Research Article

Impacts of Climate Variability and Change on Banana Yields in the CDC- Delmonte Banana Project, Tiko, South West Region, Cameroon

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ABSTRACT

Climate variability and change are existing sets of conditions which affect crop productivity. An evaluation of their impacts on banana yield in the CDC-DelMonte Banana Project at Tiko is fundamental in conceiving adaptation strategies towards coping with, and minimizing their deleterious impacts for maximum productivity within the present trends on global climate change. An assessment of records of past climatic data (rainfall and temperatures) recorded within three zones (Mondoni, Tiko and Benoe) of the Project from 1990 to 2010 indicated decreasing trends in total annual rainfall and increasing trends in averaged annual temperatures in the Mondoni and Tiko zones while the Benoe Zone showed increasing rainfall and decreasing temperatures. An evaluation of banana productivity per unit hectare indicated decreasing trends in all three zones. Nematode infestations (*Radopholus* sp, *Hoploilaimus* sp) were found to be more prevalent in the Tiko Zone followed by Mondoni with mean maximum temperatures for March 2011 of 34.0°C and 32.2°C, respectively, while the Benoe Zone with a mean maximum temperature of 27.2°C was least. This indicates that nematode populations are favoured by decreased rainfall and increased temperatures. Consequently, the prevailing increasing trends of temperature locally and globally, and the general decrease in total annual rainfall with time are causes for future concern in banana production and nematode infestation in particular in the study area.

Keywords: Tiko, CDC-Delmonte, climate change, climate variability, banana productivity, nematode infestation, adaptation strategies

RÉSUMÉ

La variabilité du climat est un ensemble existant de conditions qui affectent la productivité des cultures. Une évaluation des impacts de la variabilité climatique (température, les précipitations, le rayonnement solaire et l'humidité relative) sur le rendement de la banane dans le "Banana Project CDC-Delmonte" Tiko, est fondamentale pour minimiser l'impact délétère des conditions climatiques défavorables et à les gérer pour un maximum de productivité. Une évaluation des dossiers de données climatiques passées pour trois zones (Mondoni, Tiko et Bénoué) du Projet allant de la période 1990 à 2010 indique des tendances décroissantes du niveau total de pluie par an, et des tendances croissantes en niveau moyen de température par an dans les zone Mondoni et Tiko, alors que la zone de Bénoué montre un niveau croissant de pluie et décroissant de température. Les résultats ont montré tendances à la baisse des précipitations et tendances à la hausse de la température dans la zone Mondoni, une légère augmentation des précipitations et une augmentation de la température dans la zone Tiko et dans la zone de Benoe, l'augmentation des précipitations et la température baisse, et la baisse de productivité dans les trois zones. Une évaluation de production des bananes a indique une tendance à la base dans les trois zones d'étude. Les infestations des nématodes (Radopholus sp, Hoploilaimus sp) ont été trouvés à être plus fréquentes dans la zone Tiko suivie par Mondoni et moins dans la zone Benoe avec des températures maximales de 34.0°C, à 32.2°C et 27.2°C respectivement. Ceci est révélateur du fait que les populations de nématodes augmentent à mesure que la température augmente. Par conséquent, les tendances à la hausse en vigueur de la température sont localement et globalement préoccupante avenir dans la production de bananes et d'infestation par les nématodes en particulier dans la zone d'étude.

Mots clés : Tiko, CDC-Delmonte, changement climatique, variabilité climatique, production des bananes, infestation des nématodes, stratégies d'adaptation

INTRODUCTION

Climatic conditions may become erratic, extreme and uncertain as a result of global climate change thereby altering the biophysical environment in which crops grow (Howden *et al.,* 2007). Crop responses to changes in climatic factors (temperature and rainfall) are the initial stages of consequences that may lead to changes in production (Gworgwor, 2010). The main climate variables important for the banana crop are temperature, solar radiation, relative humidity, precipitation and wind, which, not only vary over season and year, but also on a daily basis and consequently affect the yields (IPCC, 1996). The banana crop is extremely vulnerable to such conditions in their leaf, root and reproductive systems and if frequently exposed to a variety of harsh conditions, its growth and yield is affected negatively (Draye, 2002; Monteith, 1981). In fact, reports from the IPCC (2001) state that tropical regions are vulnerable to climate change where climate variability conditions such as temperature extremes, rainfall reliability, and drought conditions are the major stress factors that affect the cultivation of this crop.

Rainfall reliability is usually the most significant risk factor because of the importance of moisture or water for this plant and the uncertainties which the variability in rainfall patterns may impose on growth and productivity. As pointed out by Simmonds (1962) and Smith *et al.,* (1998), all the large banana growing areas of the world are in the tropics between latitudes 20^0 N and S although production has been extended to the sub-tropics which are affected by climatic factors such as greater diurnal temperature fluctuations, lower night temperatures, higher rainfall and stronger winds. Furthermore, the plants grow successfully only under constantly high temperatures (27^oC) and in lowland humid conditions with continuous total annual rainfall of 2000 to 2500mm yr^{-1} (Robinson, 1996).

Most commonly cultivated bananas in Cameroon are 'Gros Michel (AAA), 'Grande Naine' (AAA), 'Cochon' (AAA-EA) (Ngoh *et al.*, 2005) with total production of bananas and plantains estimated at 1,400,000 metric tons in 2009 with dessert bananas accounting for 35%, whereas plantains and other cooking bananas account for 65% (FAO, 2011). This is compared to estimates of the Food and Agriculture Organization (FAO) statistics which showed that total *Musa* production in Cameroon was about 2.23million tons (FAO, 2007) with about 35% for *Musa* AAA Cavendish bananas and over 65 % for *Musa* AAB plantains (Temple *et al.,* 1996; Fogain and Ysenbrandt, 1998; Anon, 2005).

Weed infestations (Gold, 1994; Fogain, 1994), pests such as borer weevils, nematodes (Gold *et al.*, 2002), diseases such as the black sigatoka (Ploetz, 2004; Fogain and Ysenbrandt, 1998; Fansi and Okolle, 2008) and predators like ants and snails (Gowen, 1995; Messiaen, 2002) which have been reported on this crop in Cameroon, affect its growth and productivity thereby altering yields, but without due consideration on the impacts of climate change.

The Tiko Banana Project (TBP) also known as DelMonte is found in Tiko Sub-Division and deals with the production (cultivation, harvesting, packaging, transportation and exportation) of bananas. The project comprises nine farms covering a surface area of 2,956 ha grouped in three zones: the Benoe Zone (849ha), the Tiko Zone (1091ha), and the Mondoni Zone (1016ha), (Figure 1). An understanding of the responses of crops such as bananas within this project to their environmental conditions (rainfall and temperatures) is fundamental in minimizing the deleterious impact of unfavorable climatic conditions and for managing them for maximum productivity (Anon, 2005; Howden *et al.,* 2007).

Figure 1: Location of Tiko CDC-Delmonte Banana

Project

Although studies have asserted that the potential impact of climate variability could be severe on developing countries (Parry, 1990; Winsters *et al.*, 1999), there has been no previous evaluation of the trends of climatic parameters within the study area and their impacts on crop production and pest infestations even though records of these parameters from 1990 to present actually exist.

The present study was therefore aimed at assessing the trends of climate variability and climate change and their impacts on the yield of the banana crop within the three zones of the study area , determine yield trends per unit hectare for each zone, and assessing the influence of temperature on the prevalence of nematodes in each zone.

MATERIALS AND METHODS

The first phase of the study involved the compilation of monthly climatic data (rainfall and temperatures) from 1990 to 2010 for Mondoni Zone, 1991 to 2010 for Tiko zone, and 2000 to 2010 for Benoe Zone from the Statistics Department of CDC/Delmonte Project in Tiko. Monthly agro-data collected comprised total banana yields for each year for farms (located within zones) whose surface areas have remained constant during the entire period by the climate data.

The second phase involved the determination of the prevalence of nematodes in each of the zones based on procedures developed in the laboratory of the Research Department of the Project. Field sampling was carried out in March 2011 during which ten (10) samples of root were randomly collected from each of the three zones. The roots were then washed with clean water in the laboratory and the functional roots separated from the non-functional (dead) roots. The functional roots were placed on a chopping board and chopped into pieces with a sharp knife and their weights (in grams) obtained by weighing with an electronic balance. From the chopped roots, 25g was weighed and placed in a 300ml beaker with water made up to the 300ml mark. The roots were then ground in a blender for 60 seconds (at intervals of 20 seconds, separated by intervals of 10 seconds), washed, and passed through sieves with sizes of 0.0197, 0.011, 0.0061, 0.0017 and 0.0015mm. The residue samples left over after washing and sieving were then placed in beakers into which water was added to the 250ml mark. An agitator was placed in each beaker for uniform mixture. One (1) ml of each sample was then spread on a slide divided into grids and viewed

under the light microscope. Simple nematode counting under the microscope was then used to assess the prevalence of nematodes in this area with one nematode viewed multiplied by 1000 within the grid to get an estimated number in that field (Pinochet, 1988).

The climatic and agro data were analysed, presented in tables, and plotted in graphs using Microsoft EXCEL 2007 and the Minitab 16 statistical software. Trend models for the various plots were generated by fitting regression lines on the graphs of the various plots. The predicted values of temperatures and rainfall at time (t) in future were obtained by simple calculations using the equation of the fitted trend lines (Ayonghe, 2001).

$Y_t = â_0 + â_1 t + e_t$

where Y = Value of the data (Temperature in °C or Rainfall in mm)

t = Year under consideration

$â_0$ = Intercept on the y axis

$â_1$ = Coefficient

e_t = A constant (error margin)

Three measures which were displayed with the trend lines were used to determine the accuracy of the fitted values namely: mean absolute percentage error (MAPE), mean absolute deviation (MAD) and mean squared deviation (MSD). Pearson Correlation Matrices generated from the Minitab 16 statistical software for the three zones were used to assess the possible impacts of climate variability (temperature and rainfall) on the yield of the banana crop. The correlation matrix analysis measures the strength of the relationship between two variables. Negative values describe a relationship where an increase in one variable is accompanied by a predictable and consistent decrease in the other, while positive values describe a relationship where an increase in one variable is accompanied

by a predictable and consistent increase in the other (SPSS Inc., Version 10.0.7).

RESULTS

The rainfall and temperature (maximum and minimum) data collected from the weather stations of the farms and grouped according to the three zones are shown in Table 1 while the banana yields for the same periods are shown in Table 2.

Table 1 : Correlation Matrices for Mondoni (a), Tiko b) and Benoe (c) Zones

(a)	Yield	Rainfall	Temperature
Yield	1.00		
Rainfall	-0.24	1.00	
Temperature	-0.001	-0.013	1.00

(b)	Yield	Rainfall	Temperature
Yield	1.00		
Rainfall	-0.39	1.00	
Temperature	-0.53	0.06	1.00

(c)	Yield	Rainfall	Temperature
Yield	1.00		
Rainfall	-0.56	1.00	
Temperature	-0.19	0.50	1.00

Table 2: Nematode Population for Mondoni, Tiko and Benoe Zones.

	Radopholus sp	Hoploilaimus sp	Functional root weight (g)	Non-functional root weight (g)
Mondoni Zone	1,605,500	287,000	7251.5	982.4
Tiko Zone	3,266,000	446,100	5129.5	1411.9
Benoe Zone	611,500	304,000	3581.6	664.8

Graphs showing the trends with fitted trend lines which were used to project future trends are shown for total annual rainfall (Fig. 2) and for averaged annual temperatures (Fig. 3).

The rainfall for the Mondoni Zone showed a decreasing trend (Figure 2a), and increasing trends for both Tiko and Benoe Zones (Figure 2a and b).

Trends in temperature showed an increase for Mondoni and Tiko Zones (Figure 3a and b), and a decrease for Benoe Zone (Figure 3c).

(a)

(b)

(c)
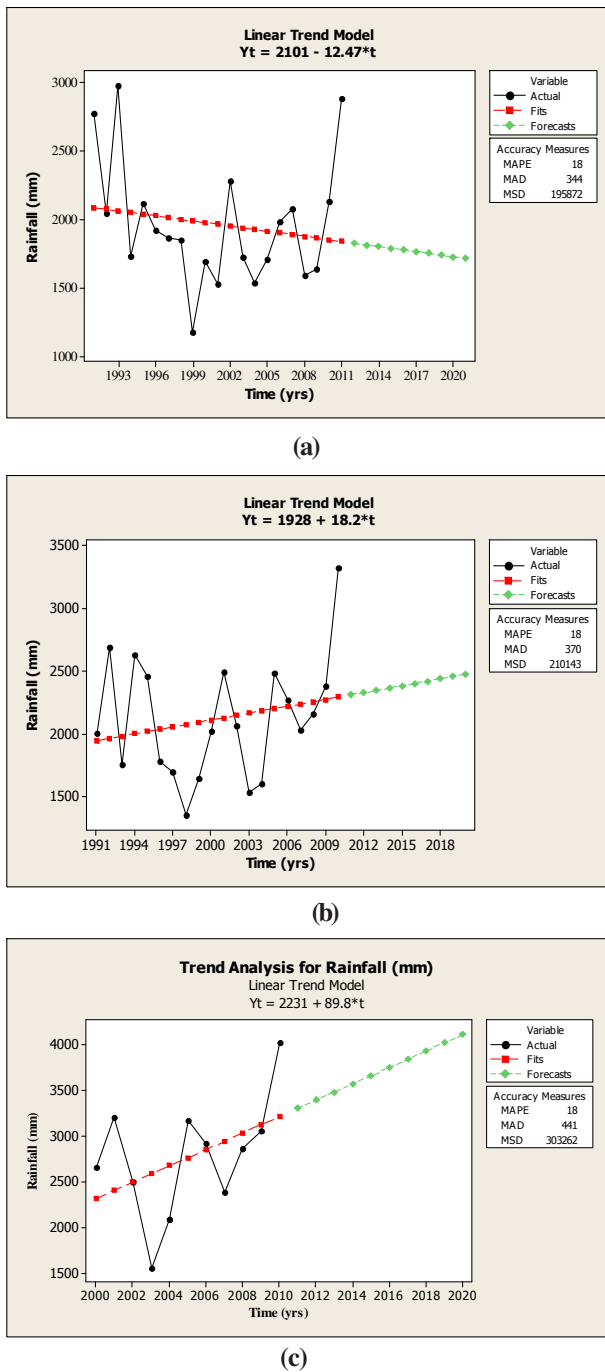
Figure 2: Trend analysis plot of total annual rainfall (mm) for Mondoni (a), Tiko (b) and Benoe (c) Zones

(a)

(b)

(c)
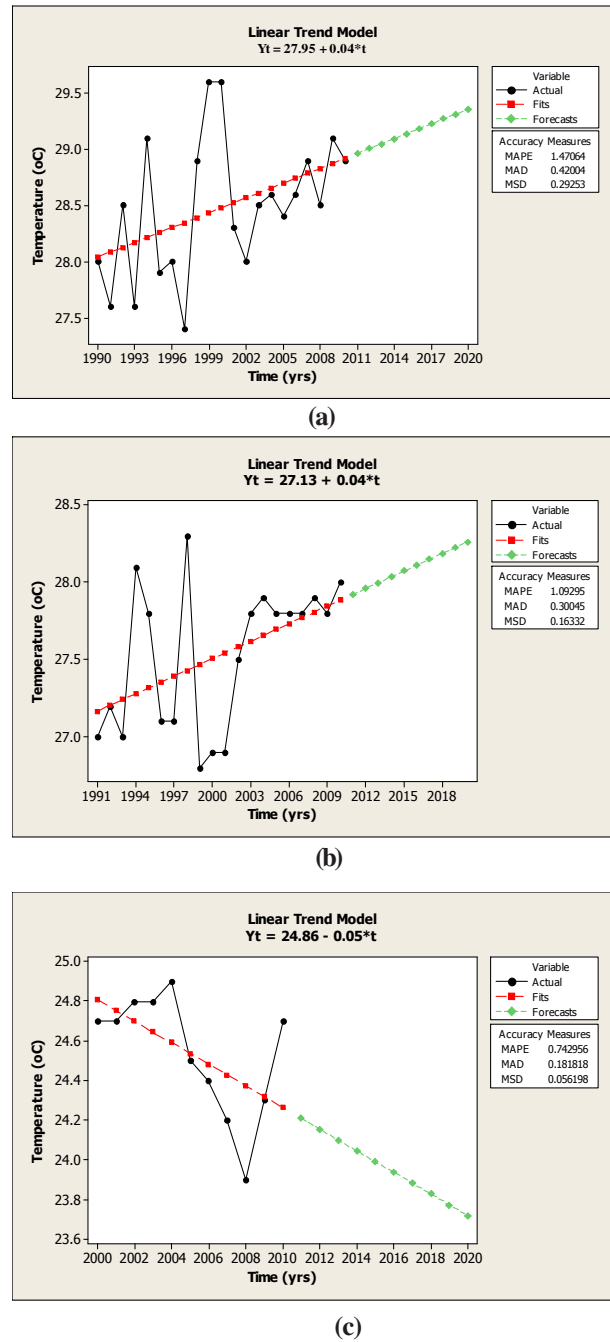
Figure 3: Trend analysis plot of averaged annual temperature (ºC) for Mondoni, Tiko and Benoe Zones

Graphs of banana production per unit hectare calculated for the various zones showed decreasing trends of yields in all three zones of the Project (Fig. 4).

(a)

(b)

(c)
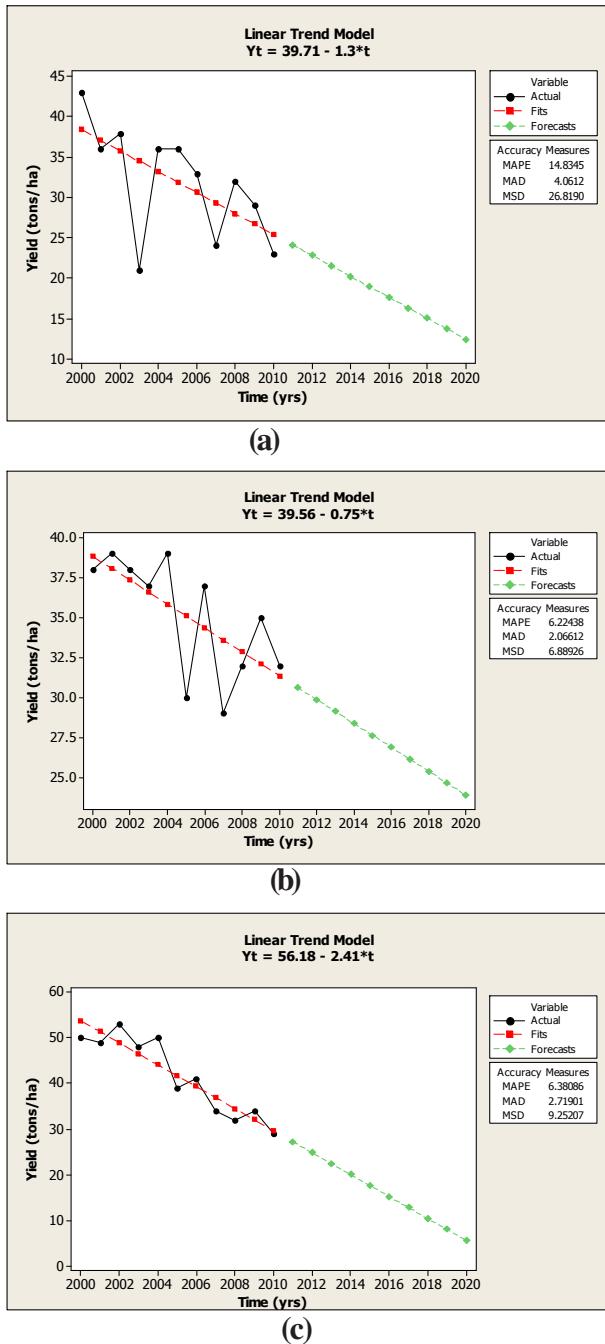
Figure 4: Trend analysis plot of banana yields (tons/ha) for Mondoni, Tiko and Benoe Zones from 2000 to 2010

Since rainfall and temperature are important factors for the growth and productivity of this plant, the statistical summary of correlation results generated for these variables for the three zones over 11 years (Table 3) showed how variability in

temperature and rainfall impacts the yield of the banana crop. In all three zones, rainfall correlated negatively with yield, with the Benoe zone (Table 1c) showing the highest negative correlation (-0.56) as compared to Mondoni (-0.24) and Tiko (-0.39) zones (Table 3a and b). Therefore an increase in rainfall in this zone will have a negative impact on the crop thereby decreasing yields. Temperature in all three zones also showed a negative correlation with yield (Table 3) with the Tiko Zone showing the highest negative correlation value (-0.53) as compared to Mondoni (-0.001) and Benoe (-0.19) Zones, indicating that temperature increase will equally have a negative impact on the crops in this area.

Two types of nematode species *Radopholus similis* and *Hoploilaimus galeatus* were identified and their degree of prevalence in the different farms within each of the zones of the Project assessed. The summed values for each farm grouped into the various zones are shown in Table 4. Highest nematode populations (for the two species) were recorded in the Tiko Zone (3,266,000 for *Radopholus similis* and 466,100 for *Hoploilaimus galeatus*) where the averaged maximum temperature recorded during this month (March 2011) was 34°C. This was followed by the Mondoni and Benoe Zones where the averaged maximum temperatures recorded were 32.2°C and 27.2°C respectively thereby indicating increases in temperatures are accompanied by increases in nematode populations.

The non-functional root (dead root) weight in these areas was also seen to be high 1411.9g (Tiko Zone), 1012.4g (Mondoni Zone), and 664.8g (Benoe Zone). These tend to reduce anchorage of the plants to the soil thereby facilitating toppling. The reduction in the functional roots of the plants also led to reduction of productivity (or yield of the crop) since very little nutrients

will be taken up from the soil by the few remaining functional roots.

DISCUSSION

Impacts of temperature and rainfall on banana yields

The trends in temperature and rainfall together with relative humidity and number of sunshine hours, are important variables for the growth of the banana crop are according to IPCC (1996).These factors interact strongly to affect the yield of the crop which is extremely vulnerable to slight changes in such climatic conditions. The plots of total annual rainfall showed a decreasing trend in the Mondoni Zone with highest peak of 2980mm yr^{-1} recorded in 2002, a slightly increasing trend in the Tiko Zone with highest amounts in 2010 (3328mmyr^{-1}), and an increasing trend in the Benoe Zone which has witnessed a continuous rise recording its highest peak of 4034mmyr^{-1}in 2010. This also falls in line with predictions of Howden *et al.* (2007), that West Africa, over the last 30 years, has witnessed changes in the spatial and temporal patterns of precipitation as a result of global warming. This has been clearly evident in the Benoe Zone which is actually closest to the coastline and showed the highest rate of increase of total annual rainfall while the Mondoni Zone which is furthest away from the coastline witnessed decreases in the amount of rainfall but temperature increases.

Rainfall or lack of it has severe implications for the physiological, pathological and management aspects of growing the crop (Robinson, 1996). Rainfall in all three zones correlates negatively with yield, with high negative values recorded for Benoe Zone (-0.56) as compared to Mondoni (-0.24) and Tiko (-0.39) Zones. According to (Robinson, 1996), an average annual rainfall of 2000 to 2500mm evenly distributed throughout the year is considered satisfactory for banana growth but the results showed that the Benoe

Zone recorded up to 4000mmyr^{-1}, allowing an average of only 3 to 5 hours of sunshine per day (Nelson *et al.,* 2006). This leads to a reduction in photosynthesis resulting in low assimilation potential, a reduction in bunch mass and of total yield.

Banana production per unit hectare (yield) showed decreasing trends in all three zones. According to Rahmstarf *et al.*, (2007), at lower latitudes especially in dry and tropical regions, crop productivity is projected to decrease for small local temperature increases of 1 or 2°C with large displacements mediated through the effects of water availability. According to forecasts on the Linear Trend Model, there is a possible rise in temperature of between 0.3°C and 0.2°C calculated at 5 years intervals from 2010 to 2020 for Mondoni zone. This falls within the predictions of Howden *et al.* (2007). These variability extremes may probably, in future, impact the growth and development of the banana plant in this area thereby affecting yields. This also might be the result of the decreasing trends in production for this area since, according to Robinson (1996), the banana crop is very vulnerable to slight changes in climate especially water availability.

Results from correlation analysis showed a negative correlation of temperature with yield, with the Tiko Zone showing high negative correlation values (-0.53) as compared to Mondoni (-0.001) and Benoe (-0.19) Zones. According to Howden *et al.* (2007), high temperatures affect the rate of plant development because temperature increases are associated with higher respiration rates, shorter periods of seed formation and consequently lower biomass production. At this point, the banana plants tend to face some negative effects of assimilation and respiration, thereby reducing infilling of fruits and consequently yields. The plants also tend to suffer leaf attacks which lead to necrosis (Fortescue and

Turner, 2005), leading to a decrease in photosynthetic tissue and consequently to a loss of gross harvest yield.

Effects of nematodes on the banana plants and impacts on yields

Toppling of some plants observed in the field were seen to be associated with the high prevalence of nematodes. These, together with other borers and weevils, (pests), tend to affect the plants leading to a reduction in productivity. According to Bridge *et al.*, (1998) and Ploetz (2004), burrowing nematodes (*Radopholus similis*, *Hoploilaimus galeatus*, *Meloidogyne* sp, *Scutellonema* sp) and borers (*Cosmoplites sordidus)* are prevalent in banana plantations especially during periods of the high temperatures of between 28 and 30°C, accompanied by relatively humid conditions. This is confirmed by the prevalence of *Radopholus* sp and *Hoploilaimus* sp in the Tiko Zone, followed by the Mondoni Zone where the averaged annual temperatures were 27.6°C and 28.7°C, respectively, and averaged maximum temperatures for March 2011 of 32.2°C and 34.0°C, respectively. These nematodes weaken the root systems, reduce yields, topple plants before harvest, make plants more prone to wind breakdown and reduce fertilizer uptake, thereby reducing the lifespan of the plant and bunch size (Gold *et al.*, 2002). Their larvae feed by boring through the plants' pseudostem eventually causing corm decay by facilitating invasion by secondary organisms and leaving a mass of rotten tissue. Such injury to the corm prevents nutrient uptake by the plant and according to Fogain and Ysenbrandt (1998), if left uncontrolled, can reduce yield by up to 100%.

According to Fansi and Okolle (2008), high rainfall of up to 3000mm.yr^{-1}, coupled with mean temperatures of about 25°C, led to rapid infection by the virulent leaf disease black sigatoka (*Mycosphaerella fijiensis*) and of development of the yellow sigatoka disease (*Mycosphaerella musicola)* which reduces the rate of photosynthesis and greatly affect yields. The disease was observed in the field especially in the Benoe Zone which recorded mean temperatures of 24.7°C leading to high de-leafing. Since aerial application of fungicides on the plants are discontinued during heavy rains, the prevalence of the disease increases, affecting the leaves of the plants, reducing photosynthesis and consequently affecting yields. Heavy rainfall also results in weeds such as *Cyperus* sp., dominating the floors of the plantation and tends to compete with the bananas for nutrients and light, reducing available uptake by the plants and thereby reducing productivity.

CONCLUSION

An assessment of trends of climatic parameters (rainfall and temperatures) from 1990 to 2010 within the CDC-Delmonte Banana Project in Tiko has been used to highlight the impacts of variations of rainfall and temperature on banana production during the same period. The results indicated increasing trends of temperatures in the Tiko and Mondoni Zones while the Benoe Zone located close to the coastline showed a decreasing trend in temperature. Conversely, the trend of rainfall increased in the Benoe and Tiko Zones but decreased with time in the Mondoni Zone located further inland.

An analysis of the prevalence of nematodes based on procedures developed in the Research Laboratory of the Project indicated highest prevalence in the Mondoni Zone where the averaged maximum temperature of the month (March 2011) during the study (34.2 °C) was recorded, and the least nematode prevalence in the coastal zone (Benoe) where the least averaged maximum temperature (27.2 °C) was recorded.

Trends of banana production per unit hectare showed drastic reductions in all zones during the same period and this is interpreted as due to the fact that this crop is extremely vulnerable to slight changes in climatic conditions.

The use of Pearson Correlation Matrices for the three zones to assess the possible impacts of temperature and rainfall on the yield of the banana crop indicated that both rainfall and increased temperatures correlated negatively with banana yields, with the highest negative correlation (-0.56) recorded in the Benoe Zone thus implying that an increase in one variable will be accompanied by a predictable and consistent decrease in the other. Thus, higher temperatures and rainfall will lead to decreases in yields in all zones. Although decreasing trends in rainfall were observed in the Mondoni Zone, the increasing temperatures here will require increased irrigation to achieve maximum productivity and this tends to serve as an adaptation strategy towards buffering the impact of the climatic variability and change.

The conception of suitable adaptation and management strategies in future in order to cope with the projected trends of climatic parameters and their consequences on the projected dwindling yields will accordingly be essential in future for this highly vulnerable banana project.

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