Journal of Agricultural and Crop Research
Vol. 9(2), pp. 40-49, February 2021
doi: 10.33495/jacr_v9i2.20.215
ISSN: 2384-731X
Research Paper

Impact of crop rotation and fertlilizers (chemical, organic and bio) on diseases and yield of maize (*Zea mays*) in Far North Cameroon

Ngoh Dooh Jules Patrice[1]* • Bamle Sabine[1] • Djile Bouba[2] • Godswill Ntsomboh Ntsefong[3] • Gaye Lorandine[4] • Tchoupou Tsouala Dany Brice[4] • Boulga Taoga[1] • Philippe Kosma[4] • Ambang Zachee[5]

[1]Department of Biological Sciences, Faculty of Science, University of Maroua, PO Box 814 Maroua, Cameroon.
[2]Institute of Agricultural Research for Development of Maroua (IRAD), PO Box 33, Cameroon.
[3]Department of Plant Biology, Faculty of Science, University of Yaounde 1 & Institute of Agricultural Research for Development (IRAD), Cameroon.
[4]Higher National Polytechnic School of Maroua, University of Maroua, PO Box 1450 Maroua, Cameroon.
[5]Laboratory of Biotechnologies, Phytopathology and Microbiology Unit, University of Yaounde I, PO Box, 812, Cameroon.

*Corresponding author: E-mail: ndjuliopat@yahoo.fr. Tel: (237) 699219391

Accepted 24th February, 2021.

Abstract. Many fertilizers are used in the Far North of Cameroon for maize production. The aim of this work was to reveal diseases and yield performance of maize in response to different fertilizers during two years (2018 and 2019). CMS 9015 maize variety was used. Three sites were selected. In the site of Kongola (crop rotation), the experimental design was in completely randomized blocks consisting of four treatments: Control (To); Bio fertilizer (Myc); mineral fertilizer (EM); organic fertilizer (EO) with three replications.Two other sites were used and where fertilizers have been used for more than 5 years. At the Meskine site, the fertilizer used was mineral (Urea 46% and NPK 23-10-5) and in Pitoaré, organic manure (cow dung, chicken dropping) was used as fertilizer. Mycorrhizae used were *Glomus* sp and *Gigaspora* sp. Several diseases were identified. Fungal diseases such as the leaf gray spot (*Cercospora zeae*), corn leaf blight (*Helmintosporum turcicum*) and physoderma brown sport (*Physoderma maydis*) were observed during the two years in the organic manure plots in Pitoare site. One viral disease, maize streak, was observed in all plots with higher incidence and severity during the two years (100 and 50 respectively).The gray spot was not influenced the yield, whereas maize streak caused adecrease of yield when the infection attack was early.Corn leaf blight and physoderma brown spot were fungal diseases with highest incidence (more than 70%) during the two seasons. The highest yield was obtained in EO treatment (9.3 t/ha) at Pitoare in 2019 growing season and the lowest was obtained in the mycorhizal plot (1.05 tonnes/ha) in 2018. Fetilizers reduce development of maize diseases when there are used in rotational cropping system than in a continuous system than in continuous system.

Keywords: *Zea mays*, fertilizers, diseases, rotation, incidence, severity, yield.

INTRODUCTION

Corn (*Zea mays*) is one of the most widely grown cereals in the world. Consumed in different forms, corn plays an important role in the basic diet and generates income for certain populations (Rouanet, 1984; FAO, 1992; Nkongolo *et al*., 2016). The planted area and production of maizein the Far North of Cameroon were respectively

92290 ha and 141204 tonnes/ha in 2009 and 101501ha and 132405 tonnes/ha in 2011 (INS, 2015). The cultivated areas are thus in full expansion because of the demographic boom which causesa strong demand for this crop. However, yields are sometimes might not meet the demands due to various biotic factors such as parasiticplant, diseasesand pests (Picard, 1991; Teme *et al*., 1994; Kambire *et al*., 2010). Numerous projects have been implemented to improve the cultivation of corn some of which haveled to the creation of several resistant or early hybrid varieties such as the composite varieties. It has been reported that temperature variation due to climate change has an effect on the activation or inactivation of genes (Lepoivre, 2003). It is therefore important to carry out a field monitoning to determinethe behavior of resistant varieties with respect to pathogens. In addition, the yield reduction obtained is sometimes might be linked to the way in which the soil has been served is used or the use of non-quantified fertilizers, which are sometimes incorrectly dosed by farmers (Palti, 1981). The diseases encountered in the fields are caused by some cultural practices that maintain the development, proliferation or reduction of the pathogens responsible for these diseases, as well as on the parameters that govern the development of epidemics (Thurston, 1992; Tompkins *et al.*, 1992; Reid *et al*., 2001). Crop rotations, organic amendments and composting can affect the inoculum which is the primary source of disease infestation in the field (Thurston, 1992; Traore, 1997; Yaro *et al.*, 1997; Compaore *et al*., 2010). It was reported that maize plants fertilized with composted cattle manure displayed the lowest levels of gray leaf spot followed by poultry manure (Lyimo *et al*., 2012). On the other hand, the addition of certain mineral and organic fertilizers can lead to the rapid development of plants, making them more or less susceptible to attack by pathogens (Thresh, 1982; Nawal *et al*., 2014; Abiodun *et al*., 2015). Despite the knowledge about the relationship between fertilizer application and diseases expression, fertilizer application is adopted by farmers in Cameroon just to increase their crop yield thoughlittle information is available on the effect of this applied fertilizer on the incidence and severity of diseases of maize. Knowledge of host nutrition in relation to disease development provides a basis for modifying current agricultural practices to reduce disease incidence and severity. This research was undertaken to determine how maize diseases respond to chemical, organic and bio fertilizers in the locality of Maroua, Cameroon.

MATERIAL AND METHODS

Study sites

The field experiments were carried out at three locations; Kongola in the Maroua 3 subdivision (N10.65055, E014.40681). It was the main site that had been subject to rotation (the preceding crop was cowpea). The other two sites were located at Pitoaré (N10.59698, E014.30078) in the Maroua 1 subdivision where organic fertilizer was used, and Meskine (N10.54086, E014.25028) where chemical fertilizer was applied. These two fertilizers (organic and chemical) were applied to corn for more than five years continuously. The distance between sites was about 3 to 4 km.

Plant material

Plant material used was CMS 9015 maize variety, adapted to the Far North Region (IRAD, 2015).

Fertilizer types

The biological fertilizer used was, a mixture of two strains of mycorrhizal fungibelonging to the genera *Glomus* and *Gigaspora*. It was produced at the Nkolbisson biotechnology center of the University of Yaounde I, Cameroon (Nwaga, 2008).

The organic fertilizer used was a mixture of fowl droppings (1/3), cow dung (1/3) and droppings from goats and sheep (1/3).

The chemical fertilizer used was: NPK (23-10-5) and Urea 46%.

Experimental design

The experimental design at the main site (Kongola) was in completely randomized blocks. Three blocks with an area of 500 m^2 were separated by 1.5 m. Each block consisted of four plots (treatments) spaced by 1 m: (T0) control treatment that had received no fertilizer; (EM) chemical fertilizer treatment; (Myc) treatment withmycorrhizal fungi; (EO) treatment with organic fertilizers. The corn was sown at 80 × 40 cm spacings (density). The planting depth of the corn was about 1.5 cm with two seeds per pack, about 100 plants per treatment and 400 plants per block.

Application of treatments

One hundred grams (100 g) of mycorrhizal fungi were mixed with 250 ml of water and combined with 1 kg of seed to ensure adhesion of the fungal spores to the seeds. The application was made once (Ngonkeu, 2003; Benjelloun *et al*., 2004; Nwaga, 2008).

Two weeks after germination, NPK was applied at the recommended rate, 100 kg/ha. Urea was applied a month and a half after emergence, using a 50 kg bag for ¼ ha (Lambert *et al*., 1994).

The organic fertilizers were applied according to the dose recommended by the ISABU (Institute of Agronomic Sciences of Burundi) which is 15 to 20 tonnes/ha of manure. Application was made at the same time as chemical fertilizers (Bado *et al*., 1991).

Disease identification

The diseases were identified using several identification keys (Delassus *et al*., 1968; Cimmyt, 1978; Sere, 1990; Barbara *et al*., 2009). For viral diseases, the observation of typical symptoms was enough in the field since viruses cause some symptoms of their own such as mosaics (Traore *et al.*, 1996; Lepoivre, 2003). For fungal diseases, in addition to the symptoms observed in the fields, fungals spores were observed using an optical microscope (Omax) in the laboratory. Conidia were identified using identification keys (Cimmyt**,** 1978; Sere, 1990; Barbara *et al*., 2009). Two (2) methods were used, culture in a humid chamber and culture in a culture medium. Potato Dextrose Agar (PDA) and Water Agar (WA) were used. Indeed, conidia are more characteristic for identifying fungi (Sere, 1990; Lepoivre, 2003).

Observation of the fructifications (conidia) of phytopathogenic fungi

The samples were collected in the morning and taken to the laboratory. Once in the laboratory, the part of the organs showing symptoms was circumscribed and cut using a sterilized blade (with the Bunsen burner) in the laminar flow hood. The leaves were cleaned first withtap water and then in 70°C alcohol and 2% bleach for 3 min (Uaciquete, 2013). Then they were put in the culture media (WA, PDA) previously prepared. For humid room, a sterilized filter paper was placed at the bottom of the sterile Petri dishes. A few drops of sterile distilled water were added to maintain humidity, and then the diseased organs were introduced into the dishes. Part of the preparations was incubated on photoperiod 0/24h and the other part on photoperiod 12/12h. After four (4) to seven (7) days, the boxes weretaken out for the observation of sporulation.

Assessment of disease development in treatments

The incidence and severity of the diseases were assessed in the field 15, 30 and 45 days after sowing (DAS). Rainfall was assessed during the two planting seasonsusing a rain gauge.

Assessment of the incidence of the diseases observed

Incidence of diseases was evaluated using the following formula:

$$I = \frac{n \times 100}{N}$$ (Singh *et al.*, 2007)

Where I is disease incidence; n number of plants showing symptoms per plot; and N total number of plantin plot.

Assessment of the severity of the diseases observed

The severity of the disease was assessed by estimating the leaf area occupied by the symptoms of the disease using the following formula:

$$s = \frac{\Sigma a \times b}{N}$$ (Tchoumahov and Zaharova, 1990).

Where Σ is the sum of the products between the number of diseased plants (a) and the number of plants with the index given in % (b). N is the total number of plants in the plot.

The severity index used is as follows:

0 = no symptoms; 1 = 25% of diseased leaves; 2 = 50% of diseased leaves; 3 = 75% of diseased leaves; 4 = 100% diseased leaves. The number of diseased leaves per plantwas associated with this index.

Evaluation of agronomic parameters

Plant height was measured using a graduated ruler and a decameter.

The yield was evaluated in each treatment and perblock by estimating the number of the produced cobs and their weight using a balance.

Data analysis

Data collected were subjected to analysis of variance (ANOVA) and means were separated using the Duncan's multiple range test (5%). SPSS 16.0 software was used.

RESULTS

Diseases and pathogens identified in the different treatments

Fungal diseases

Many fungal diseases were identified during the 2018 and 2019 growing seasons (Figure 1).

Damping-off of seedlings: Damping-off of seedlings is the rot of seeds (grains) in the soil. It was manifested by a rapid death of the plants or seed before or after emergence.

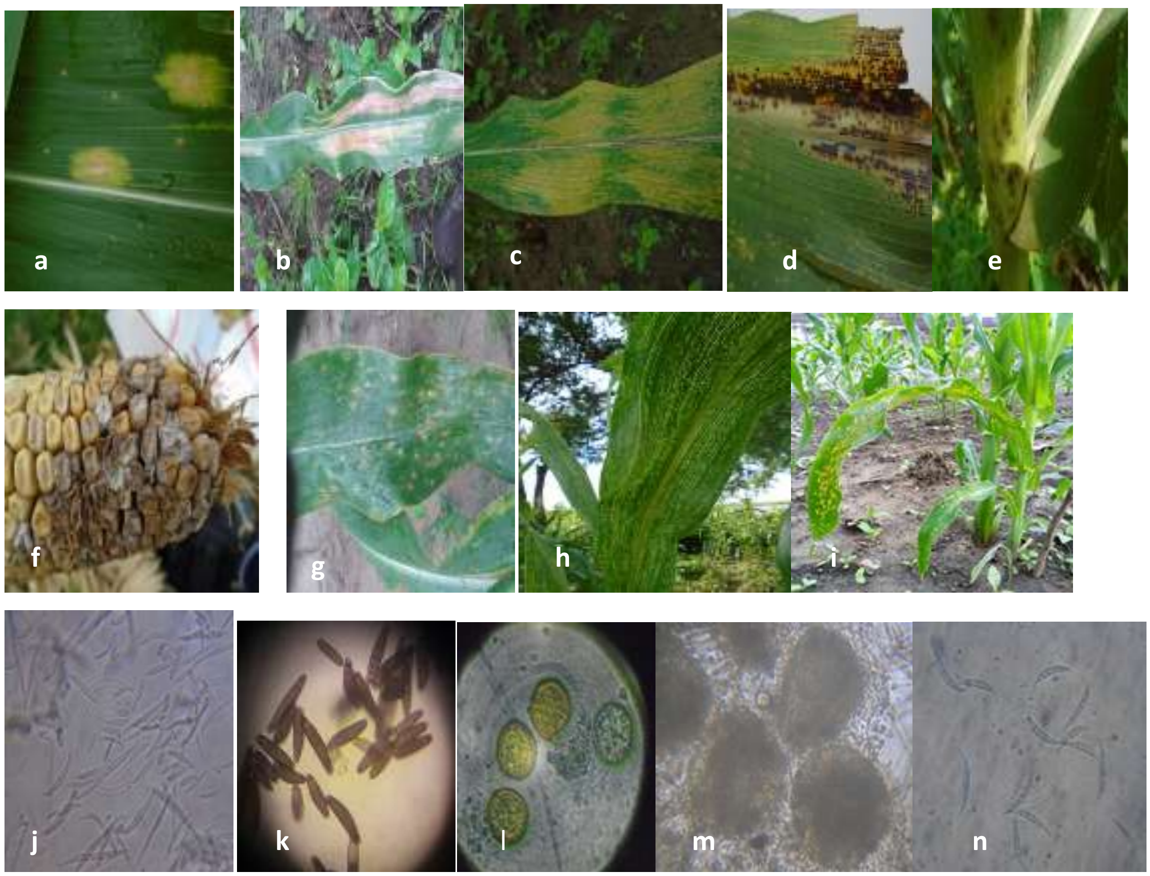

Figure 1. Symptoms and conidia of some diseases observed in the field during the two growing seasons: maize leaf blight (a andb); physoderma brown spot (c, d and e); fusarium ear rot (f); gray leaf spot (g); Leaf streak (h); unknown disease (i); conidia of *Cercospora zeae* (j); conidia of *Heminthosporium turcicum* (k); sporangia and sporangiophores of *Physoderma maydis* (l and m); conidia of *Fusarium graminearum* (n).

Microscopic observations did not permit formal identification of the fungi responsible for this disease. However, many fungi have been reported in the literature as responsible for damping-off: *Pythuim* sp, *Fusarium* spp, *Thielaviopsis basicola* and *Rhizoctonia solani.*

Leafgray spot: The leafgray spot attacks leaves. It is characterized bysmall round brown spots with a diameter of 2 to 4 mm anda round brown coloration at the tip and white on the inside (Figure 1 h). These spots get biggerover time.

Microscopic observation of the cultures revealed numerous more or less identical spindle-shaped conidia (Figure 1 j). These spores are attributed to the fungus *Cercosporazea maydis*.

Corn leaf blight: Corn leaf blight is characterized by burns or necrosis that appear on the leaves. Initially yellowish at the start (Figure 1a), they develop into large brownish spots arranged parallel to the central rib (Figure 1b).

Microscopic observations revealed numerous globose and septate spores (4 to 8 partitions) of elongated forms belonging to the fungus *Helminthosporium turcicum* (Figure 1 k).

Fusarium ear rot: This disease is characterized by the appearance of pink mold on maize cobs. The disease first appears on the tip of the corncob and then progresses to the inside (Figure 1 f).

The spores are numerous and of various sizes. These spores contain one to four partitions. On the other hand, no partition was observed on the small spores. These spores are characteristic of the *Fusarium graminicola* fungus (Figure 1 n).

Physoderma brown spot: Physoderma brown spot is a leaf and stem disease that attacks both the leaves and the stems. On the blade, a yellow coloration appears shortly before flowering on many leaves which gives a yellowish appearance to the aerial part (Figure 1 c). The symptoms develop on the central rib which turns black (Figure 1 d). These symptoms then develop on the stem as black spots (Figure 1 e).

Microscopic observation of the cultures showed the presence of numerous sporangiophores (Figure 1 m)

Table 1. Diseases occurrence according to the growing stages of maize.

Diseases	Germination	Growth	Flowering	Fruiting
Damping-off	▬			
Gray leaf spot		▬	▬	▬
Corn leaf blight		▬	▬	▬
Streak disease		▬	▬	▬
Physoderma brown spot		▬	▬	▬
Anthracnose*		▬	▬	▬
Fusarium earrot *				▬

*The disease appeared only in the second growing season.

within which are rounded sporangia (Figure 1 l) belonging to the fungus *Physoderma maydis.*

Viral diseases

Only one disease due to virus was identified during the two seasons.

Maize streak disease: It is characterized by the appearance of numerous pale yellow streaks about 30 cm on the leaves (Figure 1 h). The development of these streaks leads to their fusion forming irregularly interrupted lines and arranged parallel to the ribs. The appearance of these streaks could be early, in which case the size of the plant was very small. When late, the maize plants had a normal height. It is a viral disease caused by the *Maize Streak Virus* (MSV).

Unknown diseases

Many other symptoms were observed in the field. Three of them were attributed to diseases based on primary diagnostic rules such as the percentage of plants attacked and the evolution of symptoms. They were named as follows: Disease X (Figure 1 i), disease Y, and disease Z. These diseases are not listed in the identification keys used. In addition, after incubation of infected parts for several days and under different conditions 0/24 and 12/12, no fruiting bodies (spores) were observed. These symptoms are therefore may be not caused by fungi, but could be caused by other microorganisms such as bacteria, mycoplasmas or protozoa. The use of appropriate tools could reveal the causative agents. These diseases were observed only at the Meskine and Pitoaré sites.

Appearance of diseases according to the phenological stages of maize during 2018 and 2019 growing seasons

The appearance of different diseases on the maize crop at the different sites was appreciated in relation to the stages of disease development. Damping-off of seedlings is the only disease that appeared at germination. Five (5) diseases appeared during the growth of maize: physoderma brown spot, streak disease, leaf gray spot, corn leaf blight and anthracnose. Anthracnose was only present during the second growing season. These diseases were presented until harvest. Corn leaf blight appeared late in the first growing season, almost at flowering as well as the attack of the veins in physoderma brown spot. At fruiting, only one disease appeared, that is, Fusarium ear rot (Table 1).

Diseases occurrence persites and treatments

During the field trial, several diseases appeared at the different sites. Some diseases were not found in all sites. In Meskine, the diseases (6) inventoried were leaf spot, streak disease, corn leaf blight, physoderma brown spot, fusarium ear rot. In Kongola, the diseases identified were damping-off, leaf gray spot, streak disease, corn leaf blight. In Pitoaré, the diseases present were leaf gray spot, streak disease, corn leaf blight, physoderma brown spot and an unknown disease. Diseases were more prevalent in the plot with mineral fertilizer, with 6 occuringin the Meskine site and 4 in the Kongola plots. Fusarium ear rot and anthracnose were only present in one growing season, in 2018 and 2019 respectively (Table 2). Gray leaf spot was the only disease present at all sites and all treatments during the two growing seasons.

Evolution of diseases in treatments

Evolution of rainfall during the growing seasons

The rate of rainfall was higher in 2019 with 1124.5 mm of water against 866 mm in 2018 growing seasons respectively. The rainiest months were August and September during the 2018 campaign, respectively 264 and 116 mm of water. In 2019, the rainiest months were August, September and October with respectively 304.6,

Table 2. Number of diseases that occurred per site and treatments during the two growing seasons.

Sites	Treatments	Diseases occurence	Number
	Control	Corn leaf blight* - Leaf gray spot - Damping-off of seedlings	3
Kongola	Organic fertilizer	Corn leaf blight* - Leaf gray spot - Damping-off of seedlings	3
(Rotation)	Biofertilizer	Corn leaf blight* - Leaf gray spot - Damping-off of seedlings	3
	Mineral fertilizer	Corn leaf blight* - Leaf gray spot - Damping-off of seedlings – Streak disease	4
Pitoaré (No rotation)	Organic fertilizer	Leaf gray spot - Physoderma brown spot - Streak disease - Unknown disease - Corn leaf blight	5
Meskine (No rotation)	Mineral fertilizer	Leaf gray spot - Physoderma brown spot - Streak disease - Corn leaf blight - Anthracnose* - Fusarium ear rot*	6

*Diseases presented during one growing seasonin the treatment concerned.

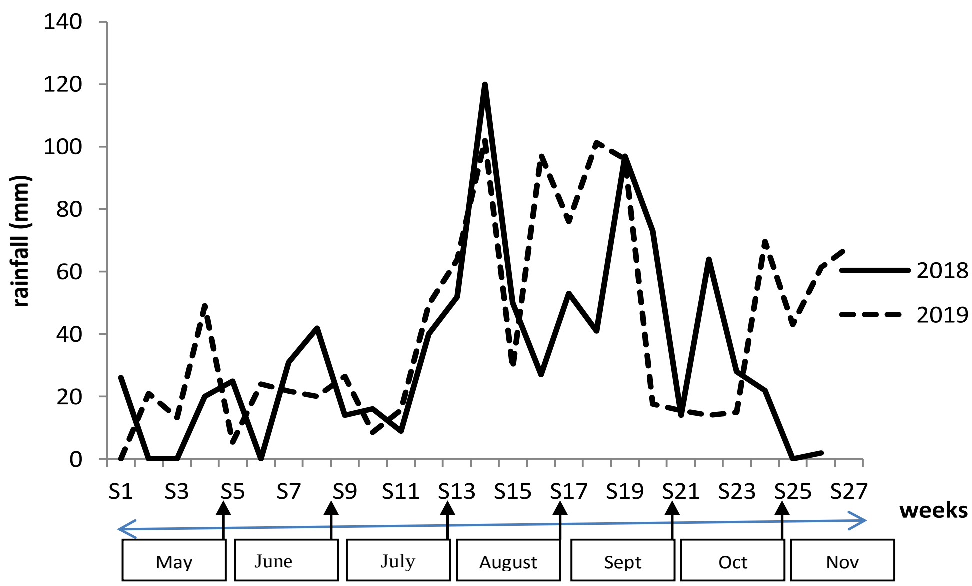

Figure 2. Evolution of rainfall during the 2018 and 2019 growing seasons.

230.5 and 141.8 mm of water (Figure 2).

Incidence of diseases during the two growing seasons

The statistical analysis performed within each treatment and for each disease revealed a significant difference (F = 1124.1; P = 0.0001). But, ANOVA did not show significant diference on effect of interaction year × treatments (P = 0.205). The incidence of leaf gray spot disease was higher during 2018 in all treatments; 100% in all sites. However, in the Meskine and Pitoare sites, this disease was more presented in 2019 with incidences of around 55.2 ± 0.1 and 65.3 ± 0.2% respectively. Streak and physoderma brown spot diseases were only present at the Meskine and Pitoare sites with incidences of 85 ± 0.1 and 52 ± 0.2% respectively at Meskine and 99 ± 0 and 82.2 ± 0, 8% in Pitoare in 2018. No significant (P > 0.05) difference was obtained with the year 2019. Corn leaf blight was less present at all sites. The highest incidences were obtained in organic and control treatments, being 46.6 ± 0 and 40 ± 0.2% respectively in 2019 growing season. Gay leaf spot, physoderma brown spot and streak maize diseases were the diseases with the highest incidence in non-rotation sites (Meskine and Pitoare) during the two growing seasons. Streak, anthracnose and physoderma brown spot diseases were practically absent at the Kongola site (Table 3).

Severity of diseases during 2018 and 2019 growing seasons

The severity of the gray spot was very high (almost 100%) in 2018. A significant difference (P < 0.05) was

Table 3. Average incidences (45 DAP) of different diseases in different treatments and sites during 2018 and 2019 growing seasons.

Sites	Treatment		LGS	CLB	PHY	STR	ANT
Kongola (rotation)	T	2018	100 ± 0 b	0 ± 0 a	0 ± 0	0 ± 0	0 ± 0
		2019	46.6 ± 0.8a	46.6 ± 0b	0 ± 0	0 ± 0	0 ± 0
	MYC	2018	100 ± 0 b	0 ± 0 a	0 ± 0	0 ± 0	0 ± 0
		2019	43.3 ± 0.6a	20.5 ± 0.2b	0 ± 0	0 ± 0	0 ± 0
	EO	2018	100 ± 0 b	2.1 ± 0.1a	0 ± 0	0 ± 0	0 ± 0
		2019	33.3 ± 0.1a	40 ± 0.2b	0 ± 0	0 ± 0	0 ± 0
	EM	2018	100 ± 0 b	0 ± 0a	0 ± 0	0.01 ± 0	0 ± 0
		2019	43.3 ± 0a	20 ± 0b	0 ± 0	00.2 ± 0	0 ± 0
Meskine	EM	2018	100 ± 0 b	25.3 ± 0.2b	52 ± 0.2a	85 ± 0.1b	0 ± 0a
		2019	55.2 ± 0.1a	20 ± 0a	49.5 ± 0.8a	65 ± 0.2a	0.1 ± 0a
Pitoare	EO	2018	100 ± 0 b	12.8 ± 0.2b	82.2 ± 0.8a	99 ± 0a	0 ± 0
		2019	65.3 ± 0.2 a	7 ± 0.1a	79.1 ± 0.5a	98 ± 0.1a	0 ± 0

The values in the same treatment, having the same letters are not significantly different at the 5% threshold according to Duncan. LGS: leaf gray spot; CLB: corn leaf blight; PHY: physoderma brown spot; STR: streak disease; ANT: anthracnose

obtained in the different treatments. Physoderma brown spot and streak disease were the most severe diseases with respectively 42.5 ± 0.5 and 55 ± 0.2% at Meskine and 86.1 ± 0.8 and 64.1 ± 1 % in Pitoarein2019. These three diseases were more severe in non-rotation sites (Meskine and Pitoare). Corn leaf blight showed the lowest severity rates (Table 4).

Average size of plants in the field

The stem height of maize plants were practically identical in the different treatments during the two growing seasons at the kongola site, 45 (day after planting), with no significant difference (F = 2.34; P = 0.167). Interaction year ×treament was not significant (P = 0.151). The height of the stem was 33.4 cm in the control and 45.7 cm in the plot that received the chemical fertilizer in 2018. However in the sites withoutrotation, a significant difference (P = 0.05) was obtained between the different height. The stem lengths were greater, respectively 65.9 and 65.06 cm at Meskine and Pitoare in 2019 (Figure 3).

Effect of fertilizers on the yield

The produced crop yield was higher in 2019 growing season at all sites and in all treatments. 2.05 t/ha were obtained in the control compared to 4.13 t/ha in the plots treated with mineral fertilizer. The highest yield was obtained at the Pitoare site with organic fertilizer, being at 9.3 t/ha. However in 2018 growing season, the produced yield was low. It varied from 1.05 t/ha in mycorrhizal plots to 3.63 t/ha in mineral fertilizer plots at the Kongola site. In non-rotation sites, the yields obtained were 2.02 t/ha at Pitoare compared to 3.6 t/ha at Meskine (Table 5).

DISCUSSION

The present work was aimed to identify and assessing the maize diseases in the field treated with mineral, organic and bio fertilizers, as well as the impact of fertilizers on plant growth and yield.

The listed diseases were fungal and viral diseases. One viral disease and six fungal diseases were identified in addition of unknown one. No bacterial disease was identified. This result is in agreement with that obtained by Barbara *et al.* (2009) and Reid *et al*. (2001) who identified fungal diseases such as helminthosporiasis in corn fields in South Africa.

A practically homogeneous distribution of gray spot disease was observed on all plants. The presence of gray spot disease in the various sites and treatments with incidences of around 100% could be linked to high pressure from the fungus responsible for the disease in the study areas. Ngoko (1993) highlighted the presence of gray spot disease in all agro-ecological zones of Cameroon. However, this result disagrees with that obtained by Lyimo *et al.* (2012) who showed that cattle and poultry manure reduced the levels of gray spot infestation.

Table 4. Average severity (45 DAS) of different diseases in different treatments and sites during 2018 and 2019 two growing seasons.

Sites	Treatment		LGS	CLB	PHY	STR	ANT
Kongola (rotation)	T	2018	100 ± 0b	0 ± 0 a	0 ± 0	0 ± 0	0 ± 0
		2019	14.1 ± 4.5a	42.6 ± 0.3b	0 ± 0	0 ± 0	0 ± 0
	MYC	2018	100 ± 0b	0 ± 0 a	0 ± 0	0 ± 0	0 ± 0
		2019	22.3 ± 6a	16.5 ± 0.5b	0 ± 0	0 ± 0	0 ± 0
	EO	2018	100 ± 0b	1.3 ± 0.1a	0 ± 0	0 ± 0	0 ± 0
		2019	23.3 ± 0.1a	7.6 ± 0.2b	0 ± 0	0 ± 0	0 ± 0
	EM	2018	100 ± 0b	0 ± 0a	0 ± 0	0.01 ± 0a	0 ± 0
		2019	14.2 ± 0.5a	16 ± 0.5b	0 ± 0	23.2 ± 0b	0 ± 0
Meskine	EM	2018	100 ± 0a	5.3 ± 0.2a	40 ± 0.1a	41 ± 0.1a	0 ± 0a
		2019	95.2 ± 3a	43 ± 0b	42.5 ± 0.5a	55 ± 0.2b	0.02 ± 0.2a
Pitoare	EO	2018	100 ± 0b	10.8 ± 0.2b	70.2 ± 0.5a	55.4 ± 0a	0 ± 0
		2019	81.3 ± 0.2a	5.2 ± 0.1a	86.1 ± 0.8b	64.1 ± 1b	0 ± 0

The values in the same treatment, having the same letters are not significantly different at the 5% threshold according to Duncan. LGS: leaf gray spot; CLB: corn leaf blight; PHY; physoderma brown spot; STR; streak disease; ANT; anthracnose

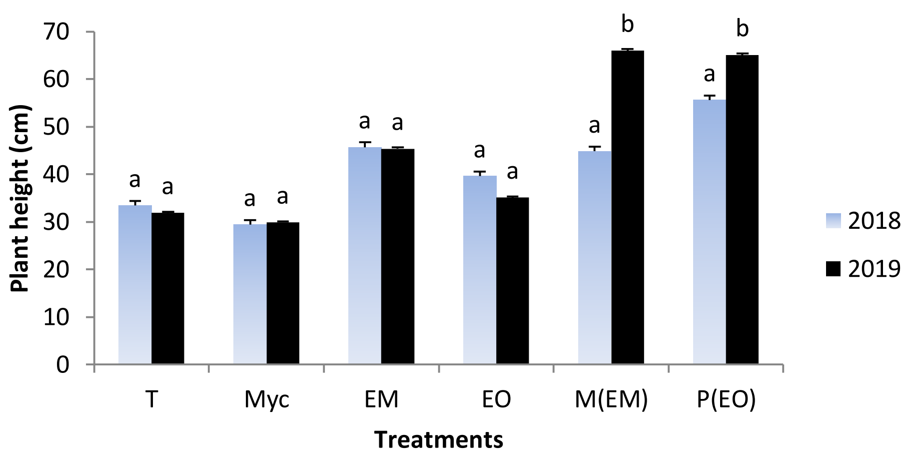

Figure 3. Maize plant height in the different treatments during the 2018 and 2019 growing seasons 45 days after sowing.

Streak disease can be explained by the presence in the area of a vector agent (insects). Indeed, in the Sahelian zone, insects are more abundant and are responsible for the transmission of many viral diseases such as streak disease. The same result was obtained by Traoré (1993), Konate and Traore (1993), Lamy *et al.* (1982) in Burkina Faso.

In the plot where organic fertilizer was used, the presence of diseases may be due to contamination of the manure by pathogens. This result is in agreement with those of Hachicha *et al*. (1992), Lepoivre (2003), and Compaore *et al.* (2010) who identified the presence of several pathogenic germs in organic waste and compost. In contrast, other authors such as Guene (1995), Charnay (2005) and Lyimo *et al*. (2012) found that composting allows partial or total elimination of pathogenic germs.

In the mycorrhizal plot, the high rate of the disease can be explained by the fact that the mycorrhizal fungi were not specific to the culture, or the fungi brought in found competition with native strains (Moser and Haselwandter, 1983; Schtiepp *et al.*, 1987; Fitter, 1991). However, it has been experimentally proven that plants inoculated with arbuscular mycorrhizal fungi are more resistant to attack

Table 5. Maize yield during 2018 and 2019 growing seasons (t/ha).

Sites	Treatments	2018	2019
Kongola (Rotation)	Control (T)	1.32	2,05
	Organic fertilizer (EO)	1.49	4.68
	Biofertilizer (Myc)	1.05	3.42
	Mineral fertilizer (EM)	3.63	4.13
Meskine (No rotation)	Mineral fertilizer (EM)	3.6	6.2
Pitoaré (No rotation)	Organic fertilizer (EO)	2.02	9.3

by pathogenic fungi and exposure to soil toxins (Dalpe, 2005; Oehl *et al*., 2011; Hamza, 2014).

Incidence and severity of the assessed diseases were high in the mineral fertilizer plots and those without rotation. Indeed, the contribution of NPK and Urea has a direct action in the penetration ofparasites. Olsen *et al.* (2003) have demonstrated the impact of N levels on wheat diseases. Blandino *et al.* (2008) demonstrated the influence of nitrogen fertilization on mycotoxin contamination of maize kernels. Linquist *et al.* (2008) showed impact of Nitrogen and potassium fertility on aggregate sheath spot disease and yields of rice. It is commonly thought that application of nitrogen fertilizer can increase disease severity via effects on crop canopy development. Thus, large canopies with high shoot densities may be more conducive to sporetransfer and pathogen infection than sparse canopies (Veresoglou *et al*., 2013). Resistance of plants can be influenced by the quality of mineral nutrition. Indeed mineral nutrition can be affected by the relationships between plants and pathogens indifferent ways either by acting on the host or on the parasite. Jensen and Munk (1997) have showed a reduction in the density of colonies and spores of *Erysiphe graminis* on wheat.

The produced yield was high in the plots that received organic and mineral fertilizers. This result corroborates that obtained by Segnou *et al.* (2012) on the mineral and organic nutrition of peppers. In addition, the heavy rains of 2019 may explain the high yields recorded during this growing season. On the other hand, the high incidence and severity of the observed diseases in the plots without rotation suggest that these diseases do not affect the yield. In the plots resulting from organic fertilizer rotation, the low yields obtained compared to those of plots without rotation can be explained by the slow degradation of the organic matter which does not provide all the mineral matter during the whole season.

CONCLUSION

This study showed that maize was attacked by several diseases in the field, including damping-off of seedlings, fusarium ear rot, corn leaf blight, physoderma brown spot, anthracnose, gray leaf spot and streak. The number of diseases was higher in plots that received organic and chemical fertilizers and in non-rotation sites. In these same sites, the incidence, severity and yields were higher during the two growing seasons. These diseases (gray leaf spots, streak disease and physoderma brown spot) seem to have no impact on the yield.

REFERENCES

Abiodun MO, Nafiu K, Osunlaja SO (2015). Different Rates of Urea as Nitrogen Fertilizer Affect Root and Stalk Rot diseases of maize in South West Nigeria. Int. J. Plant Soil Sci. 7(1):55-66.

INS (2015). Annuaire statistique du Cameroun. pp. 233-255.

Bado BV, Sedogo PM, Hien V, Lompo F (1991). Utilisation efficace des engrais azotés pour une augmentation de la production vivrière: l'expérience du Burkina. *In:* A.U.MOKUWNYE (Ed.) Alleviating Soil Fertility Constraints toIncreased Crop Production in West Africa, Kluwer Academie Publishers, Netherlands,pp. 115-123.

Barbara M, Korsman J, Frederik JK, Dave KB (2009). *Cercospora Zea* is thee causal agent of grey leaf spot disease of maize in southern Africa. Eur. J. plant pathol. 124:577-583.

Benjelloun S, Ghachouli NEL, Benbrahimk, Amrani JK, yamani JEL (2004). Influence de la mycorhization par le champignon glomus mossae sur la croissance et le metabolisme du maïs (*Zea mays*) sous les condition de stress hydrique. J. Catal. Mat. Env. 3:31-36.

Blandino M, Reyneri A, Vanara F (2008). Influence of nitrogen fertilization on mycotoxin contamination of maize kernels. Crop Protect. 27:222-30.

Cimmyt (1978). Maladies du mais, deuxieme edition, EL Batan, Mexico. p. 97.

Charnay F (2005). Compostage des déchets dansles Paysen Développement: elaboration d'une démarcheméthodologiquepouruneproductionpérennedecompost.Thèsede Doctorat, Université deLimoge (France). p. 448

Compaore E, Nanema LS, Bonkoungou S, Sedogo MP (2010). Évaluationde la qualité decompostsdedéchetsurbainssolidesdelavillede Bobo-Dioulasso, Burkina Faso pouruneutilisation efficienteen agriculture. J. Appl. Biosci. 33:2076-2083.

Dalpé Y (2005). Les mycorhizes: outil de protection des plantes mais non une panacée. Phytoprotection 865(1):53-59.

Delassus M (1968). Principales maladies du maïs dans l'Ouest-Cameroun. L'Agronomie Tropicale, 23(4):429-434.

FAO (1992). *Le système de stockage du maïs en milieu paysan béninois: bilan et perspectives,* par Y.-S. Fiagan. Rome. Chapitre 2:176.

Fitter AH (1991). Implication for functioning under natural conditions. Experientia 47(1991:350-355.

Guene O (1995). Compostageartisanalintégréàlagestiondesorduresménagères. Données deterrain et outils de diffusion, CREPA, Ouagadougou (BurkinaFaso), 68p.

Hachicha R, Hassen A, Jedidi N, Kallali H (1992). Optimal conditions for MSW composting, JWaste Recyc. 33(6):76-77.

Hamza N (2014). Application des mycorhizes arbusculaires en culture maraîchère cas de la pastèque (*Citrullus lanatus*) p. 83.

IRAD (2015). *Guide d'identification des insectes nuisibles et utiles dans la culture du maïs* InstitutdeRechercheAgricole pourle Développement, p. 115.

Jensen B, Munk L (1997). Nitrogen-induced changes in colony density and spore production of *Erysiphe graminis* f. sp. hordei on seedlings of six spring barley cultivars. Plant Pathol. 46:191-202.

Kambire H, Abdel-Rahman G, Bacye B, Dembele Y (2010). Modeling of Maize Yields in theSouth-Sudanian Zone of Burkina Faso - West Africa. American-Eurasian J. Agric. Environ. Sci. 7(2):195-201.

Konaté G, Traoré O (1992). « Les hôtes réservoirs du virus de la striure du maïs (MSV) en zone soudano-sahélienne: identification et distribution spatio-temporelle », Phytoprotection, 73(3):111-117.

Lambert J, Tremblay N, Hamel CH (1994). Nutrition minérale des plantescultivées. *In:* TAYEB AMEZIANE E.H.; PERSOONS E.; Biologie moderne: Basesphysiologiques et agronomiques de la production végétale. Hatier-AUPELF-UREF. pp. 269-292.

Lamy D, Fauquet C, Thouvenel JC (1982). Quelques viroses du maïs en Côte d'Ivoire » Agronomie Tropicale, 35(2):193-199.

Lepoivre P (2003). Phytopathologie.De loece, les presses agronomiques de Gembloux, p. 413.

Linquist BA, Byous E, Jones G (2008). Nitrogen and potassium fertility impacts on aggregate sheath spot disease and yields of rice. Plant Prod. Sci. 11:260-7.

Lyimo HJF, Pratt RC, Mnyuku RSOW (2012). Composted cattle and poultry manures provide excellent fertility and improved management of gray leaf spot in maize. Field Crop Res.126:97-103.

Nawal I, Abdellatif OC, Mohamed C, Jihane T, Amina OT, Rachid B, Allal D(2014). Effet de la fertilisation par différents niveaux de N P K sur le développement des maladies foliaires du riz J. Anim. Plant Sci. 23(1):3601-3625. **Olsen JE, Jorgensen LN, Petersen J, Mortensen JV (2003).** Effects of rates and timing of nitrogen fertilizer on disease control by fungicides in winter wheat. 2. Crop growth and disease development. J. Agric Sci. 140:15-29.

Ngoko Z (1994). Les maladies du maïs dans les hauts plateaux du Cameroun. IRA/ MINREST Yaoundé. p. 22.

Ngonkeu MEL (2003). Biodiversité et potentiel des champignons mycorhiziens à arbuscules de quelques zones agro écologiques du Cameroun. Thèse de Doctorat 3e, cycle Université de Yaoundé I. p. 258.

Nkongolo MM, Mutombo TJM, Cibanda MJ, Muka MP, MasenguTT, Tshibangu KG (2016). Contribution à l'étude de la gestion intégrée de la fertilité du sol pour la culture de maïs (Zea mays) dans la Région de Mbujimayi, RDC. J. Appl. Biosci. 99:9416-9422.

Nwaga D (2008). *Biofertilisants myco*, 4eme édition, fiche technique. Centre de Biotechnologie et de Faculté des Sciences, Université de Yaoundé I, p. 2.

Oehl F, Jansa J, Kurt I, Mader P, Heijden MV (2011). Champignons mycorhiziens arbusculaires, bio indicateurs dans les sols agricoles suisses. Recherche Agronomique, 2(7-8):303-310.

Palti J (1981). Cultural practices and infectious crop diseases. Berlin, Springer Verlag, p. 193-218.

Picard D (1991). *Physiologie et production du maïs*. Paris, Éditions Quae, pp. 115-123.

Reid LM, Zhu X, Ma BL (2001). Crop rotation and nitrogen effects on maize susceptibility to gibberella (*Fusarium graminearum*) ear rot, Plant Soil 237:1-14.

Rouanet G (1984). Le maïs: Le technicien d'Agriculture tropicale. Édition Maisonneuve et Larose, Paris, France, p. 142.

Schtiepp H, Dehn B, Sticher H (1987). Interaktionen zwis-chen VA-Mykorrhiza und Schwermetallbelastungen. Angew. Bot. 61:85-96.

Segnou J, Akoua A, Youmbi E, Njoya J (2012). Effet de la fertilisation minérale et organique sur le rendement en fruits du piment (*Camsicum annuum* L., Solanaceae) en zone forestière de Base Altitude du Cameroun. Agronomie Africaine 24(3):231-240.

Sere Y (1990). La striure et les autres maladies du maïs au Burkina Faso. In Lutte intégrée contre les ennemis des cultures vivrières dans le Sahel. Proceedings du séminaire international de lutte intégrée, 4-9 Janvier 1990. Institut du Sahel, Bamako, Mali, pp. 276-284.

Singh G, Chen W, Rubiales D, Moore K, Sharma YR, Gan Y (2007). Diseases and their management. In: Yadav S, Redden B, Chen W, Sharma B (eds) Chickpea breeding and management. CAB International, Wallingford, pp. 497-519.

Tchoumakov AE, Zaharova (1990). Influence et statistique du développement des maladies. In: Dommage causé par les maladies aux cultures agricoles. Edition Agroprome, Moscou, pp. 5-60.

Teme B, Sanogo O, Boughton D (1994). « Le maïs dans les systèmes de production du sud du Mali: historique et perspectives ». Dans *Productionet valorisation du maïs à l'échelon villageois en Afrique de l'Ouest*; Actes du séminaire "Maïs prospère" 25-28 janvier 1994, Cotonou, Bénin/Centre de Coopération Internationale en Recherche Agronomique pour le Développement, Montpellier (France); Université Nationale du Bénin, Cotonou (Bénin). Faculté des Sciences Agronomiques, pp. 173-179.

Thresh J 1982). Cropping practices and virus spread. Annu. Rev. Phytopathol. 20:193-218.

Thurston HD (1992). Sustainable practices for plant diseases management in traditional farming systems New Delhi, Westvew Press& Oxford&IBH Publishing Co.Pvt.Ltd.

Traore NS (1997). Etude bioécologique des Cicadelles du genre *Cicadulina (Homoptera Cicadellidae),* vectrices de la striure du maïs au Burkina Faso. Implication épidémiologique. Thèse de doctorat d'Etat, Université de Cocody, Abidjan, Cote d'Ivoire, p. 248.

Traore O (1993). Épidémiologie de la striure du Maïs en zone soudano-sahélienne: cas du.

Burkina Faso. Thèse de Doctorat, université de Ouagadougou, Burkina Faso, p. 116.

Traore S, Leclant F, Ouedraogo I, Dabiret R (1996). Inventaire, distribution géographique et capacité intrinsèque de Cicadulina spp. (Homoptera: Auchenorrynques: Cicadellidae) à transmettre le virus de la striure du maïs au Burkina Faso. Ann. Univ.de Ouagadougou, Series B, vol IV, p. 24.

Tompkins DK, Wright AT, Fowler DB (1992). Foliar disease development in no-till winter wheat: influence of agronomic practices on powdery mildew development. Can. J. Plant Sci. 72:965-972.

Uaciquete A (2013). Charactérization, epidemiology and control strategies for the anthracnose pathogène (*Colletotrichum* spp.) on cashew (*Anacardium occidentale* L.) in Mozambique.Thèse de Doctorat, Université de Pretoria p. 93.

Yaro DT, Iwuafor ENO, Chude VO, Tarfa BD (1997). Use of organique manure and inorganique fertilizer in maize production: A field evaluation. In strategy for sustainable maize production in west and central Africa, pp. 237-239.