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Organic and Inorganic Fertilizer Effects on Incidence of Weevil (*Cylas* spp.), Growth and Yield of Sweet Potato in the Forest, Savannah Transitional Zone of Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. Author IA designed the study, performed the analysis, and wrote the first draft of the manuscript. Authors MEE and EBBL. supervised the study and analyzed the data. All the authors managed the literature search and writing of the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Two field experiments were conducted at the Multipurpose Crop Nursery of the University of Education Winneba, Mampong Ashanti campus during from September, 2017 to December, 2018. The study was aimed at determining the organic and inorganic fertilizer effects on the incidence of

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weevil *(Cylas spp.),* on the sequential harvesting and vertical distribution of tubers and the, growth and yield of sweet potatoes in the forest-savannah transitional zone of Ghana. Severe weevil infestation was more prevalent on Ogyatanaa than Ogyefo in the minor season; there was a more severe weevil infestation at the second harvest than at the first harvest in the minor season, In the major season there was more severe weevil infestation on tubers at the first harvest than at the second harvest. *Ogyatanaa* grown at 5 t/ha Chicken Manure produced the highest number of weevil *(Cylas spp.),* infested tubers at the first harvest. *Ogyatanaa* grown at 300 kg/ha N.P.K. produced the lowest number of weevils *(Cylas spp.)*, infestations at the first and second harvests. *Ogyatanaa* grown at 300 kg/ha N.P.K at a depth of 5cm recorded the highest number of (8) weevils infested tubers at the minor season. At a depth of 10 cm, six (6) tubers were found to be infested, while at a depth of 15 cm and 20 cm the number of infested tubers was found to be four (4) and two (2), respectively at the minor and major seasons. *Ogyefo* grown with 150 kg/ha N.P.K. + and 2.5 t/ha Chicken Manure produced the lowest level of weevil infestation at a depth of 5 cm, only two weevils and at a 10 cm depth, only one weevil was found at the minor and major seasons. At 15cm and 20cm depths no weevils were found. In the minor and major seasons Ogyefo and Ogyatanaa should be grown with 150 kg/ha N.P.K. and 2.5 t/ha Chicken manure and ridging should be done to bury the tubers deep in the soil, to get longer vertical distribution to produce the lowest level of weevil infestation.

Keywords: Sweet potato; weevil; Cylas Spp; ogyefo; ogyatanaa; physiological maturity.

1. INTRODUCTION

Scientists believe the sweet potato crop was domesticated more than 5,000 years ago [1]. Globally, every year, more than 133 million tonnes are produced. In Africa, Ghana ranks fourth in sweet potato production [2]. The sweet potato is one of the most important carbohydrates crops in merging countries. The majority of Ghana's sweet potatoes are produced in three northern regions: the Northern and Upper East regions yield between three and six tonnes per acre, while the Upper West region yields less, between one and two tonnes per acre [3-6]. Approximately 73,400 hectares of sweet potato land are harvested in Ghana, with important root crops like cassava and yam following sweet potatoes [7].

Biofertilizers are one of the most important organic sources because they contain beneficial, viable organisms that have the potential to deploy nutritionally important elements from non-usable to usable forms through biological processes [8]. Azospirillum is known to be a very active nitrogen fixer in the laboratory as well as in soil conditions, providing fast growth, better plant health, and higher a yield [9]. The response of organic sources with or without chemical fertilizers to a large number of crops has been reported by several workers [10,11,12]. According to Cherryl and Matt, there are numerous types of sweet potatoes, In horticultural traits, it can be distinguished by their fresh color, skin color and root shape. Due to their varying growing seasons, some cultivars have different insect resistances [13].

The crop research institute of the CSIR (Council for Scientific and Industrial Research) of Ghana has released several varieties of sweet potato. However, although there is an abundance of hybrid varieties, there is a problem of serious pest infestation in several of these released varieties, thereby posing food insecurity threats [14]. The major serious pest of sweet potato is the sweet potato weevil *(Cylas spp*.). The pest was first reported in the state of Louisiana in the U.S.A. in 1875, and it causes damage in the field and in storage. In Ghana, the pest is found in all the major production areas of sweet potatoes, particularly the Northern, Upper East, Upper West, and some parts of the Brong Ahafo Region [15]. The sweet potato weevil feeds on plants in the Convolvulaceae family. A complete life cycle takes about one to two months, thereby posing serious problems to fields and harvested crops if not well catered for. Three species have been identified in Africa. Their dissemination in Africa is being surveyed and it appears that all three species have a similar life history, making all of them difficult targets for conventional pest control measures. The sweet potato weevil *(Cylas spp*.) has three different species: Cylas coleoptera, Cylas brennlidue, and Cylas fornicarius. They are the major problem for sweet potato production and utilization worldwide. Cylas brunneus Fabricius and Cylas panticolis Boheman are the most prevalent species in East Africa.

The major constraint on sweet potato production in Cuba is caused by *Cylas formicarius*. The insect limits the potential increase of sweet potato production in all provinces of Cuba, causing up to 45% damage in the absence of adequate control measures. The selection of sweet potato varieties is important for the control of sweet potato weevils. Deep-rooting and early maturing varieties (90 to 120 days) are about four times less susceptible to infestation than shallow-rooting and late maturing varieties (180 days or more). As a result, both deep storage roots and early maturing varieties tend to reduce the severity of weevil damage. Management of weevils was the highest-ranked need in relation to improved sweet potato crop management in Ghana with regards to the right variety and the desirable soil amendment that has weevil (*Cylas spp*.) resistance. There is therefore a need for research to combine released varieties of sweet potato in the same growing conditions, evaluate weevil (*Cylas spp*.) incidence, and determine the yield potentials of these released varieties. There is also the need to assess the response of sweet potatoes to both organic and inorganic fertilizers, as well as in an integrated management system, and how these affect the quality factors of the roots. This will provide farmers with alternative ways of fertilization and also provide consumers with the nutritional values of sweet potatoes, and the potential values of the crop in southern regions of Ghana. Considering the nutritional values of sweet potatoes will ensure high patronage of the crop, which will provide a market for sweet potato farmers.

2. MATERIALS AND METHODS

2.1 Experimental Site

Two field experiments were conducted on different plots at the Multipurpose Crop Nursery. Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Asante Mampong, from September to December 2017 (the minor rainy season) and April to August 2018 (major rainy season). Mampong-Ashanti (78 N, 124 W) is 457.5 m above sea level and is located in the forest-savannah transitional agro-ecological zone. The soil type in Asante Mampong is classified as savannah ochrosol, formed from the voltaian sandstone of the Afram plains. The soil is friable with a thin layer of organic matter and is a deep brown sandy loam that is well-drained and has a good water-holding capacity. The soil has been classified by FAO/UNESCO legend as chronic Luvisol and locally as the Bediesi series with a pH of 4.0 - 6.5 and is good soil for the production of crops such as vegetables, cereals, tubers, and all types of leguminous crops [16,17]. Mampong-Ashanti receives a bimodal rainfall pattern. The experimental site experiences two seasons of rain within a single year, with the major rainy season observed from March to July, and the minor rainy season from September to November, and a one-month dry spell in August [17,18]. Annual rainfall ranges between 1270 mm and 1534 mm, with monthly rainfall being 91.2 mm. The mean monthly temperature is between 25 ºC and 32 ºC [17].

2.2 Climatic Conditions

During the experimental periods Rainfall, temperature, and relative humidity were the climatic factors observed for the two cropping seasons. The total monthly rainfall during the minor rainy season was 335.8 mm, and it occurred from September to December 2017, with the peak in September and October. The minor season experienced a minimum monthly temperature of 20.3 ºC to 21.7 and a maximum temperature of 29.4 ºC to 32.0 ºC, with the highest daily at 32 ºC observed in November and December 2017. During the major rainy season, 824.6 mm of rainfall was recorded from April to August 2018 with the peak observed in August. Maximum temperature ranged from 28.3 to 31.9 ºC with the highest at 31.9 ºC, and minimum temperature ranged from 20.9ºC to 22.8 ºC with the peak occurring in April. Relative humidity at 06.00 hours ranged from 88% to 92% with its peak in June, and relative humidity at 15.00 hours ranged from 63% to 75% with the peak recorded in July [18,19].

2.3 Organic Manure Preparation

The chicken manure used for the experiment was obtained from the deep litter system of a poultry farm from the college. The manure was heaped under shade covered with plantain leaves, supported with wooden sticks for four weeks to decompose and to dry before application was done. The chicken manure was applied and worked into the soil two weeks before planting.

Table 1. Climatic data for 2017 minor rainy season for experiment one

Month	Total Rainfall (mm)	Mean Relative Humidity (%) 06.00h	15.00	Mean Temperature (ºC) Min.	Max.
September, 2017	136.7	91	73	21.1	29.4
October	114.4	83	65	21.3	31.1
November	75.2	87	61	21.7	32.0
December	9.5	84	52	20.3	32.0
Total	**335.8**				

Source: Ghana meteorological agency-Mampong Ashanti, 2017.

Table 2. Climatic data for 2018 major rainy season for experiment two

Month	Total Rainfall (mm)	Mean Relative Humidity (%) 06.00h	15.00 h	Mean Temperature (ºC) Min.	Max
April ,2018	109.6	88	63	22.8	31.9
May	185.5	90	65	22.2	31.1
June	184.6	92	69	21.8	29.6
July	157.2	88	75	21.2	28.3
August	187.7	91	74	20.9	28.6
Total	824.6				

Source: Ghana Meteorological Agency–MampongAshanti,2018.

2.4 Soil and Manure Sampling

After lining and pegging the experimental area and demarcating it into plots, samples of the soil were taken at a depth of 0-15 cm from each replicate at different spots. The soil and chicken manure were mixed together and no manure soil (control) samples were taken from the experimental site at a depth of 0-15 cm.

2.5 Soil and Chicken Manure Chemical Analyses

The soil and chicken manure samples were sent for analysis at the Soil Research Institute of CSIR at Kwadaso in Kumasi. The soil samples were air-dried and sieved through a 2 mm mesh. Soil pH, total nitrogen, exchangeable potassium, organic carbon, and available phosphorus were the chemical properties determined.

2.6 Land Preparation, Fertilizer Application, and Planting

The land measuring 13.0 m × 32.0 m was lined and pegged and cleared with cutlass to remove all vegetation on the soil and debris collected from the land. The cleared land was followed by ridge preparation with a hoe. The ridges were laid 3.0 m long x 4.0 m wide, with four ridges per plot. To ensure complete decomposition, the decomposed and dried chicken manure was worked into the soil according to treatment two weeks before planting. Inorganic fertilizer (N.P.K. 15:15:15) at a rate of 300 kg/ha was also applied to the respective treatment two weeks after the planting of the vines. Vine cuttings having at least 4-5 nodes from the apical and semi-woody vigorously growing sections were cut and used for planting. The vines that were about 30 cm in length were planted at a spacing of 1.0 m x 0.3 m per each hill, with 2-3 nodes buried inside the soil at an angle, leaving two nodes above the soil at one vine per stand. There were four ridges in each experimental plot, and each had ten plants per row or ridge, for a total of forty plants per plot. There were sixteen (16) plants within the harvest area (two central rows per plot). The vine cuttings were planted on a field that measured 32.0 m x 13.0 m (416 m^2). Each experimental plot measured 4.0 m x 3.0 m (12 m2) with 2.0 m left between blocks for each cropping season.

2.7 Agronomic Practices

Weeds were controlled using a hoe, and handpicking and sometimes cutlass in both minor and major seasons at 3 to 4 weeks after planting to reduce weed-crop competition. Subsequently, weeding was done at 7 to 8 WAP after the closure of the canopy. During the minor growing season (September to December) irrigation was carried out once every two days to promote crop growth. Each plant received the same amount of water during supplementary irrigation. A hoe was used to carry out the reshaping of the ridges from time to time. The N.P.K. (15:15:15) was applied two weeks after planting at a rate of 300 kg/ha to the respective treatments.

2.8 Data Collection and Statistical Analysis

Vegetation growth data collected were percentage crop establishment, number of branches, and vine girth. Percentage plant establishment was estimated by counting the number of vines sprouting from the two central rows per plot at 4 weeks after planting and their percentages were estimated and the mean recorded. The number of branches was counted from each of the three tagged plants per plot in the two central rows, 4 weeks after planting and at a two week interval up to 12 weeks after planting and the mean estimated. The vine girth was measured on each of the three tagged plants from the two central rows of each plot using vernier calipers from a few centimeters from the base of the plant at 4 WAP to 12 WAP and at 2 weeks' interval and the mean was estimated. The parameters measured under yield and yield components were the tuber length per plot, number of deformed tubers per plot, number of weevil infested tubers per plot, number of plants harvested per plot, vertical distribution of weevil infested tubers per plot, and sequential harvesting of tubers per plot. The length of total number of root tubers after harvest were measured separately from the base of the tuber to the tip using a meter rule and a rope and mean length estimated, with the deformed root tubers are tubers that are not having the normal shape (mishapen). The normal shape of the tubers is oblong, oval and dumbbell. The total number of deformed tubers from the two middle rows was counted after harvest and mean estimated, number of insects or weevil infested tubers per plot, this parameter was estimated by physical count, observing and by cutting through the suspected tubers of weevil infestation. Tubers that have insects or weevil infestation can easily be observed by blackish tunnels within the roots, which were sorted, counted and recorded. The vertical distribution of root tubers at harvest was obtained by measuring the length of root from the base of the plant to where the root tubers are formed vertically below at depth of 5 cm, 10 cm, 15 cm and 20 cm in the soil, using a rope and a meter rule and mean estimated, finally Sequential harvesting of tubers, this parameter was estimated by harvesting of sweet potato at physiological maturity and at one month later and the number of insects infested tubers estimated and the mean recorded. The collected data was analyzed using the standard ANOVA procedure with the aid of GenStat Statistical Package Discovery Edition 3 (Version 11.0 DE). The means that were statistically different were separated using the least significant difference (LSD) at 5% probability level.

2.9 Experimental Design and Treatment

The experimental design used was a 2 x 4 factorial experiment arranged in a randomized complete block design (RCBD) and replicated three times. The treatment was made up of three organic manure and fertilizer rates and the control (without amendment), and two sweet potato varieties (Ogyefo and Ogyatanaa) used as planting materials for the experiment were assigned to each block.

Ogyefo was developed and released by the CSIR of the Crop Research Institute of Ghana in Fumesua, near Kumasi in the Ashanti Region. The Ogyefo variety of sweet potato is 120 days (4 month) maturing improved variety, the root yield capacity is 20t/ha; the root flesh color is white, the dry matter content is 40%, and the skin color is light reddish. The Ogyatanaa variety of sweet potato is also a 120day maturing improved variety with a light yellow root flesh color and has a yield capacity of over 22t/ha, and a dry matter content of 36%.

3. RESULTS

3.1 Chemical Properties of Soil

Table 3 shows the chemical properties of the soil for both minor and major rainy seasons. The pH of the soil during the major rainy season was pH 5.55, which was acidic; % organic carbon and total nitrogen were relatively low; and organic matter was moderate. Exchangeable cations for calcium, magnesium, and sodium were relatively low, and those for potassium were high. The effective cation exchange capacity (ECEC) was relatively low. A pH of 6.03 was recorded for the minor rainy season, which was neutral. The organic carbon, total nitrogen, and organic matter were relatively low. The exchangeable cations Ca^{2+}, K^+, and Na were low for the minor rainy season and that of Mg^{2+} was high.

Table 4 shows the nutrient contents of 4-month-old chicken manure which was used for both the minor and major rainy seasons. The minor rainy season manure had a pH of 5.98 which was moderately acidic. Total nitrogen was moderately high, available potassium and available phosphorus were low, and organic carbon and organic matter were relatively high. Total exchangeable bases (TEB), exchangeable aluminum (Al+H), and effective cation exchange capacity (ECEC) were high. The major season manure had a pH of 5.72 which was also moderately acidic. Total nitrogen and organic carbon were high. Available potassium and available phosphorus were low, and organic carbon and organic matter were high.

3.2 Vegetative Growth

3.2.1 Vine length

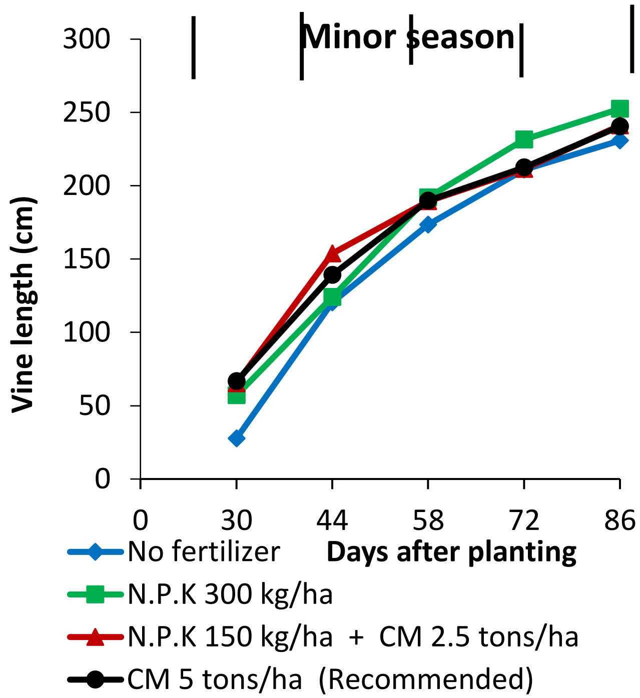
The results on vine length produced from the two varieties as influenced by chicken manure and inorganic fertilizers for the major and minor cropping seasons are presented in (Fig. 1). There was significant difference was found in two varieties in vine length and fertilizer types. The 300 kg/ha N.P.K. recorded the longest vine length at 72 DAP and 86 DAP. The control plot produced the lowest vine length at 30 DAP. During the major cropping season, there was a significant difference between the two varieties in vine length and fertilizer types. For fertilizer type, the 5 t/ha CM had the second highest vine length and differed significantly from other treatments from 72 DAP to 86 DAP. The control produced the longest vine length, followed by 300 kg/ha N.P.K. for the entire growing period. The shortest vine length was produced by 150 kg/ha N.P.K. and 2.5 t/ha Chicken Manure at 86 DAP.

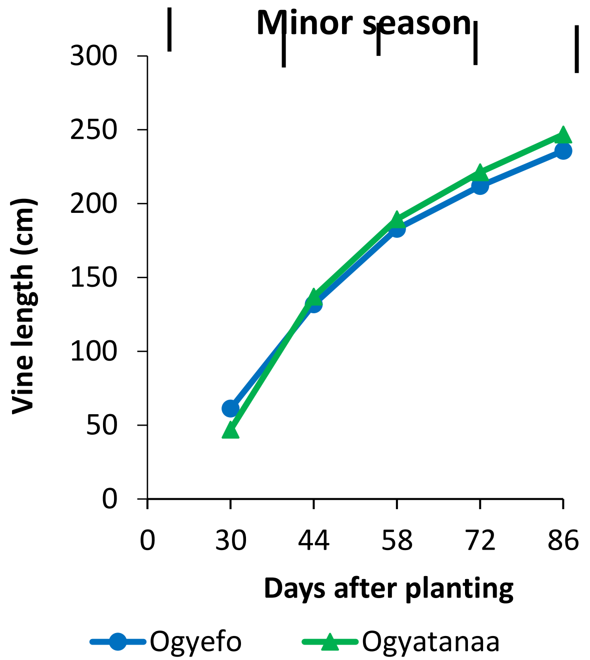
Table 3. Chemical properties of the soil for both Minor and Major Rainy Seasons

Property	Minor Season	Major Season
pH (1:2.5)	6.03	5.55
Organic carbon (%)	0.91	0.80
Total nitrogen (%)	0.09	0.08
Organic matter (%)	1.57	1.38
Exchangeable cations (Cmol/kg)		
Ca^{2+} (mg/100g)	3.47	4.54
Mg^{2+}(mg/100g)	0.54	3.47
K^{+} (mg/100g)	0.62	0.17
Na^{+} (mg/100)	0.10	0.08
Total exchangeable bases (Cmol/kg)	4.73	8.27
Exchangeable Acidity (Cmol/kg)	0.15	0.60
Effective Cation exchange capacity (Cmol/kg)	4.88	8.87
Base saturated (%)	96.92	93.23

Table 4. Chemical Properties of Chicken Manure used for both Minor and Major Rainy Seasons 2017 and 2018

Property	Minor Season	Major Season
pH (1:5)	5.98	5.72
Total nitrogen (%)	3.45	3.86
Available Potassium (%)	2.65	3.38
Available Phosphorus (%)	0.34	0.56
Organic Carbon (%)	3.96	4.36
Organic Matter (%)	7.32	8.24
Total Exchangeable basses (T.E.B)	33.41	24.31
Exchangeable Aluminum ($Al^{+}H$)	0.06	18.93
Effective Cation Exchange Capacity (Me/100g)	34.57	22.43
Bases saturation	99.70	98.45
Exchangeable cat ions		
Ca^{2+}(mg/100g)	23.14	20.34
$Mg^{2+(}$mg /100g)	12.75	6.31
K^{+}(mg /100g)	0.43	0.63


Minor season
Vine length (cm)
300
250
200
150
100
50
0
0
30
44
58
72
86
Days after planting
No fertilizer
N.P.K 300 kg/ha
N.P.K 150 kg/ha + CM 2.5 tons/ha
CM 5 tons/ha (Recommended)


Minor season
Vine length (cm)
300
250
200
150
100
50
0
0
30
44
58
72
86
Days after planting
Ogyefo
Ogyatanaa

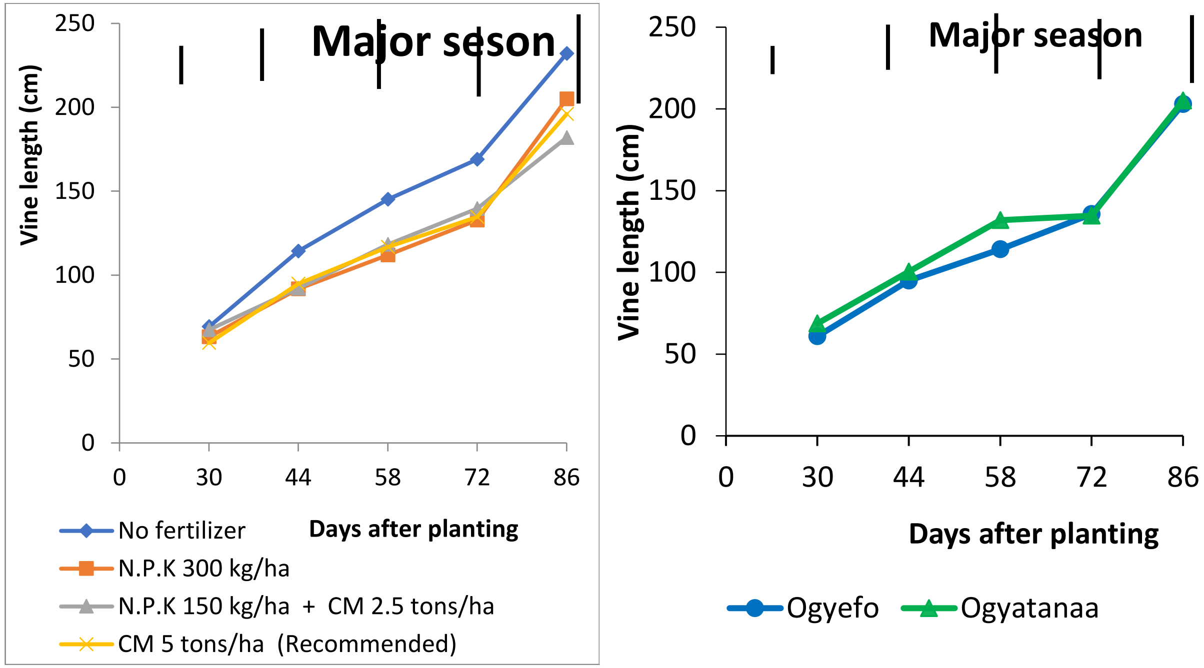


Fig. 1. Vine length as influenced by organic manure and inorganic fertilizer

3.2.2 Whiteflies incidence

The influence of chicken manure and inorganic fertilizer on the incidence in whitefly of two varieties of sweet potatoes is presented in Fig. 2. During the minor season, there was a significant difference between varieties in whitefly incidence. The whitefly incidence was significantly greater (P < 0.05) in ogyatanaa variety than in Ogyefo at 86 DAP. There was a significant difference between the fertilizer types. The amended and unamended plots produced high levels of whiteflies incidence at 86 DAP. The 300 kg/ha N.P.K. and the control produced the same level of whitefly incidence at 72 DAP. The 150 kg/ha N.P.K. and 2.5 t/ha CM produced the highest level of whitefly incidence for the entire minor growing season. During the major cropping season, there was no significant difference between varieties in whiteflies incidence. However, there was a significant difference between fertilizer types. The 150 kg/ha N.P.K. and 2.5 t/ha Chicken Manure produced the lowest whitefly incidence at 30 DAP. The 5 t/ha Chicken Manure produced the highest whiteflies incidence at 44, 72, and 86 DAP. The N.P.K. and 2.5t/ha CM produced the same level of whitefly incidence at 72 DAP.

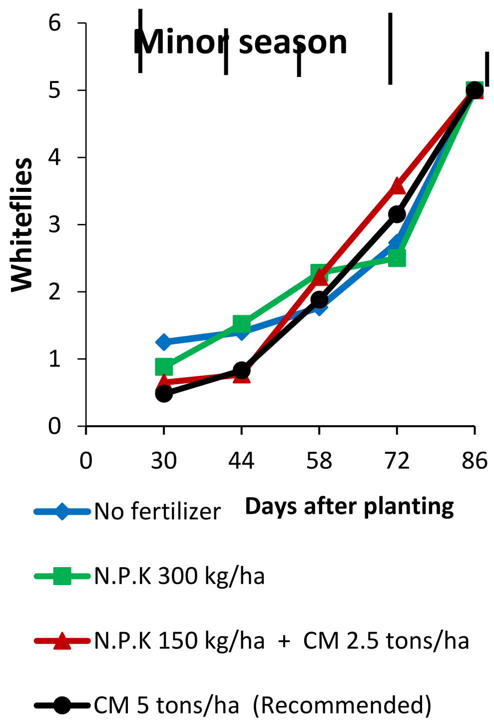
3.3 Yield and Yield Components of Sweet Potato

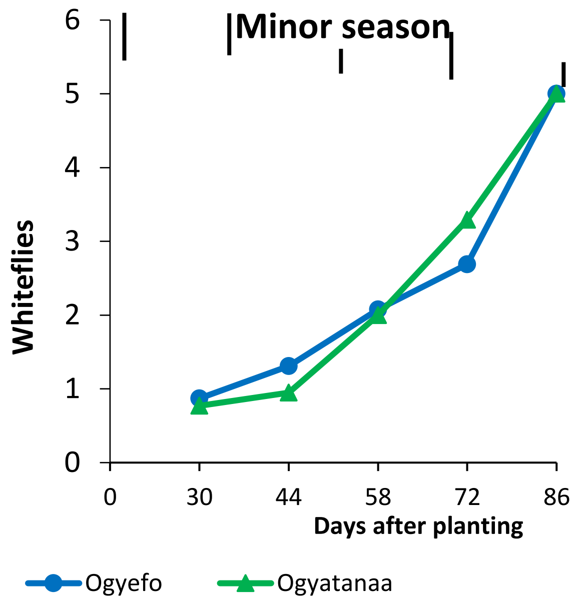
Table 5 shows the average tuber length per plot as influenced by chicken manure and inorganic fertilizers. During the minor season (2017), there was a significant difference between varieties in tuber length per plot. *Ogyefo* produced significantly (P< 0.05) longer tuber length per plot than ogyatanaa, fertilizer treatments did not significantly (P > 0.05) affect tuber length per plot during the minor season. In the major season (2018), *Ogyefo* differed significantly (P<0.05) from *Ogyatanaa* in tuber length per plot. However, there was no significant difference between the fertilizer types although 300 kg/ha N.P.K. produced longer tuber length per plot than other amended treatments and control. Averagely the tuber lengths produced in the major season were longer than those produced in the minor season.

Number of deformed tubers per plot: Table 3 shows the number of deformed tubers per plot as influenced by chicken manure and inorganic fertilizers. During the minor season (2017), there was no significant difference between varieties and fertilizer types in the number of deformed tubers per plot, although the 150 kg/ha NPK. and 2.5 t /ha Chicken Manure had the highest. The 5 t/ha Chicken Manure and the control were at par in number of deformed tubers per plot. During the major season (2018), there was a significant (P < 0.05) difference between Ogyatanaa and Ogyefo in number the of deformed tubers per plot. There was a significant (P < 0.05) difference between 300 kg/ha N.P.K. and 5 t/ha CM and the control in the number of deformed tubers per plot.

Number of Weevil (Cylas spp.) infested tubers per plot: The result on the number of weevil infected tubers as influenced by chicken manure and N.P.K. fertilizers is presented in Table 6. During the minor season (2017), there was no significant difference between varieties in the number of weevil infested tubers per plot, there was a significant difference between 5 t/ha CM from 150 kg/ha N.P.K. and 2.5 t/ha Chicken Manure and the control the in number of weevil infested tubers per plot. During the major season (2018), there was a significant difference between Ogyatanaa and Ogyefo in the number of weevil-infested tubers per plot. There was a significant (P< 0.05) difference between 150 kg/ha N.P.K. and 2.5 t/ha Chicken Manure from other amended plots in the number of weevil infested tubers per plot with 5 t/ha Chicken Manure producing the lowest in the number of weevil infested tubers per plot.

Number of plants harvested: The results on the number of plants harvested from plants amended with chicken manure and inorganic fertilizer are presented in Table 6. During the minor season (2017), there was a significant difference between varieties in the number of plants harvested. For fertilizer type, 150 kg/ha N.P.K and 2.5 t/ha Chicken Manure and 300 kg/ha N.P.K. were at par and produced the same number of plants harvested. There was no significant (P <0.05) difference between fertilizer types during the minor season, although the 5 t/ha Chicken Manure recorded the highest number of plants harvested. During the major season (2018), there was a significant difference between varieties in the number of plants harvested. However, there was no significant difference between the fertilizer types. Generally, the minor season produced a higher number of plants harvested than in the major season (Table 6).


Minor season
Whiteflies
Days after planting
No fertilizer
N.P.K 300 kg/ha
N.P.K 150 kg/ha + CM 2.5 tons/ha
CM 5 tons/ha (Recommended)


Minor season
Whiteflies
Days after planting
Ogyefo
Ogyatanaa

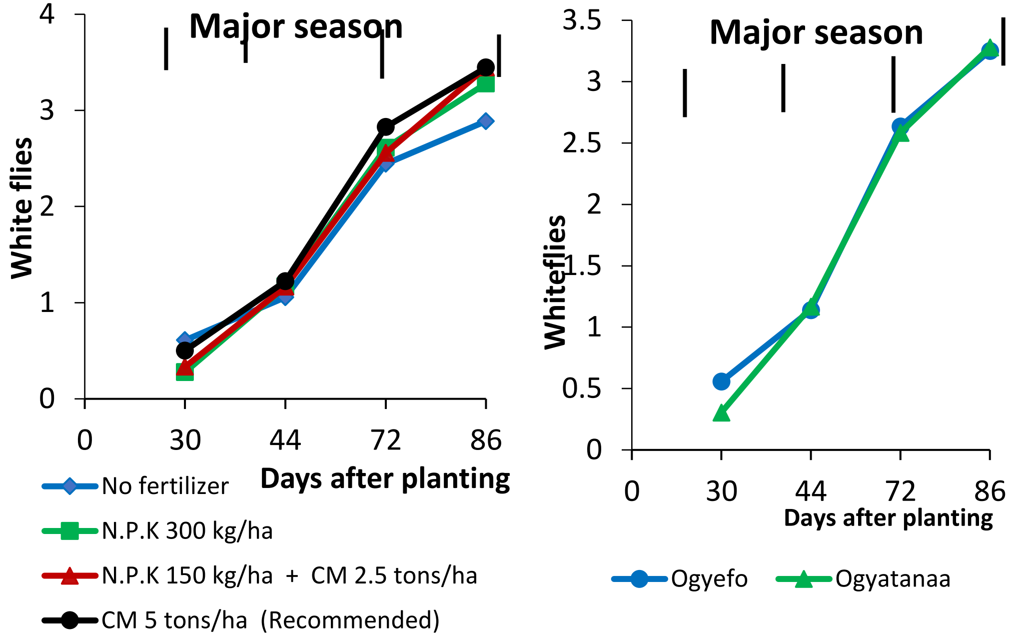


Fig. 2. Whiteflies count as influenced by organic manure and inorganic fertilizer

Table 5. Effect of variety and fertilizer type on tuber length per plot and number of deformed tubers per plot

	Tuber length per plot		Number of deformed tubers per plot	
Treatment	**Minor season, 2017**	**Major season,2018**	**Minor season,2017**	**Major season,2018**
Variety				
Ogyefo	16.11	16.90	1.75	2.92
Ogyatanaa	14.02	14.69	1.50	3.58
LSD (P ≤ 0.05)	0.422	1.048	NS	0.528
Fertilizer rate				
300 kg/ha N.P.K	15.32	17.01	1.50	4.00
150 kg/ha N.P.K + 2.5 t /ha CM	14.44	14.45	2.33	3.67
5t/ha CM	14.42	15.48	1.33	2.83
No fertilizer (control)	16.14	16.23	1.33	2.50
LSD (P ≤ 0.05)	NS	NS	NS	0.747
CV (%)	16.60	14.87	76.60	53.76

Table 6. Effect of variety and fertilizer type on the number of Weevil (Cylas spp.), infested tubers per plot and total tuber weight per plot

	Number of Weevil (*Cylas* spp.*)*, infested tubers per plot		***Number of plants harvested***	
Treatment	**Minor season,2017**	**Major season,2018**	**Minor season,2017**	**Major season,2018**
Variety				
Ogyefo	2.92	6.7	14.83	13.75
Ogyatanaa	2.50	9.2	15.75	12.83
LSD (P ≤ 0.05)	NS	1.44	0.325	0.575
Fertilizer rate				
300 kg/ha N.P.K	9.00	2.00	15.00	13.17
150 kg/ha N.P.K + 2.5 t /ha CM	5.3	3.50	15.00	13.00
5t/ha CM	9.8	2.33	15.67	13.33
No fertilizer (control)	7.7	3.00	15.50	13.67
LSD (P ≤ 0.05)	2.04	0.80	NS	NS
CV (%)	58.20	34.09	25.64	27.5

Effect of organic and inorganic fertilizers on vertical distribution of weevil infested sweet potato tubers at different soil depth: The result shows that during the minor season (2017), there was a significant (P<0.05) difference between Ogyefo and Ogyatanaa planted on chicken manure and N.P.K. (Fig. 3). Ogyatanaa grown on 300 kg/ha N.P.K. at a depth of 5 cm produced the highest number of eight weevils-infested tubers. At a depth of 10 cm six tubers were found to be infested, while at depth of 15 cm and 20 cm the number of infested tubers was found to be four and two, respectively. Ogyefo grown 150 kg/ha N.P.K. and 2.5 t/ha recorded the lowest level of weevil-infestation at a depth of 5 cm with two weevil infested tubers, and at a 10 cm depth, only one weevil infested tuber was obtained. However, at 15 cm and 20 cm depths, there were no weevils-infested tubers. During the major season (2018), there was no significant difference between Ogyatanaa and Ogyefo in the vertical distribution of tubers per plot. There was no significant difference between the fertilizer types, although differences exist between treatments.

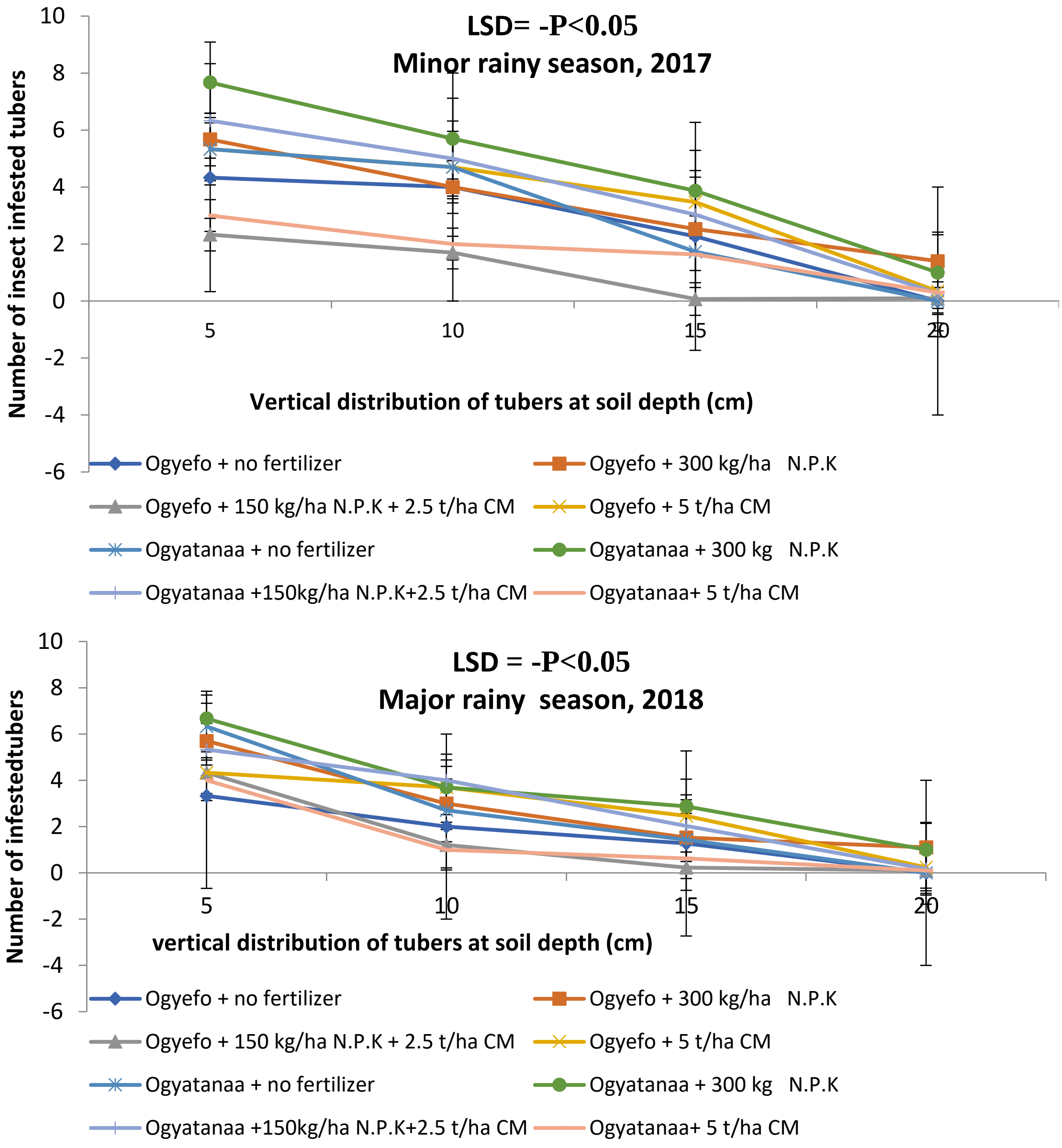


Fig. 3. Vertical distributions of infested tubers as influenced by organic manure and inorganic fertilizer

Effect of organic and inorganic fertilizers and sequential harvesting on incidence of sweet potato weevil:

Sequential harvesting of tubers per plot: The result of sequential harvesting of tubers on the number of weevil infested tubers per plot as influenced by chicken manure and inorganic fertilizer is presented in Fig. 4. During the minor season (2017), Ogyefo grown on 300 kg/ha N.P.K. recorded the highest number of weevil infested tubers at the first harvest. Ogyatanaa grown on the control produced the lowest number of weevil infested tubers at the first harvest, Ogyatanaa grown on 300 kg/ha N.P.K and on the control produced the same weevil infested tubers at the first harvest. In the second harvest Ogyatanaa grown on 5 t/ha Chicken Manure produced the highest level of weevil infested tubers. However, Ogyefo grown on 5 t/ha Chicken Manure produced the lowest level of weevil infested tubers at the second harvest. There was a more severe weevil infestation of tubers in the second harvest than in the first harvest. In the major season (2018), there was a more severe weevil infestation of tubers in the first harvest than in the second harvest. Ogyatanaa grown on 5 t/ha Chicken Manure produced the highest number of (12) weevil-infested tubers in the first harvest. Ogyefo grown on 5t/ha Chicken Manure recorded the lowest number (4) of weevil infested tubers in the first harvest. In the second harvest, Ogyefo grown on 5 t/ha Chicken Manure had the highest level of weevil infested tubers. Ogyantanaa grown on 300 kg/ha N.P.K. produced the lowest number of weevil infested tubers in the second harvest.

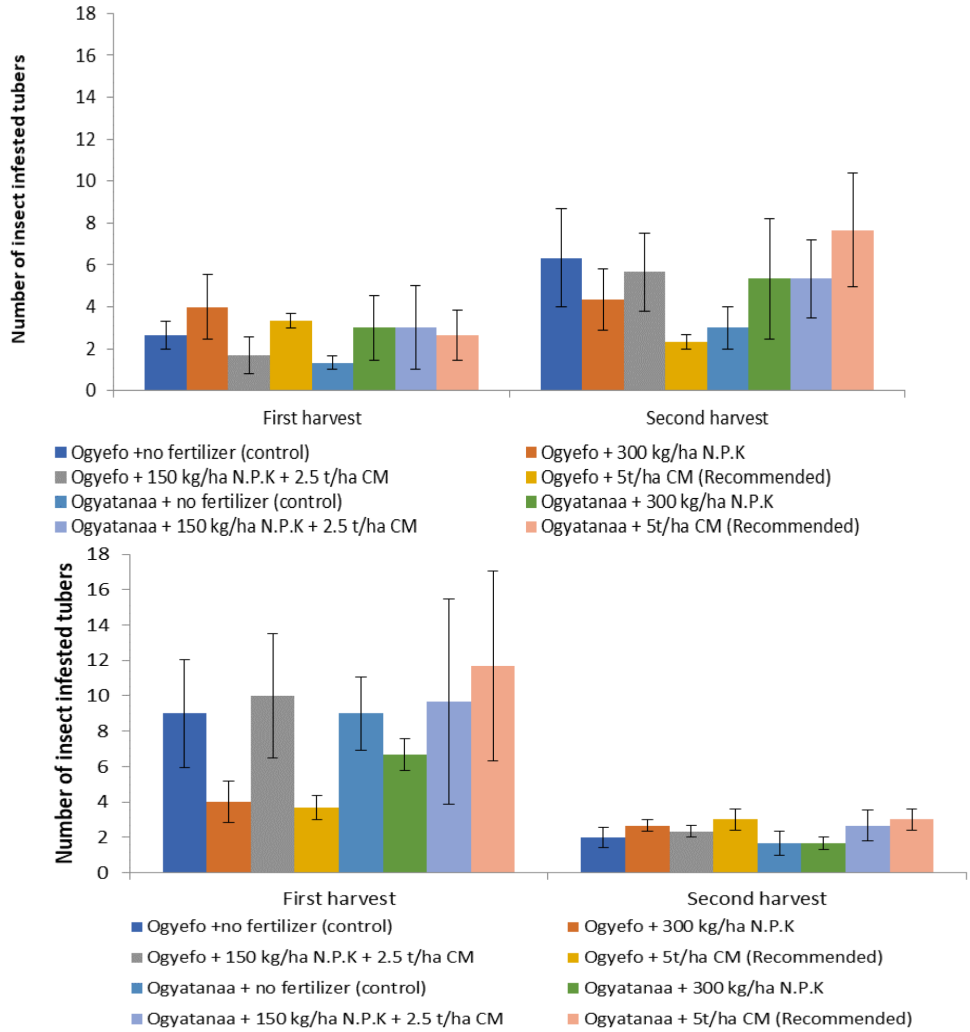


Fig. 4. Number Infested tubers during sequential harvesting as influenced by organic manure and inorganic fertilizer

4. DISCUSSION

4.1 Chemical Properties of Soil and Chicken Manure

The chemical properties of the soil for both seasons experimental sites showed major season site, pH was 5.55 and pH of 6.03 was recorded for the minor rainy season site. The differences in pH could be attributed to soil leaching due to the intensive rainfall during the major season, soil texture, and the amendment that was applied to the soil.

Percentage organic carbon and total nitrogen were relatively low; this could be due to soil organic carbon and total nitrogen which decrease with increasing soil depth. Exchangeable cations for calcium, potassium, and effective cation exchange capacity (ECEC.) were low; this could be due to low soil pH and cation exchange capacity (CEC.).

The nutrient contents of 4-month-old chicken manure used for both the minor and major rainy seasons showed that the minor rainy season had a pH of 5.98, and the major season had a pH of 5.72. The difference in pH that existed between the chicken manure used for the two experiments could be attributed to differences in climatic conditions.

Total nitrogen was moderately high, for all seasons and this could be due to high uric acid and undigested proteins. Organic carbon and organic matter were relatively high, which could be due to the Chicken solid and liquid excreta that are excreted together resulting in no urine loss.

4.2 Vegetative Growth of Sweet Potato

4.2.1 Vine length during the minor season

Vine length differed significantly between varieties. The significant difference could be due to the amendment's effect on the variety. The 300 kg/ha N.P.K. had the longest vine length from 72 DAP to 86 DAP. This might be due to differences in soil fertility status due to the increased availability of nitrogen in inorganic fertilizer applied to the organically manured plots. Ogyefo and Ogyatanaa grown with either inorganic fertilizer or chicken manure performed better than the control. This is in line with Nedunchezhiyan et *al*., who reported positive responses to organic manure and chemical fertilizers on sweet potato growth [10]. Ogyefo had the longest vine length across all the treatments. This could be due to differences in varietal characteristics. There was a significant difference between Ogyefo and Ogyatanaa in vine length during the major season. This could be attributed to the amendment's effect on the variety. The 300 kg/ha N.P.K. had a steady increase in vine growth at 58 DAP, 72 DAP, and 86 DAP, whilst the 5 t/ha CM had the highest vine length for the entire growing period in the major rainy season. This might be due to the application of chicken manure, as it provides both micro and macronutrients coupled with the initial high rainfall experienced during the growing period, which enhanced the continuous supply of nutrients to the different vine lengths. Generally, the major season experienced longer vine lengths than the minor season. This could be attributed to the initial higher rainfall experienced during the major rainy season growing period than in the minor rainy season. Mukthar et *al*. attest to the fact that nitrogen could result in excessive vine growth and that application of organic and inorganic fertilizer to two cultivars of sweet potato produced significant differences in vine length [20].

4.2.2 Whiteflies incidence

During the minor season, there was a significant difference between varieties in whitefly incidence. The whitefly incidence was significantly greater ($P < 0.05$) in the Ogyatanaa variety than in Ogyefo at 86 DAP. This could be due to varietal characteristics. There was a significant difference between the fertilizer types. The amended and unamended plots produced high levels of whitefly incidence at 86 DAP; this could be due to environmental characteristics. The 300 kg/ha N.P.K. and the control produced the same level of whitefly incidence at 72 DAP. The 150 kg/ha N.P.K. and 2.5 t/ha Chicken Manure produced the highest level of whitefly incidence for the entire minor growing season; this could be due to the high foliage exhibited. During the major cropping season, there was no significant difference between varieties in whitefly incidence. However, there was a significant difference between fertilizer types. The 150 kg/ha N.P.K. and 2.5 t/ha Chicken Manure produced the lowest whitefly incidence at 30 DAP. The 5 t/ha CM produced the highest whitefly incidence at 44, 72, and 86 DAP. The 150 kg/ha N.P.K. and 2.5 t/ha Chicken Manure produced the same level of whitefly incidence at 72 DAP.

4.3 Yield and Yield Components of Sweet Potato

Effect of variety and fertilizer type on tuber length per plot and number of deformed tubers per plot: There was a significant difference between Ogyefo and Ogyatanaa in tuber length per plot in both cropping seasons. This could be due to differences in genetic characteristics. The control produced the longest tuber length in the minor rainy season. The increase in tuber length in the control could be due to the amendment having no effect on tuber length. The 300 kg/ha N.P.K. recorded the longest tuber length in the major season. This might be due to differences in crop responses to soil nutrients coupled with the high rainfall experienced during the major rainy season. This is in line with Teshome *et al.,* who attested that sustaining soil fertility in intensive cropping systems for higher crop yields and better quality can be achieved through inorganic nutrient management [21]. There was no significant difference between Ogyefo and Ogyatanaa in the number of deformed tubers per plot in the minor season. The non-significant difference could be due to the amendment having no effect on the variety. However, in the major season, the number of deformed tubers was higher than in the minor season. This could be due to differences in plant response to amendments applied and climatic conditions in terms of high rainfall experienced during the major season.

Effect of variety and fertilizer type on the number of weevil (*Cylas* spp.) infested tubers per plot and number of plants harvested: The level of weevil incidence was higher in Ogyatanaa than in Ogyefo. The difference in incidence could be due to varietal characteristics and environmental factors. This confirms with Stathers et *al.*, who attested that deep-rooted varieties seem to be less attacked than shallow-rooted varieties, as the weevils cannot reach the storage roots so easily when deep in the soil. Early maturing varieties can also escape attack because they are harvested early before the soil dries out, cracks, and provides easy access to the roots [22]. The 5 t/ha Chicken Manure had the highest number of weevil-infested tubers in the minor season. This could be due to cracks on the soil surface due to the longer period of dryness as a result of less rainfall experienced during the latter growth stage of the crop. This is in line with Kabi et *al.*, who attested that weevil *(Cylas spp.*) populations build up during dry seasons [23]. This also agrees with Ebregt et *al.*, who reported that delay in harvesting, especially at drier periods, increases infestation and damage to sweet potato roots [24]. In the major season, Ogyatanaa had the highest number of weevil-infested tubers compared to Ogyefo. The level of weevil infestation was higher in the minor season than in the major season. This could be due to cracks in the soil and the longer period of dryness. This confirms Sowley et *al.*, who reported that weevil infestation is most serious when drought persists for a long time and that warm conditions increase the likelihood of serious pest infestation [11]. The 150 kg/ha N.P.K. and 2.5 t/ha Chicken Manure, 300 kg/ha N.P.K. and the control were not significantly different in the number of plants harvested in the minor season. This indicates that the amendment had no effect on the number of plants harvested and they were similar. The major season produced a higher number of plants at harvest than in the minor season. This could be due to the high rainfall experienced during the major season since sweet potato requires adequate moisture supply to encourage early vegetative growth.

Effect of organic and inorganic fertilizers on vertical distribution of weevil infested sweet potato tubers at different soil depths: The results indicated that Ogyefo and Ogyatanaa grown with amended and unamended plots recorded the highest level of weevil (*Cylas spp*.) infestations at the top 5 cm depth vertical distribution of tubers at the minor and major rainy seasons. Generally, the level of infestations decreases gradually up to 20 cm deep because varieties with deep or higher depth of tubers tend to escape weevil damage. This confirms Sowley et *al.*, who attested that deep-rooted sweet potato varieties escape weevil damage because their roots are less accessible for females to lay eggs. Such varieties of sweet potato used in India have thin tubers scattered within the ground and well below the surface and are less severely damaged than those with large tubers near the surface of the soil [11].

Effect of organic and inorganic fertilizers and sequential harvesting on incidence of sweet potato weevil: The effect of organic and inorganic fertilizers and sequential harvesting on the incidence of sweet potato weevil showed that Ogyefo produced the highest number of weevil incidence at the first harvest compared to Ogyatanaa. This could be due to differences in varietal characteristics and environmental factors. In the minor rainy season, there was severe weevil infestation of tubers at the second harvest compared to the first harvest. This could be due to varietal characteristics and environmental factors. This confirms Kabi et *al.*, who attested that weevil populations build up when harvesting is delayed because it allows continuous reproduction on available food. Delay in harvesting increases infestation and damage to sweet potato roots [23]. In the major rainy season (2018), there was a severe weevil (*Cylas spp*.) infestation at the first harvest compared to the second harvest. This could be due to high rainfall experienced during the rainy season, coupled with environmental factors.

5. CONCLUSION

The application of chicken manure and inorganic fertilizer as mineral supplements either singly or in combination, influenced the incidence of weevil (*Cylas spp.),* the vegetative growth, and the yield of sweet potatoes across both seasons. Generally, to reduce weevil infestation on sweet potato tubers, ogyefo should be grown with a combination of organic and inorganic fertilizers in the minor season in the forest transitional zone of Ghana similarly in the major season, it is also recommended that Ogyatanaa and ogyefo should be grown with 150 kg/ha N.P.K. and 2.5 t/ha Chicken manure to produce the lowest number of weevil (*Cylas spp*.)-infestations. In the minor and major seasons Ogyefo and Ogyatanaa should be grown with 150 kg/ha N.P.K. and 2.5 t/ha Chicken manure, ridging should be done to bury the tubers deep in the soil for longer vertical distribution to produce the lowest level of weevil infestation. The future prospects for sweet potato production in the world economies is very prosperous with potential for expansion and general sustainability because of its nutritional value, calorie yield, adaptability to various climates in the world and vegetative mode of reproduction. The crop also has the potential of alleviating starvation and malnutrition has not been fully exploited, particularly in underdeveloped countries. The crop can also provide economic diversification in the area of value-added products.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) I hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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