INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 18, No. 1, p. 82-92, 2021

RESEARCH PAPER OPEN ACCESS

Influence of fertilizers on incidence and severity of early blight and late blight potato diseases under field condition

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Key words: *Solanum tuberosum*, Fertilizers, Late blight, Early blight, AUDPC, AUDSIPC.

http://dx.doi.org/10.12692/ijb/18.1.82-92 Article published on January 20, 2021

Abstract

The potato (*Solanum tuberosum*) production in the Far North Region, Cameroon is confronted with, diseases and pests. To improve the production of this plant, a study was carried out in Mouvou and Gouria to evaluate the impact of fertilizers on the development of late blight and early blight diseases of this plant. The experimental design used was a completely randomized block with 4 treatments: Mycorrhizae (MYC), NPK (20-10-10) chemical fertilizers, chicken droppings (CD) and a control (T). The plant material used was a local variety of potato (Dosa). Disease incidence and severity and rainfall were evaluated. Area Under Disease Progress Curve was calculated. At 60 DAS, mean incidences recorded for fertilizers were 5.7, 3.6, 1.8 and 0.8 % respectively for control, MYC, NPK and CD. In general, early blight severity decreased from 22.1% at 45 DAS to 0.3 % at 60 DAS. The highest AUDPC value of late blight at Mouvou site was observed in NPK treatment while potato in CD treatment had the lowest. The lowest AUDPC value of early blight was observed in CD treatment at both sites. AUDSIPC value for late blight was significantly higher in NPK treatment in both sites. The highest value of AUDPSIC of early blight was recorded in MYC treatment, 45 DAS in both sites. The average rainfall was higher in the Gouria site (716.5mm) than in Mouvou site (679 mm). The CD treatment can be recommended to the farmers for the phytosanitary protection of potatoes.

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Introduction

The potato (*Solanum tuberosum* L.) is an important food in many countries and is in the fourth place after the wheat, rice and corn crops. It is therefore the main non-cereal foodstuff in the world (FAO, 2013).World production was estimated at more than 368 million tonnes on 19.4 million hectares in 2013 (Issa *et al.*, 2017).

Originally from the highlands of Peru (Spooner *et al.*, 2005), it was introduced to Africa during the colonial period (1884-1914). In Cameroon, potato is cultivated in areas of high altitudes, especially by small farmers (IRAD, 2012). Six of the ten regions are concerned, the North-West, the South-West, the West, Adamawa, the Littoral and the Far -North (Fontem *et al.*, 2004). It constitutes a basic food for the populations of these regions and an important source of income because part of the production is either sold in the local market or exported to the neighboring countries. National production was estimated at 229 000 tonnes over 23 500 hectares in 2009 (IRAD, 2012). Thus, despite the importance of the potato in the national economy, total production remains below, yields are generally low (Njualem *et al.*, 2001; Diop *et al.*, 2019) and are between 3 and 11tonnes per hectare, while those of European countries are on average 25 tonnes per hectare ha and reach 60 tonnes per hectare (Sayed *et al.* 2015).

In the Far North Cameroon Region, particularly in the Mogodé subdivision (Mayo-Tsanaga), the only and main production area, the low yields observed are associated with poor peasant farming practices (Ngoyi *et al.*, 2020), the scarcity or inequality of the rains and especially to diseases and pests.

Many diseases have been reported on potatoes in several countries (Alkher *et al.*, 2015; Son *et al.*, 2018) and in Cameroon (Fontem 2003; Fontem *et al.*, 2004; Lontsi *et al.*, 2019). Brown rot and Bacterial wilt (*Ralstonia solanacearum*) of potato are the major bacterial diseases in potato production area (Kong *et al.*, 2016; Charkowski, 2020). Whereas more than 50 different viruses and one viroid have been reported infecting potatoes worldwide only a handful of them cause major losses (10–40 %) globally (Chiunga and Valkonen, 2013). Late blight (*Phytophthora infestans*) and Alternaria or early blight (*Alternaria* spp) appear to be the major fungi diseases threatening the production of potato in the world with more than 80% of losses (Ah-Fong *et al.*, 2017; Abuley and Nielsen 2017).

Several solutions have been proposed to overcome these diseases production constraints and increase yield These include the use of varieties with high potential production, resistance to diseases and adaptation to the agro-ecological zone (IRAD, 2012) and the use of chemical fertilizers by farmers. However, these fertilizers when there are within the reach of farmers, there is a lack of control over their use.

This practice can disrupt the environmental balance. On the other hand, diseases encountered in the fields are caused by some cultural practices that enhance the development, proliferation, or reduction of the pathogens responsible for diseases, as well as epidemiological parameters (Thurston, 1992; Tompkins *et al.*, 1992; Reid *et al.*, 2004). Organic amendments and composting can affect the inoculum which is the primary source of disease infestation in the field (Thurston, 1992).

Otherwise, 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; Abiodum *et al.*, 2015). Despite the knowledge about the relationship between fertilizer application and disease expression, fertilizer application is adopted by farmers in Cameroon just to increase their crop yield. But, little information is available on the effect of this applied fertilizer on the incidence and severity of diseases of potato. Knowledge of host nutrition concerning disease development provides a basis for modifying current agricultural practices to reduce disease incidence and severity (Lepoivre, 2003).

It is necessary to implement strategies aimed at improving agricultural production that is based on the respect of ecological, economic and toxicological functionalities in the context of food security and environmental protection. Hence bio fertilization by mycorrhizae is more resistant to pathogenic bacterial and fungi attacks and exposure to soil toxins (Moser and Haselwandter, 1983; Ngonkeu, 2003; Gnamkoulamba *et al.*, 2018). Organic fertilization by the use of chicken droppings that provide more mineral elements (potassium) improves plant resistance to pathogens and environmental balance. Therefore, this study was carried out to evaluate the influence of fertilizers (mycorrhizae and chicken droppings) on the development of potato late blight and early blight diseases in the district of Mogodé (Mayo-Tsanaga) Far-North, Cameroon.

Materials and methods

Plant material and fertilizers

The plant material used for this trial was a local variety of potato (Dosa), round in shape with white skin and flowers. Its cycle of development is three (3) months. The biological fertilizer (mycorrhizal inoculum) used was a mixture of two strains of mycorrhizal fungi belonging to the genera *Glomus* sp. and *Gigaspora* sp. It was produced and provided at the Nkolbisson Biotechnology Center of the University of Yaounde I (Nwaga, 2008).The organic manure used was chicken droppings from the Teufack Poultry Farm in Mokolo.The chemical fertilizer was NPK (20-10-10), purchased in the local market.

Experimental design

The experimental design was in completely randomized blocks (03). Each block consisted of 4 treatment or plots units.

The treatments were Mycorrhizae (MYC), chemical fertilizer (NPK), Chicken droppings (CD), and control (T). Each site receiveda total of 60 plants per plot. i.e180 plants per block and 420 plants per site.In total, almost 840 seeds of potatoes were monitored for the trial at the two sites. The plots were separated by 1m. Each site had an area of 525 m².

Application of treatments and sowing

The sowing was direct according to the spacings of 80 cm between the rows and 25 cm between the pockets. Each pocket received one (1) pre-germinated tuber. The sowing depth was approximately 5 cm.Ten (10) grams of mycorrhizal inoculum were applied with the tubers, per plot at the time of sowing. The application was made once (Ngonkeu, 2003; Benjelloun *et al.*, 2004).For the treatment of chicken droppings (CD), 200 g were taken and applied per bunch at sowingTwenty (20 g) of NPK was applied per bunch 15- 30 days after sowing.The application was made once. The control treatment (T) did not receive any application during the entire study.

Evaluation of the effect of treatments on the development of diseases

Incidence and severity were measured to assess the development of the diseases identified in the treatments. Leaves were removed after counting. Environmental parameters were quantified by monitoring rainfall at both sites.

Assessment of incidence of late and early blight

Incidence of diseases was scored, 15, 30, 45 and 60 DAS, using the formula: $\boldsymbol{I}(\%) = \frac{n}{N} \times 100$

where I is incidence; n number of plants showing symptoms per plot; and N total numbers of the plant in the plot.

Assessment of severity of late and early blight

The severity of the disease was 15, 30, 45 and 60 DAS, by estimating the leaf area occupied by the symptoms of the disease using the formula:

$$Sévérité = \frac{\sum n \text{ X } I}{N} \times 100$$

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 was used as an estimation scale: 0=no symptoms; 1/4 of the diseased leaf corresponds to 25%; 2/4=50% of the attacked leaf; 3/4=75% and 4/4=100% of the diseased leaves. The number of disease leaves per plant was associated with this index.

The area under the disease progress curve

The areas of disease progression were calculated using the incidence and disease severity index. Thus, the area under the disease progress curve (AUDPC) for disease incidence was calculated using the formula described by Muengula-Manyi *et al.* (2013) and Kone *et al.* (2017):

$$\text{AUDPC} = \Sigma_{i=n}^{n}(X1 + X\,(n+1)/2(t).$$

Xi is the incidence of disease at the time i, Xi + 1 is disease incidence recorded at the time i + 1, n, the number of registration on the incidence, and t, days between the registration of Xi and Xi + 1.

The Area under severity index progress curve (AUSIPC) for disease severity was calculated using the formula described by Shaner and Finney (1977) as below:

$$\text{AUDSIPC} = \Sigma_{n}^{n-1}(DS1 + DS2)\,/2) \times (t2 - t1).$$

where DS1 is disease severity recorded in time 1 and DS2 the disease severity recorded in time 2.

Quantification of the environment

The evaluation of rainfall provides information on the degree of precipitation that can influence the state of crop planting and the evolution of the disease. The data were collected using two rain gauges installed in the middle of the fields in Mouvou and Gouria.

Data analysis

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

Results

Evolution of rainfall in the two study sites

Rainfall was ranged from 0 mm (week 1 of June) to 1620 mm (week 2 of September) at the Mouvou site with a peak of 1620 mm observed in the second week of September and from 0 mm (week 1 of June) to 1800 mm (week 1 of September) with a peak of 1800 mm observed in the first week of September at the Gouria site. Average rainfall was higher at the Gouria site (716.5mm) than in Mouvou site, which received (679 mm) (Fig.1).

Incidence of both diseases

The field evaluation on the effect of fertilizers on the mean incidence of late blight and early blight diseases at different growth stages showed interesting results (Table 1). ANOVA showed significant difference among the fertilizers in terms of mean disease incidence at 45 DAS ($P = 0.036$) and60 DAS ($P < 0.001$) for early blight and 30 DAS ($P < 0.05$) ; 45 DAS ($P=0.03$) and 60 DAS ($P < 0.001$) for late blight. Symptoms of early blight occurred,first 45 DAS while symptoms of late blight occurred 30 DAS.

Table 1. Mean disease incidence in two sites at different growth stages.

		15DAS				30DAS				45DAS				60DAS			
Disease	Site	T	MYC	NPK	CD	T	MYC	NPK	CD	T	MYC	NPK	CD	T	MYC	NPK	CD
	Mouvou	0	0	0	0	0	0	0	0	5.5	19.4	13.1	0.5	7.2	1.1	3.2	0.5
	GOuria	0	0	0	0	0	0	0	0	18.3	37.2	32.8	3.2	4.3	6.1	0.5	1.1
Early blight	Mean	0	0	0	0	0	0	0	0	11.9b	28.3d	22.9c	1.8a	5.7d	3.6c	1.8b	08a
	Mouvou	0	0	0	0	8.3	13.8	20	2.8	12.7	12.7	12.7	0	1.1	0	5.5	0
	Gouria	0	0	0	0	4.6	5.5	7,9	3.9	10.5	18.9	23.4	34.5	11.5	22.9	23.1	26.8
Late blight	Mean	0	0	0	0	6.4b	9.6c	13.9d	3.3a	11.6a	15.8b	18d	17.2c	6.3a	11.5b	14.3dc	13.4c

Means in the same row within a growth stage bearing the same letters are not significantly different by Duncan test at 5% level of probability. T control, MYC mychorrizae, NPK chemical fertilizers, CD chicken dropping. DAS: day after sowing.

Early blight disease incidence reduced with the growth stage. At the final growth stage (60 DAS), mean incidences recorded for fertilizers were 5.7, 3.6, 1.8 and 0.8% respectively for control, MYC, NPK and CD. CD treatment showsthe lowest incidence while NPK and MYC showed the higher. Late blight disease incidence increased with the growth stage. At the 60 DAS, no significant difference was observed among CD (13.4 %) and NPK (14.3 %) treatments (Table 1).

The severity of both diseases

The mean disease severity recorded for the different fertilizers was significantly different at, 30, 45 and 60 DAS. In general, early blight severity decreased from 22.1% at 45 DAS to 0.3 % at 60 DAS. At the end of the observations (60DAS), the variation of disease severity showed the highest value of 24.8 % that was recorded in a plot with MYC treatment whereas the lowest value of 4.8 % was recorded in control followed by CD (7.5%) and NPK (7.2%) treatments.

The severity of late blight was low during the growth stage in CD treatments, 4.3, 0.2 and 9.1 respectively at 30, 45 and 60 DAS (Table 2)0

Table 2. Mean disease severity in two sites at different growth stages.

		15DAS				30DAS				45DAS				60DAS			
Disease	Site	T	MYC	NPK	CD	T	MYC	NPK	CD	T	MYC	NPK	CD	T	MYC	NPK	CD
	Mouvou	0	0	0	0	0	0	0	0	12.3	9.9	11.1	8.3	9.4	32.2	13.9	2.5
	Gouria	0	0	0	0	0	0	0	0	22.1	20.7	21	16.5	0.3	17.4	0.5	12.5
Early ight	Mean	0	0	0	0	0	0	0	0	17.7c	15.3b	16.0b	12.4a	4.8a	24.8c	7.2b	7.5b
	Mouvou	0	0	0	0	16.6	22.8	28.3	8.2	21.4	24	22.7	0	10	0	10	0
	Gouria	0	0	0	0	16.6	12	24	0.5	31.5	22	19	0.5	0.7	0.8	25	18.3
Late light	Mean	0	0	0	0	16.6b	17.4b	26.1c	4.3a	26.4dc	23bc	20.9b	0.2a	5.3b	0.4a	22.5d	9.1c

Means in the same row within a growth stage bearing the same letters are not significantly different by Duncan test at 5% level of probability. T control, MYC mychorrizae, NPK chemical fertilizers, CD chicken dropping. DAS: day after sowing.

Areas under disease progress curve using incidence for both diseases

ANOVA for the AUDPC values based on disease incidence of late blight showed a significant difference (P=0,001) among the treatments (Fig.2). At 45 and 60 DAS, a significant difference was observed among treatments. (P = 0,009 and P=0,001respectively).The highest AUDPC value of late blight at Mouvou site was observed in NPK treatment whilepotato in CD treatment had the lowest value of AUDPC. But at the Gouria site, the highest value of AUDPC was observed in CD treatment from 30 DAS while the control had the lowest. In both sites, incidence (AUDPC) was higher in NPK and Myc treatments (Fig.2).ANOVA for the AUDPC values based on disease incidence of early blight showed a significant difference (P=0,004) among the treatments (Fig.2). The incidence (AUDPC) of early blight was higher in CD and NPK treatments in Mouvou sites as well as Gouria sites. The lowest AUDPC value of early blight at Mouvou site and Gouria site was observed in CD treatment. But at the Gouria site, the highest value of AUDPC was observed in CD treatment from 30 DAS while the control had the lowest. In both sites, incidence (AUDPC) was higher in NPK and Myc treatments (Fig.2).

Areas under severity index progress curve

The total amount of disease that occurred on potato growing in different plots with different fertilizers was calculated and expressed as the AUDSIPC as shown in Fig.3.ANOVA showed a significant difference among the treatments (P = 0.014). AUDSIPC value for late blight was significantly higher in NPKtreatments in both sites while in CD treatment severity was lowest.A significant difference was observed among treatments with AUDSIPC of early blight. The highest value of AUDPSIC was recorded in MYC treatment, 45 DAS in both sites. Severity was lowest in Mouvou with CD treatment. No significant difference (P=0.39) was observed among treatments, 30 DAS at Gouria site (Fig.3).

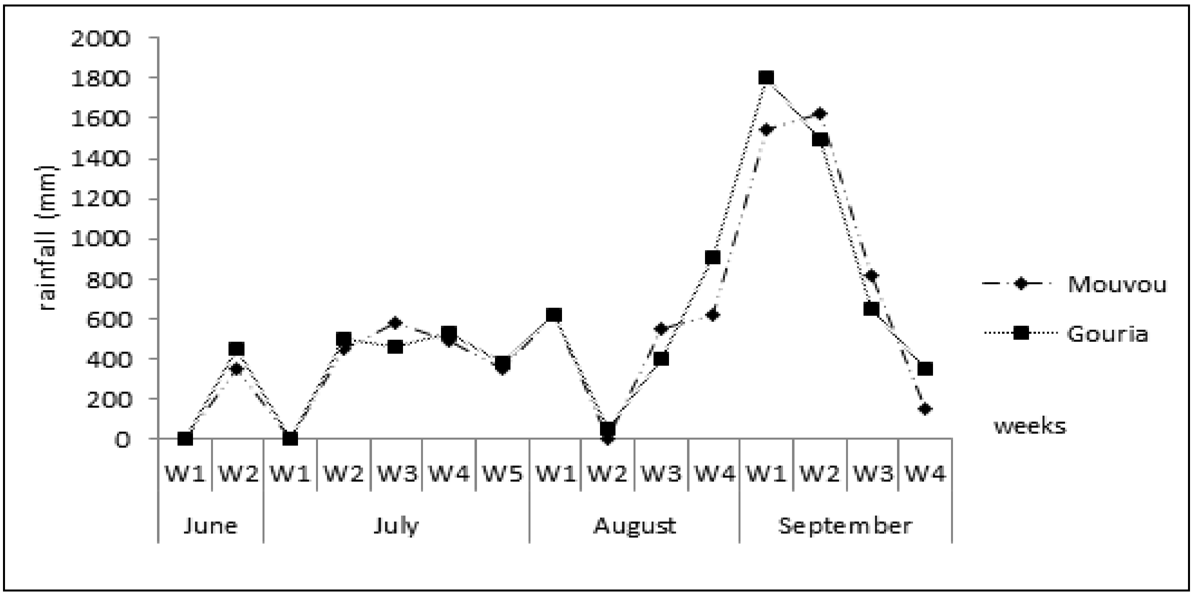

Fig. 1. Evolution of rainfall in the two study sites.

Discussion

This study demonstrated the susceptibility of potato to fungal (late blight and early blight) infections when used with somefertilizers in this field experiments. The incidences in all treatments occurred almost 15 DAS. Assuming that symptoms already occur two weeks after infection, this means that fungal transmission must have taken place already when seedlings were just one week old. These attacks occurred after germination, and mainly during the phases of vegetative growth, flowering, fruiting-maturation and harvesting. Mulger and Turkensteen, (2005) and Chiunga and Valkonen (2013) have shown that the vegetative propagation mode per tuber favours a greater spread of pathogens than by seed multiplication and it is not rare for a tuber to harbour several pathogens.

The almost homogeneous distribution of fungal diseases under all treatments in the two sites is explained by the fact that both sites are located in the same agro-ecological zone (Sudano-Sahelian zone), and therefore, there is the presence of similar vector agents responsible for the transmission of dissemination in the zone. Otherwise, potato is always cultivated in Mogode every year, so that, so that spores of fungal *Phytophthora infestans* (late blight) and *Alternaria solani* and *Alternaria alternata* are in the soil. Ngoh Dooh *et al.* (2020) have shown that late blight and early blight are the diseases with the highest incidence, and present in all sites of the main production area (Mogode) in Far North Cameroon. Fontem *et al.* (2004) have shown that Crop Sanitation can affect Late Blight Severity and Tomato Yields in Cameroon.

The absorption of nutrients by the roots of the plant is generally accompanied by direct penetration of pathogens into the plant, which may justify the presence and highest AUDPC of the diseases at the sites.Litschmann *et al.* (2020) have proved that some parameters of climate (temperature, rainfall…) can influence, development of late blight in the field.

The treatments applied influenced the development of the early blight and late blight identified in the two study sites. The AUDPC was lowest in the CD treatments in almost both sites.

This result can be explained by the effectiveness of the chicken droppings which provided more mineral elements (e.g. potassium) that improved plant resistance to pathogens and reduced both soil and leaf pathogens. These results are in agreement with those of Shaner and Finney (1977) who have shown that many minerals like phosphorus and potassium can enhance the resistance of plants in the field. On contrary, higher AUDPC obtained in NPK treatment with both diseases can explain the fact thatunder- or over-fertilization of nitrogen is detrimental to crop productivity. In underdose, it does not allow the plant to have optimal growth. In over-dose it will favour over-abundant foliage which will be favourable to the development of diseases and will delay maturity and harvest. Nitrogen remains nevertheless essential to ensure good growth (Issa *et al.*, 2017 ; Son *et al.*, 2018 ; Kariuku *et al.*, 2020).

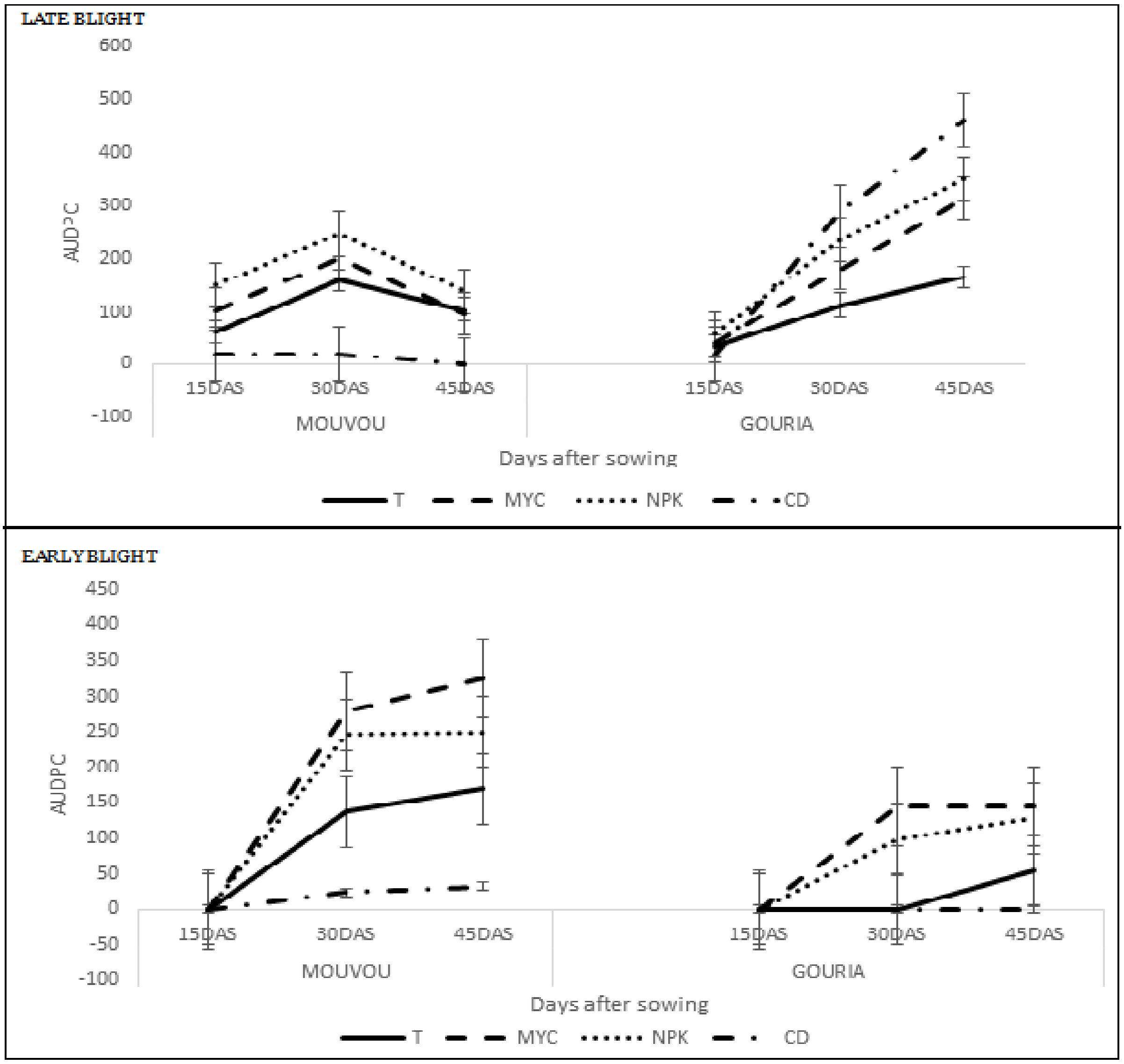

Fig. 2. The area under disease progress curve using disease incidence of early and late blight of potato growing in plots with fertilizers (NPK, MYC, CD and control) in two sites (Mouvou and Gouria).

On the order hand, a potash deficiency will have a direct impact on the maintenance of cell turgidity and thus the regulation of water in the plant. Potash will also be essential for the quality of tuberization. Finally, it will enable the plant to increase its natural resistance, particularly against frost, disease and drought (Reid *et al.*, 2004). AUDSIPC was highest in MYC and NPK treatments. The Efficacity of Mychorrizae has been proved with earth-born diseases than with airborne diseases. it has been experimentally proven that plants inoculated with arbuscular mycorrhizal fungi are more resistant to attack by pathogenic fungi and exposure to soil toxins (Ngonkeu, 2003; Issa *et al.*, 2017; Gnamkoulamba *et al.*, 2018). On the other hand, the mycorrhizal fungi were, perhaps not specific to the potato, or the fungi brought in found competition with native strains (Moser and Haselwandter, 1983). Veresogloua *et al.*

(2013) have shown that fertilization affects the severity of diseases caused by fungal plant pathogens. AUDSIPC of both two diseases was higher in Mouvou as well as Gouria despite the highest rainfall recorded in Gouria than in Mouvou. Rainfall is very important in the spread of fungal diseases.

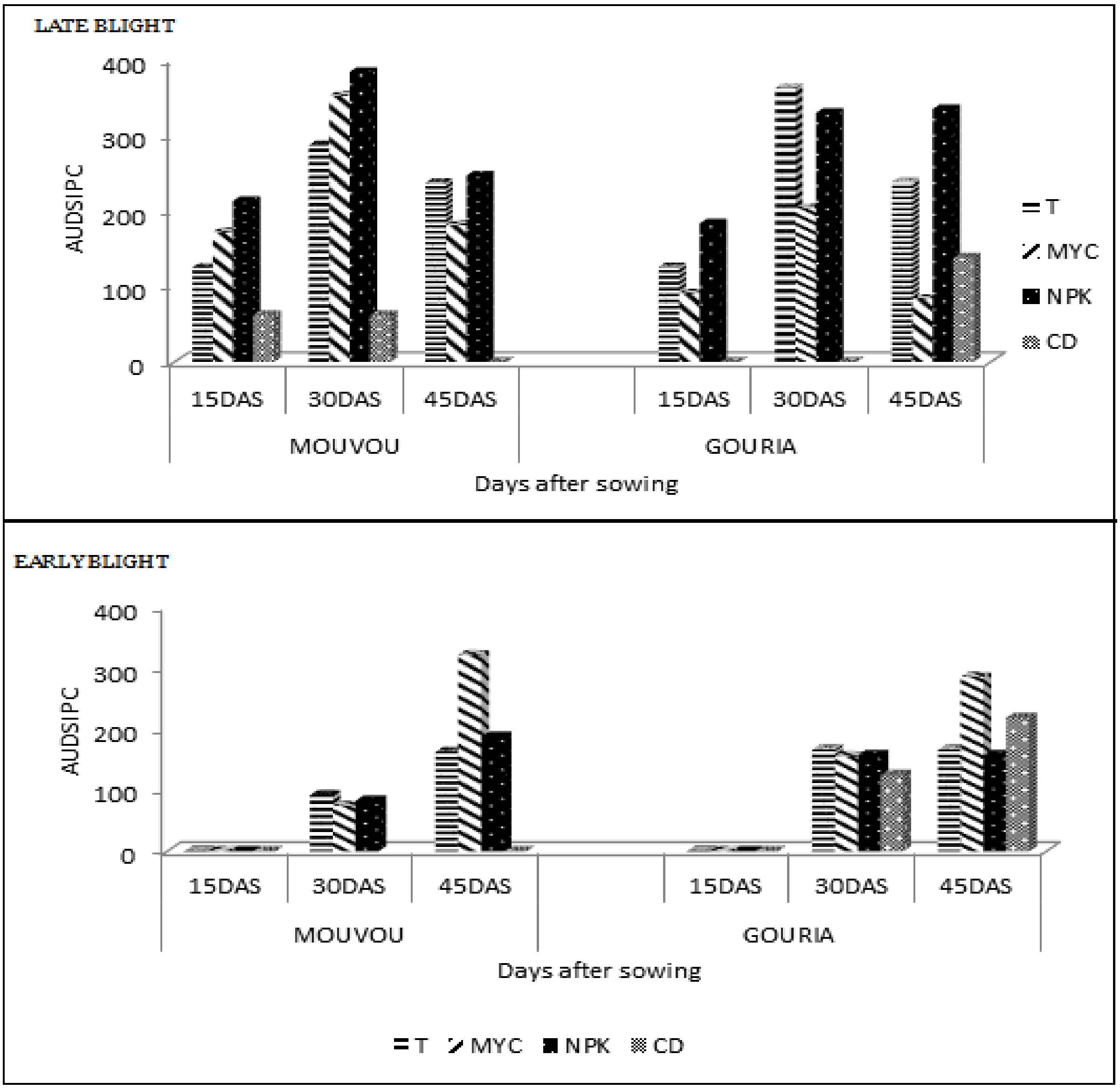

Fig. 3. The area under disease severity index progress curve using disease severities of early and late blight of potato growing in plots with fertilizers (NPK, MYC, CD and control) in two sites (Mouvou and Gouria).

Conclusion

The AUDPC and AUDSIPC of late blight and early blight diseases were lowest in the CD treatment and Highest in NPK and MYC treatments. The CD treatment proved to be the most beneficial in terms of potato phytosanitary protection.

Conflict of interest

The authors declare that they have no conflict of interest.

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