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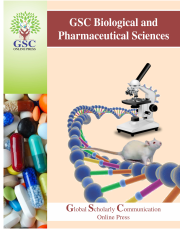

(RESEARCH ARTICLE)

Climate change impacts on field crops with reference to stem borer infestation in maize

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Abstract

Climate change is the focus of this research work as a result of the consequences of its impacts on human activities and the natural environment. The survey considered two locations: Abadigba and Apata-Okene, as well as three sowing periods: March/April, April/May and June/July, while 10 farms were sampled /sowing period. Surveys of 60 (30 farms/location) purposely selected farms measuring at least an acre were conducted to ascertain the prevalence of stem borer incidences among sampled maize farms. A total of 240 quadrate throws (75×75cm) were randomly conducted at an average of 4 quadrate throws per maize field and investigated for stem borer infestation then tagged for subsequent data collection. Data were collected by either manual counting of affected plants and recorded as percentage of plants in the sampled quadrates, or by visual assessment as it affects levels of leaf damage resulting from stem borer activities. Data collected include: number of infested maize stands per quadrate throws expressed in percentage; assessment of the levels of leaf damage; and cobs yield per maize stand. Results obtained from the farm surveys were subjected to the percentile method of presentation. The results reveal varying degrees of stem borer infestation and crop damage; percentage infestation varies with planting date, as well as location, with crops sown between March and April suffering the highest infestation, while those sown between June and July gave the least pest infestation in both locations.

Keywords: Abadigba; Apata-Okene; Anyigba; Maize; Stem Borer; Climate, Temperature

1. Introduction

The location of Nigeria is within the geographical latitudes: 4°N-14°N and longitudes 2°E - 15°E, occupying a total area of 923,768 square kilometers, and located between the Equator and Tropic of Cancer. The latitude of the country falls within the tropical zone, though the climatic conditions are not completely tropical. The climatic conditions vary from the northern part of the country to the southern part; the northern part is arid and the southern part is an equatorial climate [1]. Nigeria's soils and climate conditions allow for the cultivation of a wide range of food and cash crops, with agriculture accounting for the biggest employer of labour (over 60 per cent of the workforce, working mainly in small-holdings usually less 1 ha of land, using basic farm tools such as hoes and cutlasses) [2].

In sub-Saharan Africa, evidences of climate change are unmistakably everywhere [3]: temperature changes (high and low), delays in rainfalls, or early commencement or sudden cessation of rain, droughts in some cases, incidences of pests and diseases, among other noticeable effects. Even temperate environments are not excluded from climate change effects: depressing temperatures, with occasional heating up, unusual snow falls, amongst other effects.

Climate change has become one of the most serious environmental threats facing mankind worldwide [4] in recent time. It affects agriculture in several ways, besides its direct impact on food production and the possible impact on pests and

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diseases; observing that agriculture, particularly crop, is perhaps the most environment (weather, pests and diseases) sensitive of all human economic activities.

Global temperatures have increased rapidly in recent times than previous historical records on temperatures have shown. Scientists believe this accelerated heating of the atmosphere is because increasing amounts of greenhouse gases trap more and more heat [5, 6]. However, there are many different factors that complicate this system, including clouds, volcanic eruptions, oceans as well as human activities, besides other likely factors which are yet to be identified.

Temperature variations play a major role in climate variability, as such the need to continue to monitor the trends in temperature even in locations where temperature patterns have been established [1]. Temperature trends vary on a global scale, from the unusually cold weather conditions in the Arctic to the unusually warmer conditions in the Tropics [1].

United States, National Research Council reported that in the last decade the Earth reached the hottest level ever experienced in 400 or possibly 2,000years.Studies have shown that the mean global surface temperature has increased by approximately 0.3-0.6°C over the decades [1]; the largest increase recorded in surface temperatures in the last 1,000 years.

One of the expected impacts of such temperature (climate) change is possible increases in pests and diseases such pest is the stem borer attacks in maize. Is this assumption a myth or reality, only time will tell?

The consequence of stem borer on maize yield is variable from negligible to total yield loss, depending on the location, season, sowing date, stem borer species composition, level of abundance, varietal susceptibility, and crop pest interaction as mediated by the climatic, edaphic and biotic environment [7, 8].

Reference made to climate as one of the mediating factor in stem borer infestation underpins the possible relevance of climate change, particularly temperature increases, on stem borer infestation in maize fields.

Maize plants are less able to tolerate stem borer attack than sorghum and pearl millet plants and the effect on grain yields is therefore greater. Crop losses decreased when stand densities were reduced and increased when the crop suffered from water stress [9].

Larvae of stem borers usually cause damage to maize, with estimated yield losses caused by stem borers in Africa ranging from 10-100% [10].However, the 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 [11].

Stem borers damage plants by feeding on the leaves and on the stems and cobs. Early instars of *Chilo spp.* and *B. fusca* typically migrate from the ovipositor 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 expands out of the leaf sheath [9, 12].

Considering observed effects of climate change in recent time, particularly in Kogi state, the experiment set out to quantify effect of climate change on stem borer incidence in maize fields within Anyigba and its environ.

2. Material and methods

2.1. Location of the Survey

The survey area lies within latitude 7°15^1 to 7°29^{1}N and longitude 7°11^1 to 7°32^{1}E and with an altitude of 420 mm above sea level in the southern Guinea savannah Agro ecological zone of Nigeria. It is located within Anyigba with an average temperature of 27°C and an annual average rainfall of 1260 mm.

2.2. Sampled Population/Survey Area and Data Collection

The survey considered two locations: Abadigba and Apata-Okene, as well as three sowing periods: March/April, April/May and June/July, while 10 farms were sampled /sowing period. Surveys of 60 (30 farms/location) purposely selected farms measuring at least an acre were conducted to ascertain the prevalence of stem borer incidences among sampled maize farms. A total of 240 quadrate throws (75×75 cm) were randomly conducted at an average of 4 quadrate throws per maize field and investigated for stem borer infestation then tagged for subsequent data collection.

Data were collected by either manual counting of affected plants and recorded as percentage of plants in the sampled quadrates, or by visual assessment as it affects levels of leaf damage resulting from stem borer activities. Data collected include:

- Number of infested maize stands per quadrate throws expressed in percentage;
- Assessment of the levels of leaf damage;
- Cobs yield per maize stand.

3. Results and discussion

Figures 1, 2, 3, 4 and 5 show sampled maize stands with varying degrees of stem borer infestation as well as crop foliar damage which resulted from stem borer attacks in fields surveyed in 2016 cropping period, while Figure 3 show additional effects of crop wilting resulting from sudden cessation of rains complicated by temperature increase, a characteristic of climate change. The prevalence of stem borer infestation in the study areas within the period under study, particularly in 2016 were likely due to increase in atmospheric temperatures (Tables 1, 2) complicated [13, 14, 15] by sudden cessation in rainfall experienced after cultivation of the cereal crop (Table 1). The cessation in rainfall observed was similar in both early (March/April) and late sown (May/June) maize. In both periods temperature increases were observed after cessation of rainfall; a condition favourable for stem borer infestation [13, 14, 15]. Moyal [9] had observed that maize losses due to stem borer increased when crops suffered from water stress, while Ajala [1]; Okweche [8] added that crop pest interaction is mediated by the climatic environment, a similar position taken by other researchers as it relates to pests and global warming [13, 14, 15].

Figure 1 2016 Cropping season: Maize fields with various degrees of stem borer infestation and crop damage.

Figure 2 2016 Cropping season: Maize fields with various degrees of stem borer infestation and crop damage.

Figure 3 2016 Cropping season: Maize field showing water stress and stem borer infestation and crop damage**.**

Figure 4 2016 Cropping season: Maize fields with various degrees of stem borer infestation and crop damage.

Figure 5 2016 Cropping season: Maize field showing relatively low stem borer infestation and crop damage**.**

Manikandan *et al*. [16] had observed that insects, as cold-blooded animals are directly under the control of temperature for their growth and they cannot sustain living below and above certain thresholds. Therefore, temperature is probably the single most important environmental factor influencing insect behavior [16]. The authors [16] had observed that current estimates of changes in climate indicate an increase in global mean annual temperatures of 1°C by 2025 and 3°C by the end of the next century. They [16] stressed that such increases in temperature may decrease the developmental time and increase the number of generations per year.

In an investigation conducted by Manikandan *et al*. [16] to understand the effect of five different constant temperatures (28.3°C, 30.6°C, 32.7°C, 34.3°C and 36°C) on the development time of Yellow Stem Borer (YSB), the results revealed that the number of eggs laid by YSB increased at higher temperatures while egg hatching was reduced. Egg hatching was higher (90.6%) in 30.6°C followed by 28.3°C. They [16] argued that development time taken by different stages of the YSB revealed that there was an inverse relationship with development time and incubation temperature level. This observation by Manikandan *et al*. [16] may have accounted for the outcome of the results gotten from the survey in the study area. That insects develop faster, thus may oviposit early is likely to grow pest population earlier than expected [16], thus the observed level of crop damage in the study area.

Table 1 Annual Heat Index from 2000 to 2013.

Climatic Factor	Month											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Temp (^0C)	29.88	30.84	31.76	33.01	33.36	32.14	32.06	32.27	32.29	32.8	32.09	30.53
Humidity	59.93	61.21	59.79	61.78	70.21	74.07	73.5	79.21	74.93	64.71	56.56	52.07
Heat Index	91	95	98	104	113	108	107	113	110	105	97	90

Source: Cited in [22]

Table 2 Monthly Heat Index from 2000 to 2013

Year	Temp (^oC)	Humidity (%)	Heat Index (HI)
2000	30.85	68.75	98
2001	31.13	66.75	99
2002	32.08	64.83	102
2003	32.60	65.67	105
2004	31.30	64.00	98
2005	31.29	65.75	99
2006	32.02	65.25	102
2007	32.18	64.17	102
2008	32.05	64.33	101
2009	32.03	64.33	101
2010	32.23	66.67	104
2011	32.66	66.00	105
2012	32.32	66.33	104
2013	32.13	66.50	103

Source: Cited in [22]

Generally, maize is an important cereal produced in all agro-ecologies of West and Central Africa, with a demonstrated high yield potential in the savanna zones, where it is a staple food for an estimated 50% of the population. In the study areas, cereals, basically maize, crops are sown as the first crop immediately on commencement and establishment of rainfall [17, 18]. As a major staple, any adverse effect on its (maize) production will definitely impact on food security in the study areas.

The observed damaging effects of stem borer activities on surveyed maize crop foliage Figures 1, 2, 3, 4 and 5 are in line with previous documentations [11], where there were reports of crop losses resulting from death of the growing point (dead hearts), early leaf senescence, reduced translocation, lodging and direct damage to the ears. Definitely, any negative impact on crop foliage should be expected to depress crop yield; though to different degrees [11].

Patterning to planting period (date) and location, stem borer infestations vary with planting period, as well as location (Tables 3 and 4). Crops sown between March and April suffered the highest infestation level, while those sown between June and July gave the least pest infestations in both locations. While recommending delay in cropping may be the first rational decision to make, such recommendation may however, not receive farmers' approval. Generally, farmers in the survey areas plant their early maize crops between March and April to alleviate hunger, or to catch-in on market prices, which are often favourable, considering that there are usually more people pursuing available maize supplies. Therefore, the role maize crop play in hunger alleviation as well as providing the farmer with cash flow may prevent delay sowing of the crop. Having such understanding, the most feasible recommendation, may be pest control mechanisms; especially, knowing that stem borer incidences are now common occurrence.

Table 3 Summary of survey result on stem borer infestation, in 2016 cropping period

Location	**Percentage of infestation / sowing period**					
	Farms	**March/April**	**Farms**	**April/May**	**Farms**	**June/July**
Abadigba	Fn_1	48.57	Fn_{11}	45.40	Fn_{21}	46.93
	Fn_2	48.55	Fn_{12}	78.50	Fn_{22}	49.20
	Fn_3	38.38	Fn_{13}	35.00	Fn_{23}	31.03
	Fn_4	88.60	Fn_{14}	66.70	Fn_{24}	55.55
	Fn_5	79.05	Fn_{15}	42.30	Fn_{25}	49.44
	Fn_6	6.79	Fn_{16}	70.30	Fn_{26}	0.00
	Fn_7	49.49	Fn_{17}	5.76	Fn_{27}	20.65
	Fn_8	3.03	Fn_{18}	11.11	Fn_{28}	0.00
	Fn_9	50.36	Fn_{19}	9.09	Fn_{29}	30.53
	Fn_{10}	49.49	Fn_{20}	42.30	Fn_{30}	31.21
	Means	46.22		40.65		31.45
Apata-Okene	Fn_1	90.76	Fn_{11}	49.49	Fn_{21}	0.00
	Fn_2	66.00	Fn_{12}	13.03	Fn_{22}	4.32
	Fn_3	41.30	Fn_{13}	50.36	Fn_{23}	31.21
	Fn_4	38.38	Fn_{14}	44.49	Fn_{24}	30.53
	Fn_5	38.38	Fn_{15}	31.03	Fn_{25}	2.65
	Fn_6	77.50	Fn_{16}	55.55	Fn_{26}	30.00
	Fn_7	34.10	Fn_{17}	49.44	Fn_{27}	50.65
	Fn_8	70.20	Fn_{18}	16.21	Fn_{28}	30.00
	Fn_9	45.40	Fn_{19}	19.09	Fn_{29}	20.65
	Fn_{10}	49.09	Fn_{20}	12.11	Fn_{30}	10.00
	Means	55.11		34.08		21,00

Key

Fn1 – Fn30……………………………………Farms

Table 4 Average numbers of cobs on sampled stands / farm

Location	Mean cops/plant					
	Farms	**March/April**	**Farms**	**April/May**	**Farms**	**June/July**
Abadigba	Fn_1	2	Fn_{11}	2	Fn_{21}	1
	Fn_2	1	Fn_{12}	2	Fn_{22}	1
	Fn_3	2	Fn_{13}	1	Fn_{23}	2
	Fn_4	2	Fn_{14}	1	Fn_{24}	2
	Fn_5	2	Fn_{15}	2	Fn_{25}	1
	Fn_6	1	Fn_{16}	2	Fn_{26}	1
	Fn_7	1	Fn_{17}	1	Fn_{27}	1
	Fn_8	2	Fn_{18}	1	Fn_{28}	2
	Fn_9	1	Fn_{19}	1	Fn_{29}	2
	Fn_{10}	2	Fn_{20}	2	Fn_{30}	2
	Means	1.6		1.5		1.5
Apata-Okene	Fn_1	1	Fn_{11}	2	Fn_{21}	1
	Fn_2	2	Fn_{12}	1	Fn_{22}	2
	Fn_3	1	Fn_{13}	3	Fn_{23}	1
	Fn_4	2	Fn_{14}	2	Fn_{24}	2
	Fn_5	1	Fn_{15}	2	Fn_{25}	1
	Fn_6	1	Fn_{16}	1	Fn_{26}	1
	Fn_7	1	Fn_{17}	1	Fn_{27}	1
	Fn_8	2	Fn_{18}	2	Fn_{28}	1
	Fn_9	2	Fn_{19}	2	Fn_{29}	2
	Fn_{10}	1	Fn_{20}	2	Fn_{30}	1
	Means	1.4		1.8		1.3

Key

F_{n1} – F_{n30}……………………………………Farms

Observing that Heat Index (HI) has shown a steady rise in the last decade [16] (Tables 1 and 2), which may have implications for pests and crop diseases [9, 16, 19, 20, 21]; a situation which may be complicated when crops experience water stress [9], there is the need for a proactive means of addressing issues related to crop pests. This is both urgent and important to ensure food security and a way of life of the farming community. Deliberate efforts should be made on crop rotation, adequate farm sanitation, and varietal selection for pests and disease resistance, among others factors that may ensure food security in the face of growing population. There is the need for a holistic approach to issues of crop production in the changing face of climate, particularly considering the additional task of feeding the over 7 billion world population.

4. Conclusion

Generally, maize derives socio-economic importance from its value as staple food item (contributing to household food security), animal feed and agro-industrial and trade item, there by growing the economy and alleviating poverty. This observation underpins the importance of the study, particularly in a changing climate. Weather conditions, particularly temperatures and rainfall are usually favorable for stem borer's infestation. The prevalence of stem borer infestation in the study areas within the period under study, particularly in 2016 were likely due to increase in atmospheric temperatures complicated by sudden cessation in rainfall experienced after cultivation of the cereal crop.

As observed earlier, to address this climate change related issue deliberate efforts should be made on crop rotation, adequate farm sanitation, and varietal selection for pests and disease resistance, among others factors that may ensure food security in the face of growing population. There is the need for a holistic approach to issues of crop production in the changing face of climate, particularly considering the additional task of feeding the over 7 billion world population.

Compliance with ethical standards

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Disclosure of conflict of interest

No observed conflict of interest whatsoever

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