccharina* larvae migrate from the oviposition sites and spread out on the leaves where they tunnel in leaf tissues near the midrib.

From about the third instar, *Chilo spp.*, *B. fusca* and *E. saccharina* bore into the stem where they feed until pupation. Sometimes larvae bore directly into the stem from the whorl and may cause a kind of damage referred to as „deadheart" where the growing point of the plants can cause side

shooting. The entrance holes chewed by larvae when entering the stem can often be seen, and in moist plants may be accompanied by frass pushed out (Overholt *et al.*, 2001).

Prior to pupation, stem borer larvae chew an exit hole for the emergence of the moth. The hole is sometimes referred to as a "window" because it is not chewed completely through the stem but leaves the transparent leaf epidermis. At the reproductive stage of maize, stem borers may be found feeding in the maize cobs (Overholt *et al.*, 2001).

2.5.2.3 Management of Stemborers

Control measures have been devised to minimize the economic impact of the damage caused by stemborers. Stemborers have been controlled by cultural, biological, host plant resistance and chemical methods (Bosque-Perez, 1995).

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2.5.2.3.1 Cultural control methods

This method of control includes agronomic practices such as crop rotation, planting and harvesting dates, and burning of stubble after harvest (Bosque-Perez, 1995). Other examples of cultural control methods include: exposing crop residues to direct sunlight or using crop residue as livestock feed or compost. This can reduce the incidence of diapausing larvae significantly (www.maizedoctor, 2010).

2.5.2.3.2 Biological control methods

This is the action of natural enemies (parasites, predators and microbial agents) including naturally occurring agents and agents which are introduced and managed by humans for pest control (also referred to as "classical biological control") (Bosque-Perez, 1995). Example of using biological

control methods for management of stem borers includes the use of natural enemies of stemborers such as Hymenoptera parasitoids to feed on their larvae, pupae and eggs (www.maizedoctor, 2010).

2.5.2.3.3 Host plant resistance methods

Host plant resistance to insects is the genetic property that enables a plant to avoid, minimize, tolerate or recover from injury caused by insects (Bosque-Perez, 1995). Therefore plant resistance to stem borers is also a genetic trait which manifests itself as antibiosis, in which the biology of the pest is adversely affected after feeding on the plant; non-preference (antixenosis), whereby the plant is not desirable as a host and the stem borer seeks alternative hosts; and tolerance, where the plant is able to withstand or recover from stem borer damage (Mugo, *et al*., 2001)

2.5.2.3.4 Chemical control methods

Under severe infestation, chemical control can provide an effective means of managing stem borers. However, chemical application is only effective if pest scouting and monitoring have been successful prior to crop damage. Furthermore as stem borers burrow into the stem, they are often protected from insecticides applications (www.maizedoctor, 2010). This control includes the use of insecticide as well as other chemicals such as attractants and repellents (Bosque-Perez, 1995).

2.5.2.3.5 Integrated Pest Management (IPM)

This is the term used to describe the management of pests by integrating compatible control methods in an environmentally sound manner. Integrated pest management of stem borers

combines cultural Biological, host plant resistance and chemical control methods to manage them. The used of insecticides is always the last resort in IPM control (Bosque-Perez, 1995).

2.6 Salicylic Acid

2.6.1 Description

Salicylic acid (SA) is a beta hydroxyl acid (BHA) with the formula C_6H_4 (OH) COOH; the chemical name is 2-Hydro-benzoic acid. It is a colorless crystalline organic acid. This is chemically identical to the active component of asprin (*acetylsalicylic acid*) (www.inchem.org, 2008).

If prepared from natural methyl salicylate, it may have a faint mint like odour. It is available in forms of ointments, cream, gel, powder, liquids and plaster. Salicylic acid is soluble; 1 in 460 to 550 of water, 1 in 15 of boiling water, 1 in 3 to 4 in alcohols, 1 in 3 in ether and 1 in 45 in chloroform. Shelf life of Salicylic acid is dependent on the manner of storage. It should be stored in well closed containers and protected from light (Reynolds, 1996).

2.6.2 Role of salicylic acid in plant physiology

Salicylic acid is a phenolic phytohormone in plants. It promotes plant growth and development, photosynthesis, transpiration, ion uptake, transport and plant defense against pathogens (Hayat and Ahmed, 2007; Huijsduijnen, 2009). It plays a role in the resistance to pathogens by inducing the production of pathogenesis-related proteins (Huijsduijnen, 2009).

Salicylic acid and related compounds have been reported to inhibit certain processes and enhancing others in plants (Raskin, 1992). Acetylsalicylic acid functions as antitranspirant in leaves of *Phaseolus vulgaris*, and inhibits the opening of stomata in epidermal strips of *Commelina communis* (Larque-Saavedra, 1978; 1979). Salicylic acid has also been recorded to reverse the closure of stomata caused by abscisic acid (ABA) (Rai *et al*., 1986). Obvious effects on yield of various crop species have been achieved following exogenous application of salicylic acid as observed in mung bean (Singh & Kaur, 1980) and *Phaseolus vulgaris* (Rendom,1983). Salicylic acid treatments stimulated photosynthesis machinery, increased the content of chlorophyll as well as blocking wound response in soybeans (Leslie & Romani,1988). More recently, it has been recognized that salicylic acid induced systemic acquired resistance against some pathogenic infections (Gaffney *et al*., 1993; Metraux *et al*., 1990; Vernooij *et al*., 1994).

According to Foidl (2009), salicylic acid application has several functions in maize. It induces a chain of self defense by burning off attacking hyphae from fungi and fending off attacking bacteria. It also kills cells which have been invaded already by hyphae. Around the exterior of the dead cells, a wall of lignin is built (Light brown haloes around necrotic spots) to avoid further penetration of the hyphae into neighboring cells. To compensate for possible damage, the plant induces rapid root and leaf area development, and increases chlorophyll concentration per active leaf area in order to capture more solar energy and produce more photosynthates. Foidl (2009) also established that salicylic acid application on maize in combination with charcoal has the ability to revert apical dominance, thus causing the maize plant to produce more cobs.

2.6.3 Effects of salicylic acid on Insect Pests and Nematodes.

A compound that is biosynthetically related to salicylic acid (Methyl Salicylate) has been identified as a stress–related plant semiochemical, and insects that were examined, including some haemotophagus insects, showed strong electrophysiological responses to this compound (Pettersson *et al.* 1994). The cereal aphids *Rhopalosiphum padi*, *Sitobion avenae* and *Metopolophium dirhodum* have, in an olfactory organ (the primary rhinarium) on the sixth antennal segment, a specific olfactory neuron for methyl salicylate. Cereal crops treated with a slow release formulation of methyl salicylate were avoided by many insects. Thus, in spring field trials, methyl salicylate applied to wheat significantly reduced (by 30-40%) the overall number of aphids colonizing the crop (Pettersson *et al.* 1994). However, in these trials, the effect was short lived and the formulation needed to continue to release to provide ongoing field activity. In other trails involving salicylic acid, Branch *et al.*, (2004) found that Salicylic acid is an important component of the signaling that leads to root-knot nematode resistance and the associated hypersensitive responses (Branch *et al.*, 2004).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Experimental site

The study was conducted both on the field and in the laboratory. The laboratory studies were carried out in the insectary of the Department of Crop and Soil Sciences and the field study was carried out at the teaching and research farm of the Department, at Kwame Nkurumah University

of Science and Technology. The major season experiment was undertaken from April 2009 to August 2009 and the minor seasons from October 2009 to January 2010.

3.2 Land preparation and sowing

The land measuring about 1.3 ha was ploughed and harrowed. The major season experiment begun in mid April and the minor season experiment begun in late October. The maize variety "Obatampa" was used for the study. The maize was planted in rows at 90 cm between rows and 40 cm between hills. After emergence the seedlings were thinned to two per hill, resulting in about 180 plants per plot. NPK (15:15:15) and Urea fertilizers were applied at three weeks and six weeks after planting respectively. The rate of the fertilizer application was 4 grams per plant for both NPK and Urea. Hoeing was done at 3 and 8 weeks after planting to control weeds. No insecticides were applied to the plants.

3.3 Experimental design

A split plot design was used; with and without fertilizer. Five treatments were replicated four times in each split. The plots that contained the different treatments were the sub-plots and the fertilized and the unfertilized plots were the two main plots.

3.4 Treatments

There were five treatments as follows:

Treatment 1: 50 grams of salicylic acid in 100 l of water/ha. (0.0005%)

Treatment 2: 100 grams of salicylic acid in 100 l of water/ha. (0.001%)

Treatment 3: 200 grams of salicylic acid in 100 l of water/ha. (0.002%) Treatment 4: 400 grams of salicylic acid in 100 l of water/ha. (0.004%)

Treatment 5: Control (water with no salicylic Acid).

The salicylic acid was weighed by using an electronic balance. The application of the various treatments commenced at 10 days after plating and was done by using a knapsack sprayer at intervals of 10 days until 60 days after planting.

3.5 Field data collection

Data was collected on the following parameters.

1. Mean number of egg masses and larvae per plant.
2. Mean number of plants infested by stemborers, taken every seven days after each salicylic acid application.
3. Mean number of crops showing symptoms of stemborer attack at 3 weeks after sowing.
4. Mean number of crops suffering "dead heart" at 3 weeks after planting.
5. Four plants were uprooted from each plot and dissected to determine the stem borer species infesting and causing the dead hearts. Samples were collected five and four times on the major and minor season experiments respectively.
6. At harvest, ten randomly selected plants were uprooted to identify any stemborer species and the number of exit holes created by the stemborers on the stalk.

3.6 Stemborer identification

Description and identification of the stemborers was carried out with reference to the key developed by Overholt *et al*., (2001).

3.7 Parasitism of stemborer larvae.

To ascertain if there were any parasitoids attacking the larvae, the larvae collected from each sub plot at the final data collection on infestation levels, were reared to the adult stage. Larvae were reared in a 200 ml rearing bottles the top of which was covered with nylon mesh. The larvae were reared on fresh maize stalks cut into pieces of 8.50 cm long. Grooves of 4.5 cm long and 0.65cm deep were made into the stem on the side of the internodes. Newly collected stemborer larvae were transferred individually into the prepared stems. The individual stems with larvae were then placed into the rearing bottles and covered with nylon mesh. The stalks were changed weekly until pupation.

3.8 Data Analysis

All data were transformed before analysis, using the square-root transformation formula $\sqrt{(x+0.5)}$. Genstat Statistical package was used for the data analysis. LSD at 5% was used to separate the means where differences were significant.

CHAPTER FOUR: RESULTS

4.1 Percentage stemborer leaf damage in the Major season

Stem borer infestations on the maize plants at three weeks after planting in the major season are illustrated in Figure 4.1.

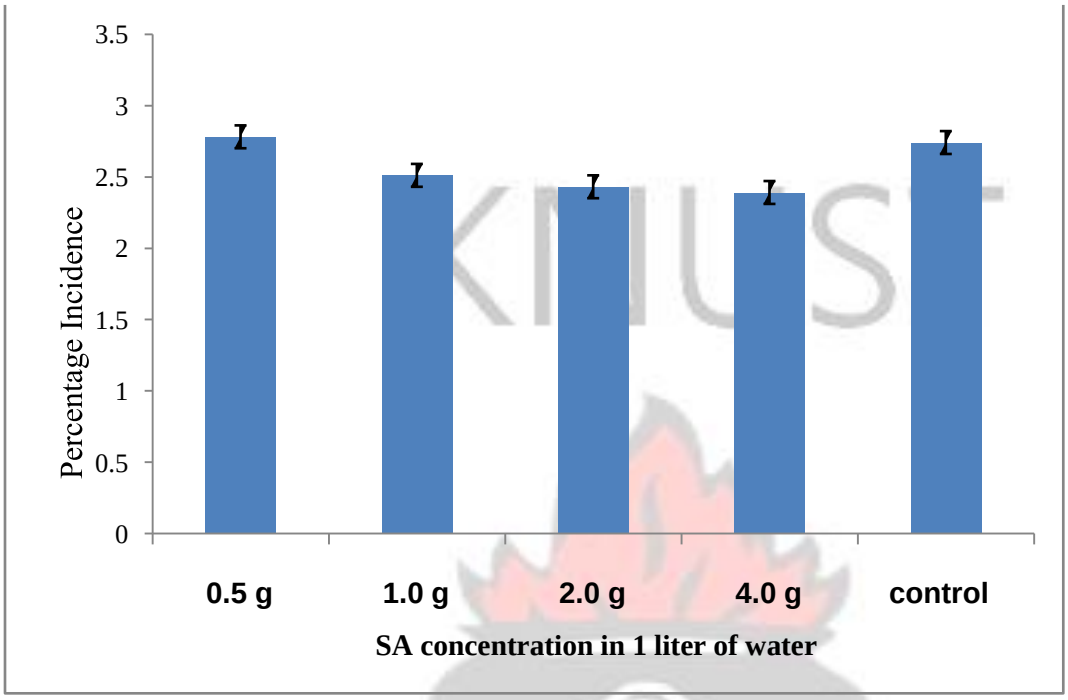

Figure 4.1: Effect of salicylic acid on stemborer damage in maize during the major season

At three weeks after planting of the major season experiment, the characteristic „dead heart" was not noticed in any of the treatments. Symptoms of stemborer damage were however present on the leaves in all treatments, but the differences between their means were not significant, although damage tended to decrease with concentration (Fig.4.1).

4.2 Percentage Dead heart and leaf damage in the Minor season

At three weeks after plating in the minor season, results obtained with regards to dead heart and damage symptoms caused by stemborers are illustrated in Figure 4.2

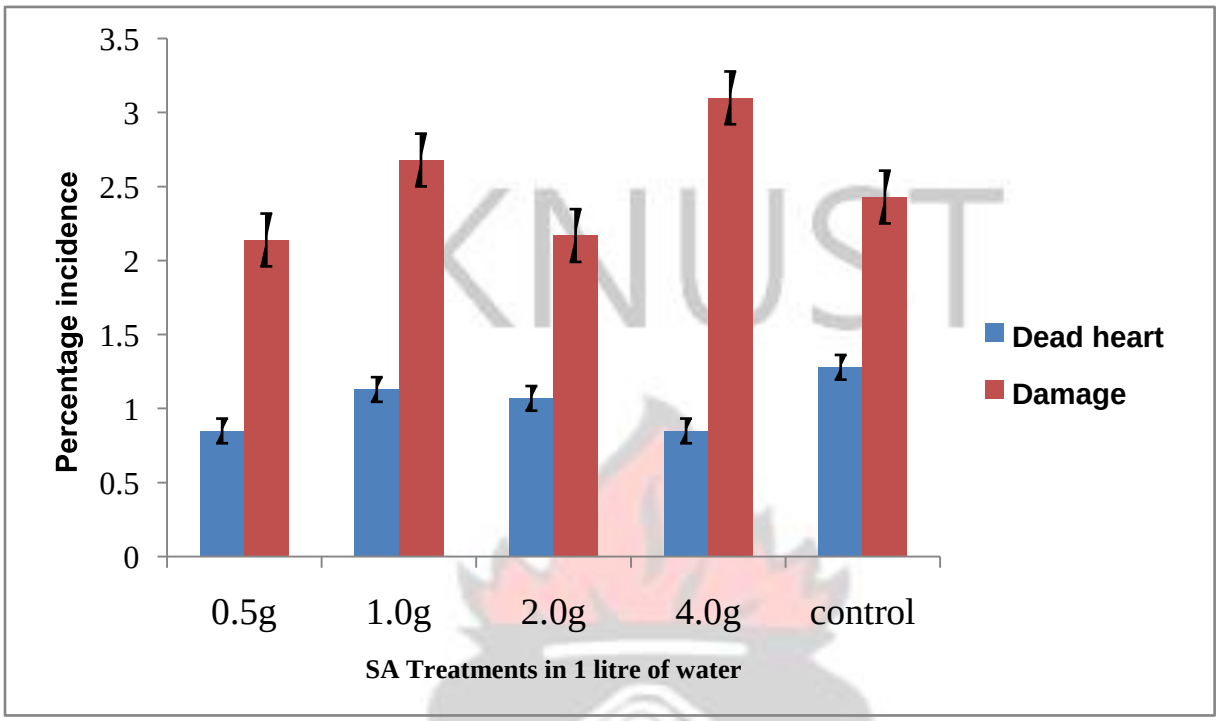

Figure 4.2: Effects of SA on dead heart and leaf damage in the minor season

In the minor season, dead hearts were present on crops unlike the major season experiment. Crops showing stemborer damage symptoms also manifested more in the minor season than in the major season. Despite this, no significant difference was recorded between the means of their treatments (Fig. 4.2). Fertilizer application also did not show statistical differences with regards to larval damage on leaves.

4.3 Egg mass numbers in the Major season

Table 4.1 shows the distribution of egg masses with respect to different doses of salicylic acid in the major season, and Figure 4.3 shows the mean distribution of egg masses within the fertilized and unfertilized crops in the major season.

Table 4.1 Effects of SA on mean numbers of egg mass in the major season

SA CONC. (g/L H_20)	Mean number of egg masses [1]				
	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP[2]
Control	1.67	0.71	0.82	0.84	0.71
0.5g	1.12	0.82	0.84	0.82	0.71
1.0g	1.03	0.71	0.71	0.82	0.71
2.0g	1.03	0.71	0.77	0.71	0.71
4.0g	1.06	0.71	0.77	0.71	0.71
LSD (5%)	NS	NS	NS	NS	NS
CV %	32.8	13.4	35.4	21.5	9.10

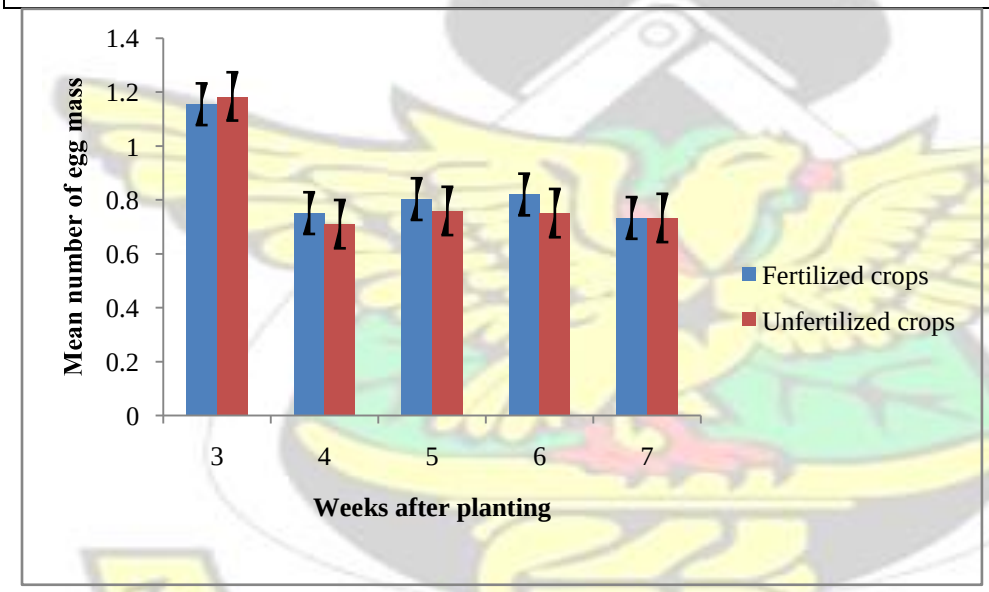

Figure 4.3 Effect of fertilizer application on mean numbers of egg mass at the vegetative stages of plant growth in the major season.

(Square root √(x+0.5) transformed data)

[1] Data transformed using √(x+0.5)

[2] Weeks after Planting

The number of egg masses were more at three weeks after planting than at the later stages but no significant differences were recorded between means of treatments from three weeks after planting to seven weeks after planting in the major season (Table 4.1).

In the fertilized and unfertilized crops, no statistical differences were recorded between numbers of egg masses too (Figure 4.3). But as expected, egg mass numbers were greatest at three weeks after planting for both the fertilized and the unfertilized crops.

4.4 Egg mass numbers in the Minor season

Table 4.2 shows the distribution of egg masses with respect to different concentration of salicylic acid, and Figure 4.4 shows the mean distribution of egg masses with regards to fertilizer applications in the minor season.

Table 4.2: Effects of SA on mean numbers of egg mass in the minor season.

SA CONC. (g/L H_20)	**Mean number of egg masses** [1]			
	3 WAP	4 WAP	5 WAP	6 WAP[2]
Control	0.81	0.84	0.71	0.71
0.5g	0.83	0.77	0.71	0.71
1.0g	0.77	0.71	0.71	0.71
2.0g	0.77	0.77	0.71	0 .71
4.0g	0.83	0.77	0.71	0.71
LSD (5%)	NS	NS	NS	NS
CV %	16.6	13.3	0.00	0.00

[1]Data transformed using √(x+0.5)

[2]Weeks after Planting

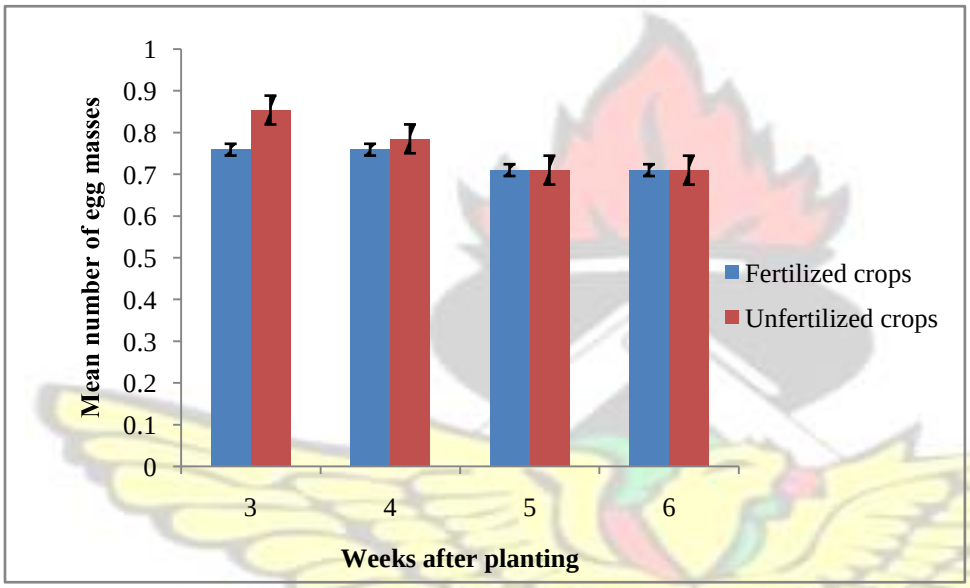

Figure 4.4: Effect of fertilizer application on mean numbers of egg mass at the vegetative stages of plant growth in the minor season.

(Square root √(x+0.5) transformed data)

In the minor season, it was also observed that the numbers of egg mass were greater at three weeks after planting, and thereafter, their numbers started dropping gradually as in the major season (Table 4.2). Even though the numbers of egg masses were a bit greater in the unfertilized crops than the fertilized crops, the differences were insignificant (Fig.4.4).

4.5 Incidence of stemborer larvae in the Major season

Table 4.3 contains infestations of stemborer larvae as affected by SA treatments at the vegetative stages of plant growth, while Figure 4.5 illustrates the effects of fertilizer application on numbers of stem borer larvae in the major season.

Table 4.3: Effects of SA on mean numbers of stem borer larvae in the major season.

SA CONC. (g/L H_20)	**Mean number of stemborer larvae[1]**				
	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP[2]
Control	1.41	1.47	1.04	0.77	1.12
0.5g	1.35	1.39	1.03	0.92	1.05
1.0g	1.55	1.26	0.90	0.84	0.88
2.0g	1,24	0.93	1.16	0.77	1.06
4.0g	1.36	0.84	0.91	0.77	1.05
LSD (5%)	NS	NS	NS	NS	NS
CV %	30.0	13.4	46.5	22.0	32.1

[1]Data transformed using √(x+0.5)

[2]Weeks after Planting

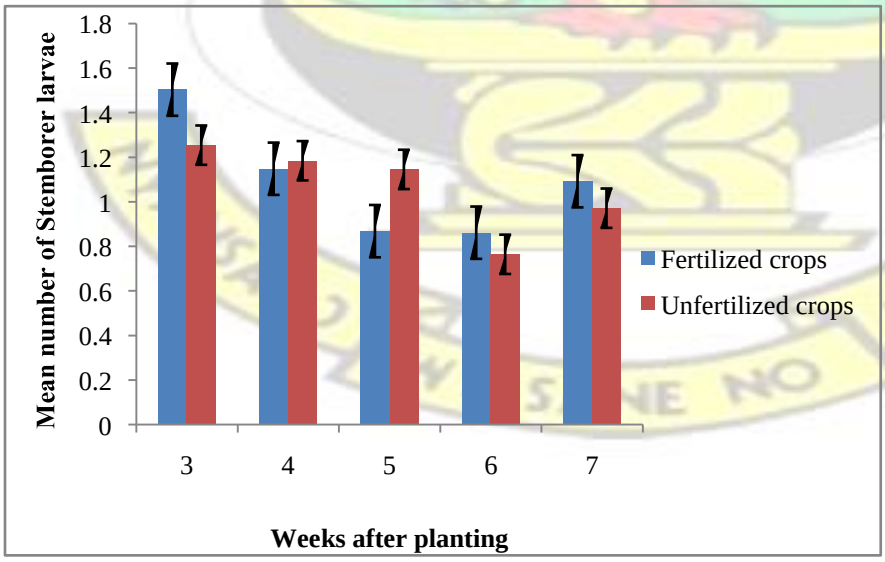

Figure 4.5:Effects of fertilizer application on mean numbers of stemborer larvae at the vegetative stages of the plant growth in the major season

(Square root √(x+0.5) transformed data)

Counts of the larvae did not show significant differences between the various SA treatments or between the fertilized and unfertilized crops at vegetative growth stages of the plant in the major season. The numbers of larvae however appeared more at three weeks after planting and appeared less at six weeks after planting (Figure 4.5).

4.6 Incidence of stemborer larvae in the Minor season

Table 4.4 shows the number of stem borer larvae recorded for the SA treatments at vegetative stages of growth of the plant, whiles Figure 4.6 shows the effect of fertilizer application on stem borer larval infestation in the minor season.

SA CONC. (g/L H_20)	**Mean number of stemborer larvae**[1]			
	3 WAP	4 WAP	5 WAP	6 WAP[1]
Control	1.11	1.43	1.43	0.90
0.5g	1.22	1.49	0.90	1.09
1.0g	1.14	1.18	0.96	1.15
2.0g	0.88	0.12	1.23	1.12
4.0g	1.11	1.08	1.25	0.84

[1] Weeks after Planting

LSD (5%)	NS	NS	NS	NS
CV %	25.0	38.8	29.9	25.0

Table 4.4: Effects of SA on mean numbers of stemborer larvae in the minor season.

[1]Data transformed using √(x+0.5)

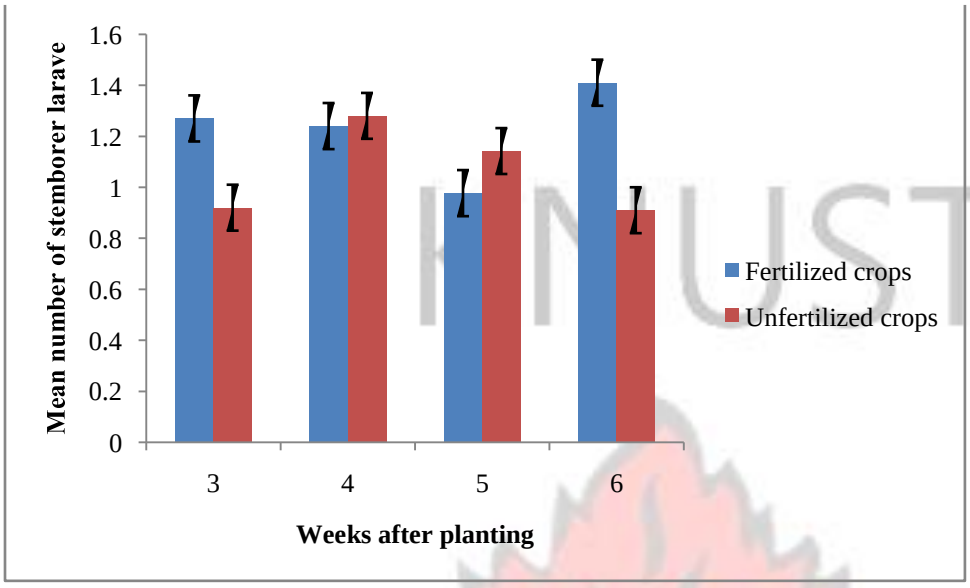

Figure 4.6: Effects of fertilizer on mean numbers of stemborer larvae at the vegetative stages of the plant growth in the minor season.

(Square root √(x+0.5) transformed data)

The differences between SA means with respect to total number of larvae infesting the minor season crop (Table 4.4), were also not significant, neither were the difference between the fertilized and unfertilized crops (Figure 4.6).

4.7 Infestation by African maize stalk borer (*B. fusca)* in the Major season

Table 4.5 shows the levels at which the stemborer species *B. fusca* infested the plants at different stages of the plant growth in the major season, whiles Figure 4.7 represents the effect of fertilizer on *B. fusca* infestation in the same season.

Table 4.5: Effects of SA on mean numbers of *B. fusca* larvae in the major season

SA CONC. (g/L H_20)	**Mean number of *B. fusca* larvae**[1]				
	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP[2]
Control	1.41	0.97	0.77	0.77	0.96
0.5g	1.35	1.09	0.96	0.85	0.95
1.0g	1.55	0.98	0.84	0.84	0.77
2.0g	1,55	0.77	1.10	0.71	0.92
4.0g	1.24	0.77	0.88	0.77	0.92
LSD (5%)	NS	NS	NS	NS	NS
CV %	30.0	26.9	35.4	21.5	22.8

[1] Data transformed using √(x+0.5)

[2] Weeks after Planting

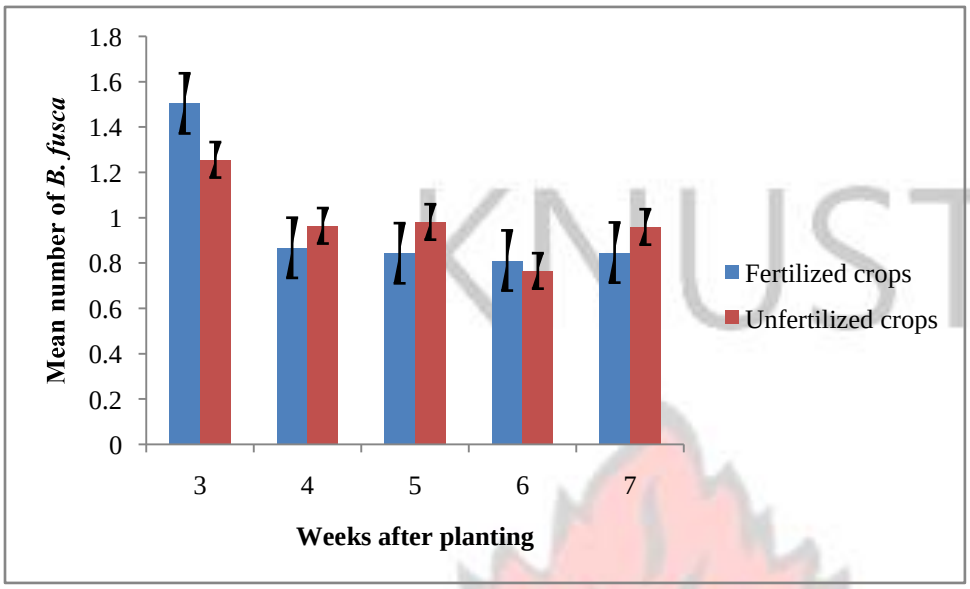

Figure 4.7: Effects of fertilizer on mean numbers of *B .fusca* larvae at the vegetative stages of the plant growth in the major season.

(Square root √(x+0.5) transformed data)

The numbers of *B. fusca* larvae were greatest at three weeks after planting (Table 4.5 & Figure 4.7) and like the previous parameters taken in the major season, the differences in *B. fusca* infestation were not significant between the SA treatments. At three weeks after planting, however the plots treated with 4.0 g of SA recorded the smallest population of *B .fusca* (Table 4.5).

Statistical differences were not recorded with respect to fertilizer applications too. At three weeks after planting, the crops with fertilizer showed slightly greater numbers of *B. fusca* than the unfertilized crops. Infestation by *B. fusca* larvae were however slightly greater in the unfertilized crops at week four, week five and week seven after planting as illustrated by Figure 4.7.

4.8 Infestation by African maize stalk borer (*B. fusca)* in the Minor season

Table 4.6 shows *B. fusca* infestation at different stages of the plant growth in the minor season, whiles Figure 4.8 illustrates the effects of fertilizer application on mean numbers of *B. fusca* larvae in the same season.

As in the major season, infestation by the stem borer species was again dominated by *B. fusca*. However no significant differences were recorded between means of SA treatments (Table 4.6) as well as between the fertilized and unfertilized crops (Fig 4.8).

Table 4.6: Effects of SA on mean numbers of *B. fusca* larvae in the minor season

SA CONC. (g/L H_20)	**Mean number of *B. fusca* larvae**[1]			
	3 WAP	4 WAP	5 WAP	6 WAP[2]
Control	0.77	1.37	0.83	0.84
0.5g	1.11	1.12	0.84	0.90
1.0g	0.95	0.95	0.93	1.05
2.0g	0.71	0.71	1.08	0.06
4.0g	0.90	0.90	0.92	0.84
LSD (5%)	NS	NS	NS	NS
CV %	37.4	37.2	25.1	22.4

[1] Data transformed using √(x+0.5)

[2] Weeks after Planting

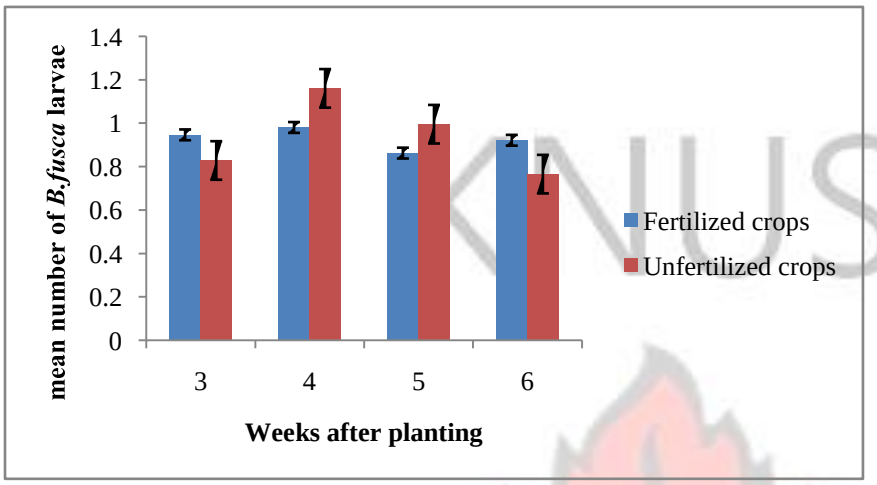

Figure 4.8: Effect of fertilizer on mean numbers of *B. fusca* larvae at vegetative stages of the plant growth in the minor season.

(Square root √(x+0.5) transformed data)

4.9 Infestation by Pink stemborer (*S. calamistis*) in the Major season

Table 4.7 and Figure 4.9 show *S. calamistis* infestations with regards to SA and fertilizer treatments respectively in the major season.

SA CONC. (g/L H_20)	Mean number of *S. calamistis*[1]				
	3WAP	4 WAP	5 WAP	6 WAP	7 WAP[1]
Control	0.71	1.26	1.02	0.71	0.88
0.5g	0.71	1.01	0.77	0.77	0.87
1.0g	0.71	1.05	0.77	0.71	0.84
2.0g	0.71	0.88	0.81	0.77	0.84
4.0g	0.71	0.77	0.77	0.71	0.77

[1] Weeks after Planting

LSD (5%)	NS	NS	NS	NS	NS
CV %	0.00	30.3	37.4	11.6	22.9

Table 4.7: Effects of SA on mean numbers of *S. calamistis* larvae in the major season

[1]Data transformed using √(x+0.5)

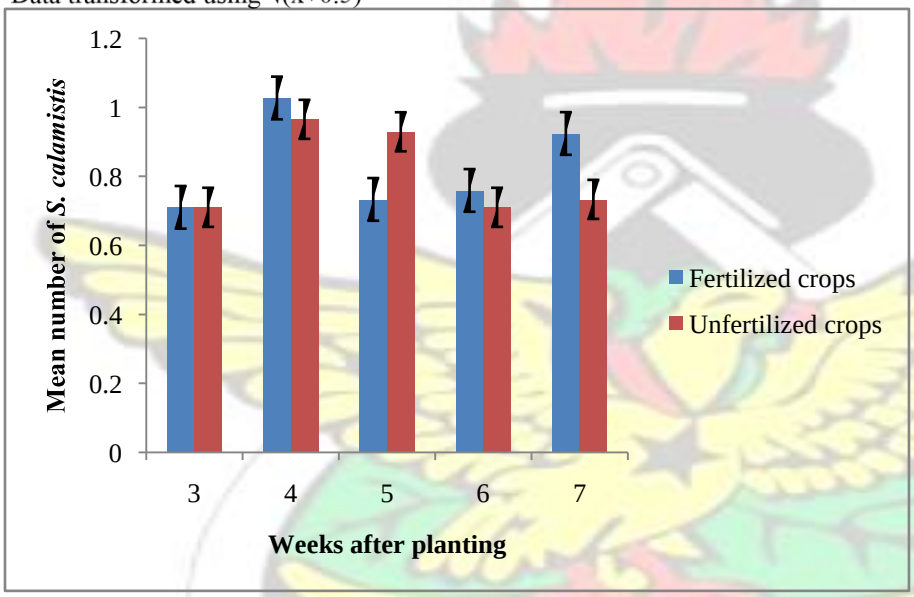

Figure 4.9: Effects of fertilizer on mean numbers of *S. calamistis* larvae at the vegetative stages of plant growth in the major season

(Square root √(x+0.5) transformed data)

S. calamistis were first sampled in the crop at four weeks after planting in the major season but there were no significant differences between means with regards to SA treatments (Table 4.7) as well as fertilizer applications (Fig.4.9).

4.10 Infestation by Pink stemborer (*S. calamistis*) in the Minor season

Table 4.8 and Figure 4.10 shows *S. calamistis* infestation of the maize plants with regards to SA and fertilizer treatments respectively at the vegetative stages of growth of the plant in the minor season.

Table 4.8: Effects of SA on mean numbers of S. *calamistis* larvae in the minor season

SA CONC. (g/L H_20)	**Mean number of *S. calamistis*[1]**			
	3 WAP	4 WAP	5 WAP	6 WAP[2]
Control	1.03	0.77	0.84	0.77
0.5g	0.84	1.10	0.71	0.96
1.0g	0.98	0.10	0.77	0.71
2.0g	0.88	0.94	0.88	0.77
4.0g	0.94	0.82	1.05	1.71
LSD (5%)	NS	NS	NS	NS
CV %	37.8	31.2	25.0	18.0

[1]Data transformed using √(x+0.5)

[2]Weeks after Planting

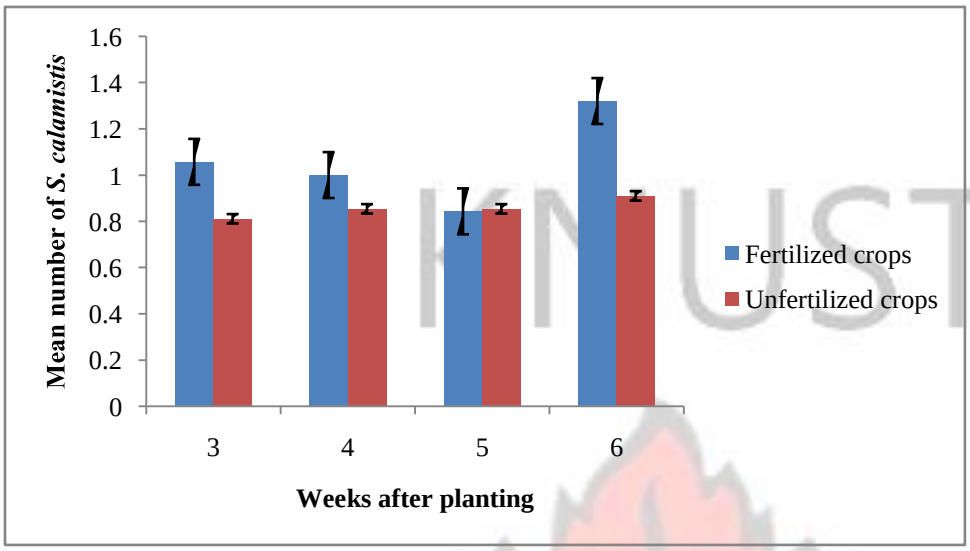

Figure 4.10: Effects of fertilizer on mean numbers of *S. calamistis* larvae at vegetative stages of the plant growth in the minor season

(Square root √(x+0.5) transformed data)

The numbers of *S. calamistis* larvae were only slightly more in the fertilized crops than the unfertilized crops in the minor season (Fig. 4.10). In the fertilized crops, the number of *Sesamia* decreased with plant age until at five weeks after planting and then increased thereafter, but in the unfertilized crops, the numbers of *Sesamia* remained fairly constant with plant age (Fig 4.10). Like *B. fusca* no statistical differences were recorded between means of SA treatments as well as between means of the fertilized and the unfertilized crops with respect to *S. calamistis* appearance in the minor season.

4.11 Infestation by African sugar cane borer (*E. saccharina*) in the Major season

Table 4.9 and Figure 4.11 show infestations by the stemborer *E. saccharina* larva*e* at the vegetative stages of the plant growth in the major season.

Table 4.9: Effects of SA on mean numbers of *E. saccharina* larvae in the major season

SA CONC. (g/L H_20)	**Mean number of *E. saccharina* larvae**[1]				
	3 WAP	4 WAP	5 WAP	6 WAP	7 WAP[2]
Control	0.77	0.71	0.71	0.71	0.77
0.5g	0.71	0.71	0.71	0.71	0.71
1.0g	0.71	0.71	0.71	0.71	0.71
2.0g	0.77	0.71	0.71	0.77	0.77
4.0g	0.77	0.71	0.71	0.71	0.77
LSD (5%)	NS	NS	NS	NS	NS
CV %	0.00	0.00	0.00	0.00	0.00

[1]Data transformed using $\sqrt{(x+0.5)}$

[2]Weeks after Planting

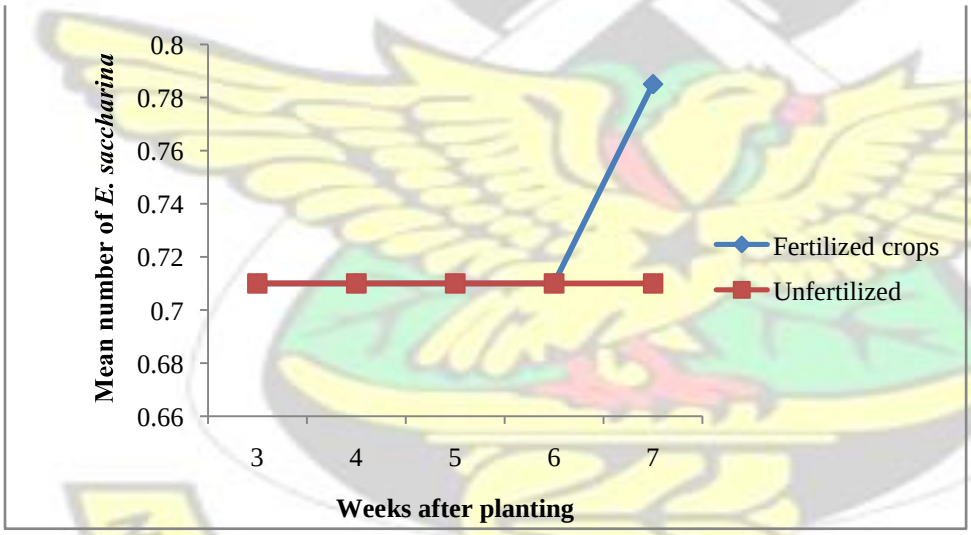

Figure 4.11: Effect of fertilizer application on mean numbers of *E. saccharina* at the vegetative stages of the plant growth in the major season

(Square root $\sqrt{(x+0.5)}$ transformed data)

The incidence of *Eldana* in the major season was virtually insignificant. *Eldana* recorded the lowest infestation levels amongst all stemborer species found in the major season. *Eldana* sp. was

not recorded in the crops until seven weeks after planting, and even so only in the fertilized crops (Figure 4.11).

4.1[1] Infestation by African sugar cane borer (*E. saccharina*) in the Minor season

Table 4.10 and Figure 4.12 show effects of SA treatments and fertilizer application respectively on number of *E. saccharina* larvae in the minor season.

Table 4.10: Effects of SA on mean numbers of *E. saccharina* larvae in the minor season

SA CONC. (g/L H_20)	**Mean number of *E. saccharina* larvae[2]**			
	3 WAP	4 WAP	5 WAP	6 WAP
Control	0.71	0.71	0.71	0.71
0.5g	0.71	0.71	0.77	0.71
1.0g	0.71	0.71	0.71	0.82
2.0g	0.71	0.71	0.77	0.82
4.0g	0.71	0.71	0.71	0.71
LSD (5%)	NS	NS	NS	NS
CV %	0.00	0.00	11.6	13.4

[1] Weeks after Planting

[2] Data transformed using $\sqrt{(x+0.5)}$

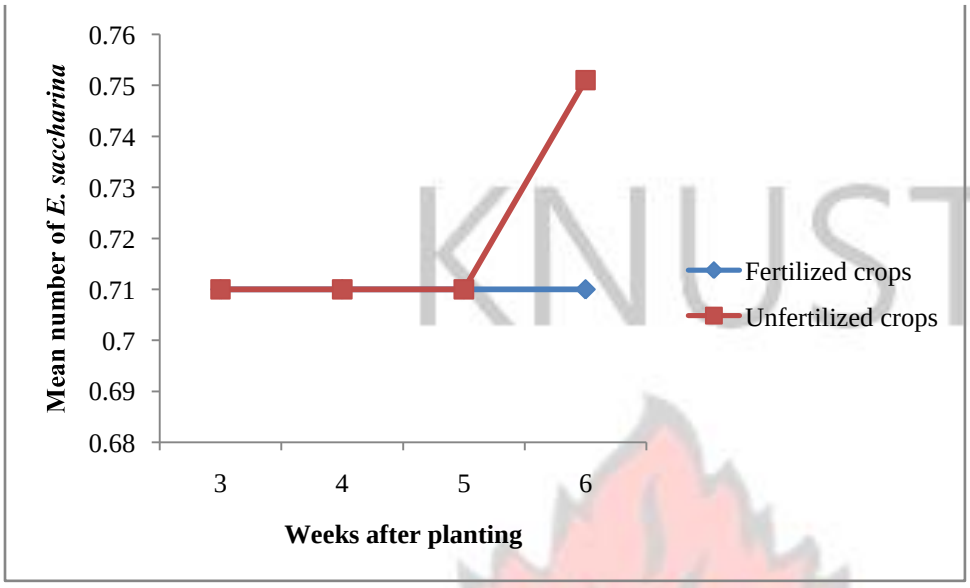

Figure 4.12: Effect of fertilizer on mean numbers of *E. saccharina* larvae at the vegetative stages of the plant growth in the minor season

(Square root √(x+0.5) transformed data)

As it was in the major season, the larvae of *E. saccharina* were the fewest amongst all the other stemborer species found. They were first observed in the minor season at six weeks after planting in the unfertilized crops, whiles in the fertilized crops unlike in the major season, they were virtually unnoticeable.

No significant differences were recorded between means of treatments with respect to *E. saccharina* from three to six weeks after planting in the minor season concerning both SA treatments (Table 4.10), as well as fertilizer applications (Figure 4.12).

4.13 Yield of the Major season experiment

Figure 4.13 shows the mean yield of crops with respect to SA treatments, whiles Figure 4.14 gives the percentage yield with regards to fertilizer application.

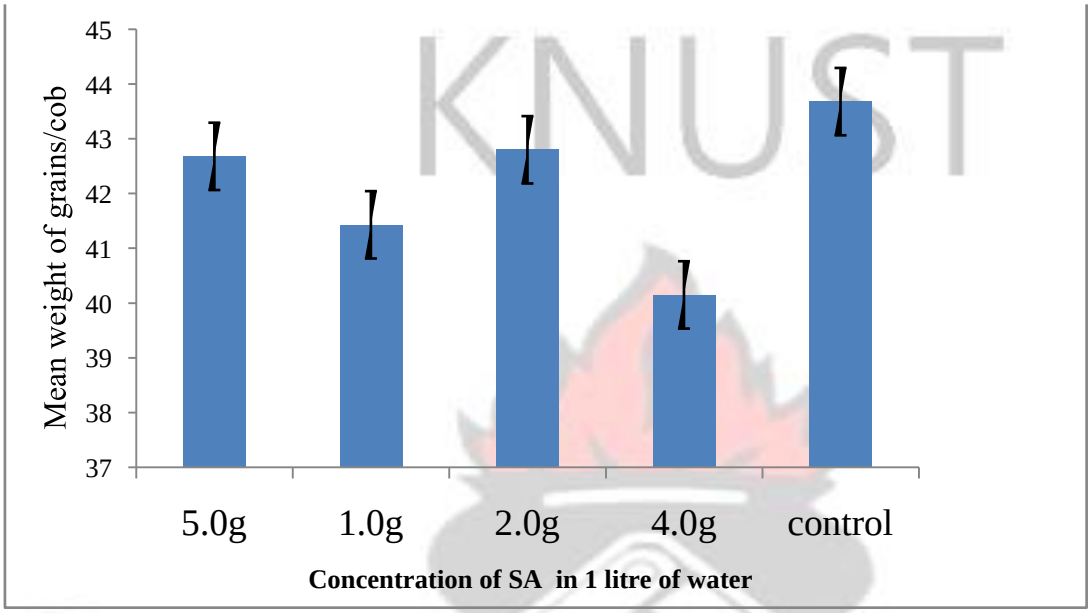

Figure 4.13: Effects of SA treatments on maize yield.

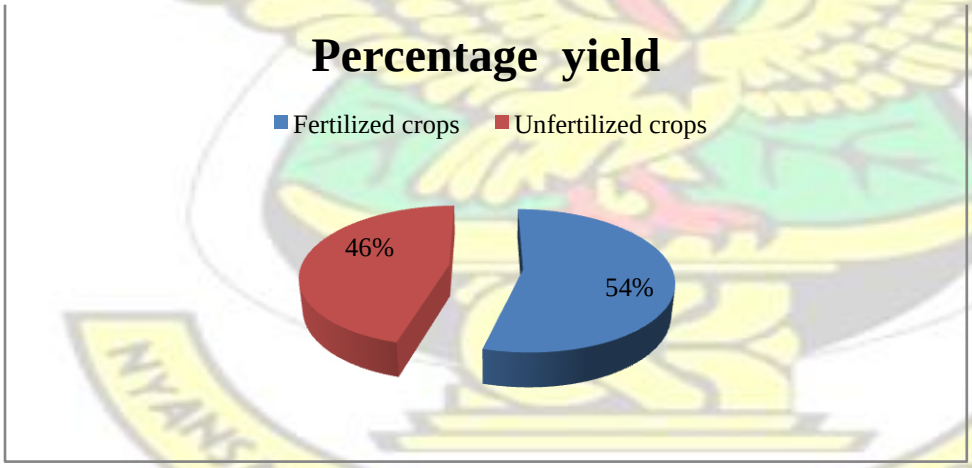

Figure 4.14: Percentage yield of the fertilized and unfertilized crops

The control treatments showed slightly greater grain yields than the SA treatments in the major season even though there were no significant differences between treatments. However the

fertilized crops produced 54% of the yield and the unfertilized crops produced a significantly smaller yield of 46% (Fig. 4.8).

Due to the inconsistency of the rain in the minor season, the plants were drying off before reaching maturity level, therefore, infestation data was taken only five times unlike the major season when data was recorded six times before yield data was taken. Yield data was also unaccounted for in minor season due to the same reason.

4.14 Stem borer infestation levels at harvest in the Major season

At harvest in the major season, mean numbers of stemborer larvae and exit holes per stalk are illustrated in Figures 4.15 and 4.16.

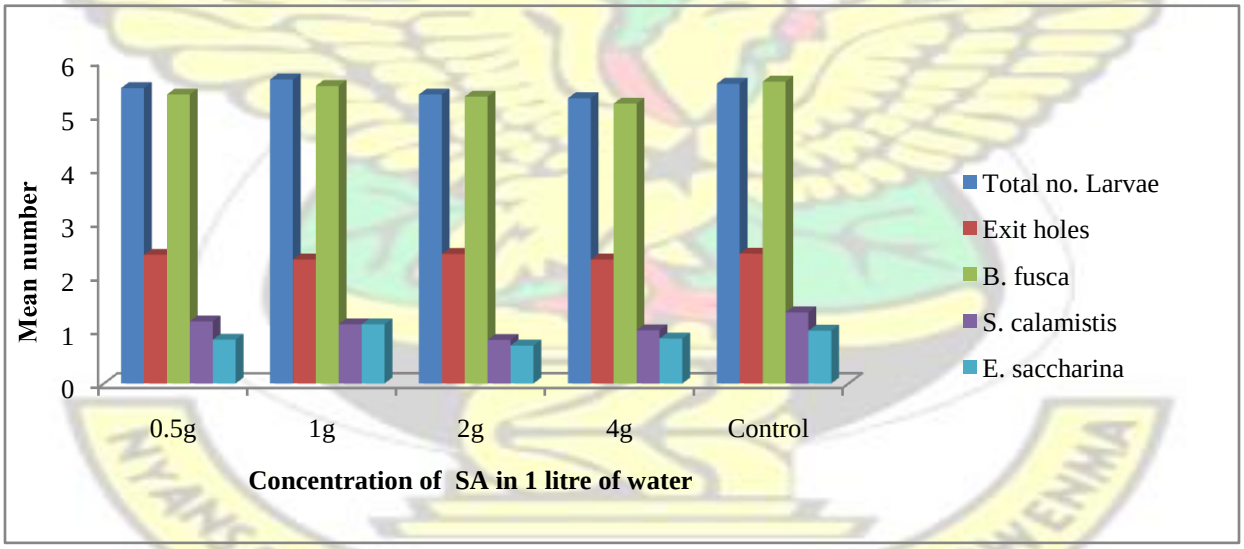

Figure 4.15: Effects of SA on mean numbers of exit holes and larvae per stalk at harvest in the major season

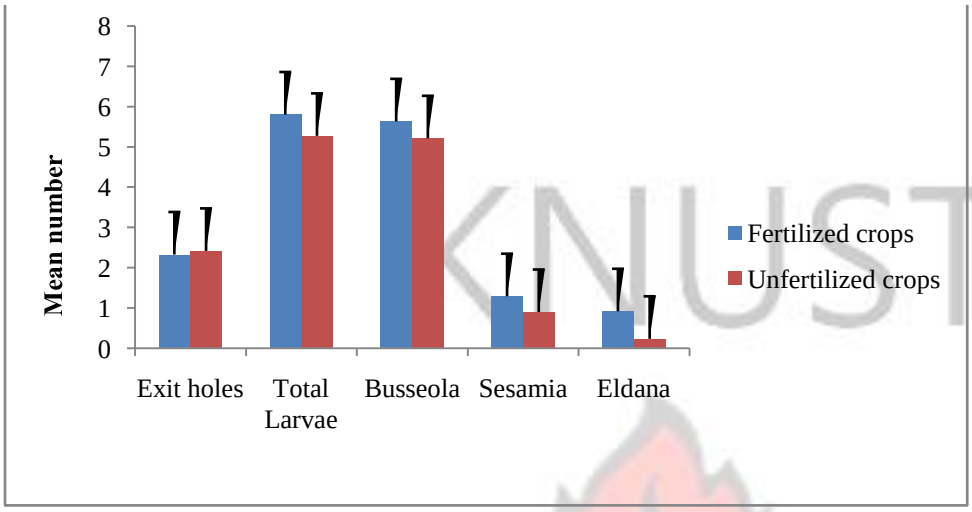

Figure 4.16: Effects of fertilizer on mean numbers of exit holes and larvae per stalk at harvest period in the major season.

At harvest in the major season, greater numbers of larvae were observed in the maize stalks but still no significant differences occurred between the means of SA treatments, and not even for the number of exit holes. The *B. fusca* species continued to form the majority of the larvae found. *S. calamistis* and *E. saccharina* also showed up at this stage but their populations were visibly lower than those of *B. fusca* species (Fig. 4.16). Also at harvest in the major season, the plots with fertilizer again showed higher numbers of larvae than the plots without fertilizer, but the differences were not significant (Fig4.16).

4.15 Stem borer infestation at harvest in the Minor season

At harvest in the minor season, mean infestation of stem borer larvae and exit holes per stalk are illustrated in Figures 4.17 and 4.18.

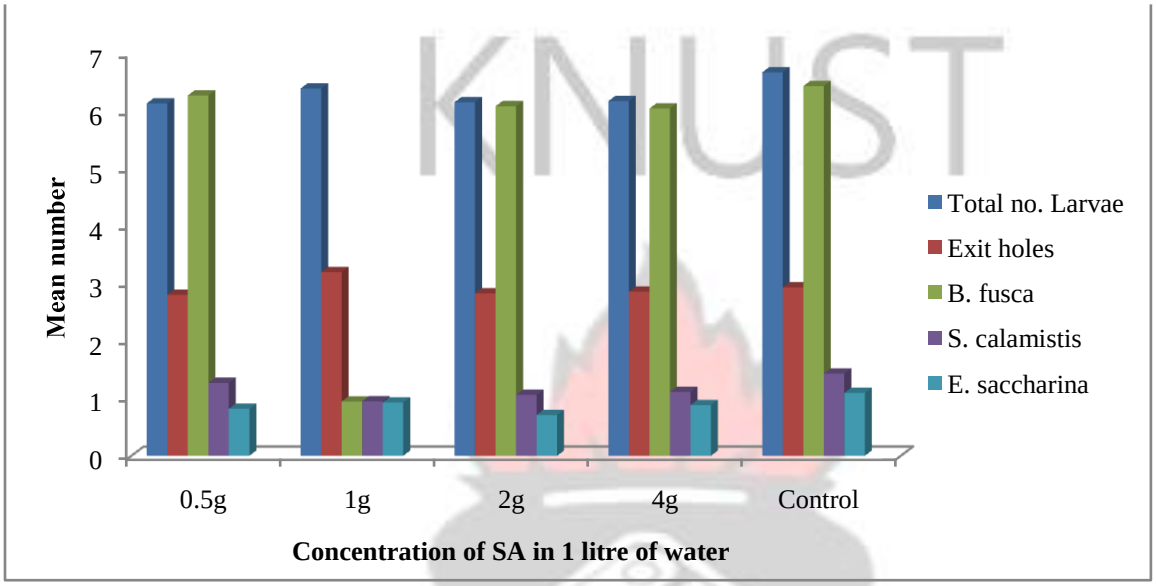

Figure 4.17: Effects of SA on mean number of exit holes and larvae per stalk at harvest in the minor season

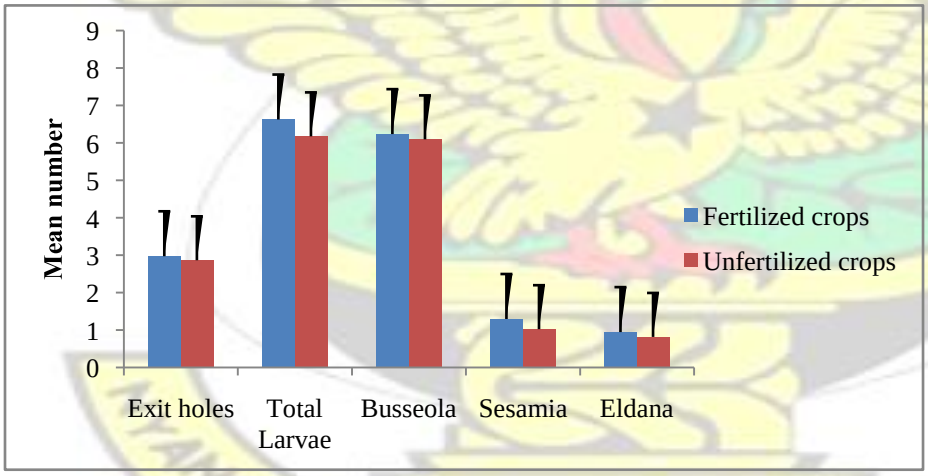

Figure 4.18: Effects of fertilizer on mean number of exit holes and larvae per stalk at harvest in the minor season.

The harvest data in the minor season was taken at about seven weeks after germination when the crops had started drying due to severe drought. Again in the minor season, *B. fusca* appeared more than any other larvae recorded (Figure 4.17), while *E. saccharina* again was the least amongst all

the species found. Similar to the major season, the fertilized plots in the minor season also showed slightly more numbers of larvae than the unfertilized plots (Fig. 4.18).

4.16 Rearing of stem borer larvae

Another thing that the two experiments (major and minor season experiments) had in common was that, when stem borer larvae were reared to adulthood in the laboratory to check for parasitoids, no parasites emerged from them.

CHAPTER FIVE: DISCUSSION

From the two experiments conducted in this study, only few statistical differences were recorded, but those differences could not be attributed to the salicylic acid treatments given to the plants but rather can be attributed to fertilizer application. The salicylic acid clearly did not manifest any effect on stemborers or on growth and yield of the plant. The salicylic acid was supposed to

override the genes that suppress the development of multiple ears in the maize (Foidl, 2009). According to Foidl (2009), SA exhibits this action best if charcoal is incorporated in the soil. Charcoal enhances the activities of soil biota influencing easier absorption through the roots. Charcoal was not incorporated into the soil, which may explain the apparent lack of action of SA on the maize. This lack of effect of the SA on stemborers, as well as on yield of the maize plants can be also attributed to high temperatures in our study environment (Ashanti region of Ghana) that may have resulted to too much loss of SA through transpiration (Burba *et al*., 2006). The average temperature in Ashanti region according to Kumasi Metropolitan Assembly ranges between 28^{o} Celsius to 35^{o}Celcius (K.M.A, 2009).

In both experiments, it was observed that *B. fusca* formed the majority of the stemborers found. This appears to agree with the report by Onyango and Ochieng-Odero (1994) that *B .fusca* is a major pest of maize in many countries in tropical Africa. In this study *S. calamistis* was also found infesting the maize, particularly in the minor season which also agrees with work done by Endrody-Younga (1968), who reported that *Sesamia* infestation in the Ashanti Region of Ghana was negligible in the major season but very high in the minor season causing serious damage to the maize crop.

It was also observed that numbers of stemborer larvae were more in the minor season than the major season even though not significantly, this is in line with work done by Atkinson (1980) who reported that heavy rains in the major season could reduce the incidence of stem borers by preventing contact of males and females for mating. Similar observations were reported by

Harcourt (1966), Jerath (1968) and Sampson & Kumar (1983) that heavy rains increased predations and normally washed off eggs and newly hatched larvae.

In this study, *E. saccahrina* infested the crops near maturity. This was also in conformity with reports by Sampson and Kumar (1985) whose findings revealed that females of *E. saccharina* lay their eggs in batches on dry leaves, thus partially explaining why they (*E. saccharina*) normally infest matured crops.

Leaf damage by stemborers was observed both in the major season and the minor season which means that even though the infestation levels in the major season were not as much as in the minor season, still damage was inflicted on the crops.

In both experiments conducted (i.e. Major and Minor season experiments) it was observed that numbers of egg masses were greater at the early developmental stage of the plants, and as the crops were approaching maturity, their numbers started declining.

It was also observed that the stemborers were marginally more prevalent in the fertilized crops than in the unfertilized crops, which agrees with the report by Kfir *et al.* (2002) stating that fertilizing crops can enhance infestation and survival of borers through an increase in the nitrogen content of the plant.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This work showed that within our study environment and the limitation (charcoal not incorporated into soil) of the experiment, salicylic acid application to maize crops did not affect crop yield or stem borer infestation levels.

6.2 Recommendation

Pot experiment should be carried out, incorporating charcoal into the soil before applying SA to the crop.

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APPENDICES

List of Acronyms

CAB Commonwealth Agricultural Bureaux

FAO Food and Agriculture Organization of the United Nation

I.N.E.R.A Institute de"l" Environnment et de Recherches

IITA International Institute of Tropical Agriculture

IPM Integrated Pest Management

LSD Least Significant Difference

SCARDA Strengthening Capacity for Agricultural Research and Development in Africa.

Tables of Appendices

Table 1: Summmary Anova of Percentage stemborer damage in the major season

Source of variation	**Degree of freedom**	**Sums of Square**	**Means of square**	**F. Value**	**F. Probability**
Salicylic acid	4	1.0224	0.2556	0.72	0.597
Fertilizer	1	0.5770	0.5770	1.18	0.295
Salicylic Acid. Fertilizer	4	2.2676	0.5669	1.16	0.368
residual	15	7.3490	0.4899		
Total	39	15.8744			

Table 2: Summary Anova of percentage stemborer damage in the minor season

Source of variation	**Degree of freedom**	**Sums of Square**	**Means of square**	**F. Value**	**F. Probability**
Salicylic acid	4	4.0740	1.0185	1.39	0.296
Fertilizer	1	0.8337	0.8337	1.83	0.196
Salicylic Acid. Fertilizer	4	0.9996	0.2499	0.55	0.703
residual	15	6.8425	0.4562		
Total	39	23.4862			

Table 3: Summary Anova of mean number *of Busseola fusca* at three weeks after planting in the major season

Source of variation	**Degree of freedom**	**Sums of Square**	**Means of square**	**F. Value**	**F. Probability**

Salicylic acid	4	0.4144	0.1036	0.30	0.871
Fertilizer	1	0.6198	0.6198	1.96	0.182
Salicylic Acid. Fertilizer	4	1.9456	0.4864	1.54	0.242
Residual	15	4.7519	0.3168		
Total	39	12.8312			

Table 4: Summary Anova of mean number *of Busseola fusca* at three weeks after planting in the minor season

Source of variation	**Degree of freedom**	**Sums of Square**	**Means of square**	**F. Value**	**F. Probability**
Salicylic acid	4	1.3430	0.3358	1.07	0.415
Fertilizer	1	0.3327	0.3327	0.82	0.381
Salicylic Acid. Fertilizer	4	0.6703	0.1676	0.41	0.798
Residual	15	6.1132	0.4075		
Total	39	13.4703			

Table 5: Summary Anova of mean number of larvae at three weeks after planting in the major season

Source of variation	**Degree of freedom**	**Sums of Square**	**Means of square**	**F. Value**	**F. Probability**
Salicylic acid	4	0.4144	0.1036	0.30	0.871
Fertilizer	1	0.6198	0.6198	1.96	0.182
Salicylic Acid. Fertilizer	4	1.9456	0.4864	1.54	0.242

residual	15	4.7519	0.3168		
Total	39	12.8312			

Table 6: Summary Anova of mean number of larvae at three weeks after germination in the minor season

Source of variation	**Degree of freedom**	**Sums of Square**	**Means of square**	**F. Value**	**F. Probability**
Salicylic acid	4	1.1427	0.2857	0.96	0.465
Fertilizer	1	0.0099	0.0099	0.02	0.885
Salicylic Acid. Fertilizer	4	2.0704	0.5176	1.12	0.384
Residual	15	6.9297	0.4620		
Total	39	16.5463			

Table 7: Summary Anova of mean yield of experiment one

Source of variation	**Degree of freedom**	**Sums of Square**	**Means of square**	**F. Value**	**F. Probability**
Salicylic acid	4	60.60	15.15	0.54	0.710
Fertilizer	1	528.75	528.75	26.03	<.001
Salicylic Acid. Fertilizer	4	31.18	7.79	0.38	0.817
residual	15	304.73	20.32		
Total	39	1323.32			

Table 8: Summary Anova of mean number of *Eldana saccharrina* at harvest in the minor season

Source of variation	Degree of freedom	Sums of Square	Means of square	F. Value	F. Probability
Salicylic acid	4	0.6538	0.1635	1.31	0.321
Fertilizer	1	0.1661	0.1661	0.96	0.344
SalicylicAcid Fertilizer	4	0.7020	0.1755	1.01	0.433
residual	15	2.6047	0.1736		
Total	39	5.6823			

Table 9: Summary Anova of mean number of exit holes at harvest period in the major season

Source of variation	Degree of freedom	Sums of Square	Means of square	F. Value	F. Probability
Salicylic acid	4	0.09861	0.02465	0.74	0.581
Fertilizer	1	0.08186	0.08186	1.95	0.183
Salicylic Acid Fertilizer	4	0.11949	0.02987	0.71	0.597
residual	15	0.63058	0.04204		
Total	39	1.70361			

Table 10: Summary Anova of mean number of exit holes at harvest period in the minor season

Source of variation	Degree of freedom	Sums of Square	Means of square	F. Value	F. Probability
Salicylic acid	4	0.8325	0.2081	1.11	0.395
Fertilizer	1	0.1160	0.1160	0.58	0.457
Salicylic Acid Fertilizer	4	1.2150	0.3037	1.53	0.244
residual	15	2.9807	0.1987		
Total	39	7.5220			