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# OCCURRENCE AND DISTRIBUTION OF DAMPING-OFF IN *Vigna subterranea* IN BENIN AND IDENTIFICATION OF ASSOCIATED CAUSAL AGENTS

L.D.R. BOSSOU [1,2], A. ADANDONON [2,3], C.M. ZOUNDJI [1,2,3], T.M. AKPLO [1],
B.H. HOUNGNANDAN [4] and P. HOUNGNANDAN [1,2,3]

[1]Laboratoire de Microbiologie des Sols et d'Ecologie Microbienne, Faculté des Sciences Agronomiques de l'Université d'Abomey-Calavi; 01 BP 526 Recette Principale, Cotonou, Benin
[2]Laboratoire de Sciences Végétale, Horticole et Forestière, Ecole doctorale des Sciences
[3]Agronomiques et de l'Eau, Université Nationale d'Agriculture de Porto-Novo; BP : 43, Kétou, Benin
[4]Ecole de Gestion et de Production Végétale et Semencière, Université Nationale d'Agriculture de Porto Novo ; BP : 43 Kétou, Benin
**Corresponding author:** bossouleslie17@gmail.com

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## ABSTRACT

Bambara groundnut (*Vigna subterranea* (L.) Verdc.), also called ground peas or Bambara groundnut, is a West African seed legume of the Fabaceae family, playing an important social and economic role. The objective of the current study was to determine the occurrence, distribution and incidence of this disease on Bambara groundnut in agroecological production zones in Benin and to identify the causal agents responsible for the damages caused to the crop. A survey was conducted from 2019 to 2020 in five agroecological zones (AEZs) of Benin (AEZ2, AEZ3, AEZ4, AEZ5 and AEZ6). A total of 30 fields of Bambara groundnut were surveyed from 10 municipalities located in the agroeclogical zones of production at the early vegetative stage of the crop. Fields' size of 0.5 ha were selected and scouted alongside both diagonals to evaluate the damping-off disease incidence. The results showed that damping-off occurred in four out of the five AEZs surveyed. The incidence rates varied from 0.00 to 23.33% in the AEZs 5 and 6 in 2019, and from 0.00 to 18.33% in the AEZ 6 in 2020. The highest incidence rates were obtained in the West Zone of Atacora (AEZ 4) and in the Food crop region of South (AEZ 3). Results of the correlation test showed a relationship between incidence, distribution of damping-off and climatic factors. However, most of regression equations showed a strong relationship between chemical properties of soils and incidence of damping-off. *Sclerotium rolfssi* was identified in the laboratory as the causal agent of the damping-off disease and isolated from diseased plants in the fields and during greenhouse pathogenicity tests. To the best of our knowledge, this is the first report of identification of pathogenic fungus as the causal agent of damping-off on Bambara groundnut seedlings in Benin.

*Key Words*: Agroecological zones, Bambara groundnut, Benin, damping-off, *Sclerotium rolfsii*

## RÉSUMÉ

Voandzou (*Vigna subterranea* (L.) Verdc.), également appelé pois de terre ou pois bambara, est une légumineuse à graines d'Afrique de l'Ouest de la famille des Fabacées, jouant un rôle social et économique important. L'objectif de la présente étude était de déterminer l'occurrence, la distribution et l'incidence de cette maladie sur le Voandzou dans les zones de production agroécologique du Bénin et d'identifier les agents causals responsables des dégâts causés à la culture du voandzou. Une enquête a été menée de 2019 à 2020 dans cinq zones agroécologiques (ZAE) du Bénin (ZAE 2, ZAE 3, ZAE 4, ZAE 5 et ZAE 6). Au total, 30 champs de Voandzou ont été enquêtés dans 10 communes situées dans les zones agroécologiques de production au stade végétatif précoce de la culture. Des champs de 0,5 ha ont été sélectionnés et repérés le long des deux diagonales pour évaluer l'incidence de la fonte des semis. Les résultats ont montré que la fonte des semis s'est produite dans quatre des cinq ZAE étudiées. Les taux d'incidence ont varié de 0,00 à 23,33 % dans les ZAE 5 et 6 en 2019, et de 0,00 à 18,33 % dans la ZAE 6 en 2020. Les taux d'incidence les plus élevés ont été obtenus dans la Zone Ouest de l'Atacora (ZAE 4) et dans la Région vivrière du Sud (ZAE 3). Les résultats du test de corrélation ont montré une relation entre l'incidence, la distribution de la fonte des semis et les facteurs climatiques. Cependant, la plupart des équations de régression ont montré une relation très forte entre les propriétés chimiques des sols et l'incidence de la fonte des semis. *Sclerotium rolfssi* a été identifié en laboratoire comme l'agent causal de la fonte des semis et isolé à partir de plantes malades dans les champs et lors de tests de pathogénicité en serre. A notre connaissance, il s'agit du premier signalement d'identification d'un champignon pathogène comme agent causal de la fonte des semis sur des plantules de Voandzou au Bénin.


*Mots Clés*: Zones agroécologiques, Voandzou, Bénin, fonte des semis, *Sclerotium rolfsii*

## INTRODUCTION

Bambara groundnut (*Vigna subterranea* (L) Verdc.), also called ground peas or Bambara groundnut, is a West African seed legume of the Fabaceae family, playing an important social and economic role (Bamshaiye *et al.* ., 2011). West Africa provides 45 to 50% of the world production estimated at 330,000 tonnes per year and is the primary production area (Baudoin and Mergeai, 2001; Brink *et al.*, 2006). It is a complete food due to its high nutritional value in protein and antioxidant (Minka and Bruneteau, 2000; Amarteifio *et al.*, 2006; Onwubiko *et al.*, 2011; Mbaiogaou *et al.*, 2013; FAO, 2016); and a hardy crop owing to its tolerance to drought and its ability to produce on soils considered not very suitable for the cultivation of other crops (FAO, 2001; Brink and Belay, 2006; Basu *et al.*, 2007; Mkandawire, 2007). Despite its advantages, Bambara groundnut has remained an under-exploited crop in Benin with low yields of about 650 kg $ha^{-1}$, compared to the potential yield of 4 ha (Dansi *et al.*, 2012).

The low grain yields of Bambara groundnut are attributable to several biotic and abiotic factors (Niba, 2011), including pathogenic microorganisms causing damping-off disease (Ayandoo *et al.*, 2003). This disease results in rotting of hypocotyls and seedlings just after they emerge from the ground. The pathogens responsible for damping-off disease are fungal species of the genera *Botrytis*, *Fusarium*, *Phytophthora*, *Pythium*, *Sclerotium*., etc. Among these pathogens, damping-off caused by *Sclerotium rolfsii* Sacc. is arguably one of the best known with severe damages affecting various crops around the world, especially in tropical and subtropical countries (Adandonon *et al.*, 2005; Xie *et al.*, 2014).

*Sclerotium rolfsii* is an important stem and root rot pathogen of many crops (Talukder *et al.*, 2019). This fungus is a highly polyphagous pathogen, and due to its wide host range, it is considered one of the most destructive pathogens in the world (Paul *et al*., 2017). The pathogen attacks around 500 plant species from 100 different botanical families (Punja, 1985; Blancard, 1988). Among its cultivated host plants are tomato (Sikirou *et al*., 2011), potato, cassava, chili, carrot, cabbage, peanut (Dwivedi and Prasad, 2016), cowpea (Adandonon *et al.,* 2015), sweet potato (Paul *et al*., 2017), coffee, oil palm (Okabe and Matsumoto, 2000), Bambara groundnut and fruit plants (banana, citrus) (Ayandoo *et al*., 2003).

Bambara groundnut is a widely cultivated in different AEZs in Benin. To our knowledge, to date, no study has been carried out on the occurrence of the damping-off disease on this crop in Benin. The objective of the current study was to determine the occurrence, distribution and incidence of this disease on Bambara groundnut in agroecological production zones in Benin and to identify the causal agents responsible for the damages caused to the crop.

## MATERIALS AND METHODS

A surveys was carried out in August in 2019 and 2020 in five main agro-ecological zones of Bambara groundnut in Benin (Fig. 1). The municipalities surveyed were chosen based on their production potential.

Two municipalities per AEZ and three fields of approximately 0.5 ha per municipality were haphazardly chosen. In total, 30 fields over 10 municipalities in the different AEZs were surveyed during the first two weeks of Bambara groundnut growing stage in the field. Incidence of damping-off was assessed in each field surveyed by haphazardly observing 30 plants over the two diagonal lines of the field. The presence or absence of the disease was visually noted on each plant based on the characteristic symptoms of damping-off, which are: low emergence rate, wilting seedling, stem rot, development and appearance of mycelia, presence or absence of *sclerotia* (shape, size, colour, etc.). The number of plants observed with disease symptoms were recorded.

The incidence of the disease was determined by the formula:

$$I = (Pd / Pt) \times 100$$

Where:

I = disease incidence expressed as a percentage of diseased plants;
Pd = number of diseased plants showing symptoms of damping-off; and
Pt = total number of plants observed in the prospected field.

Damping-off disease distribution mapping was drawn taking into consideration all surveyed sites.

**Pathogenicity test and pathogen identification.** Root and stem samples were taken from plants showing symptoms characteristic of damping-off. The samples taken were kept in press in newspapers for laboratory identification of the pathogen. About 2 mm of the infected root and stem part of each sample was cut off, and washed in 0.5% sodium hydrochloride (NaOCl) and alcohol. They were rinsed with sterile water and put on towel to wring out the water. These diseased plant samples were plated in culture media containing Potato Dextrose Agar (PDA). The media with samples were then incubated at 27 ± 1 ° C for at least 72 hours (Domsch *et al*., 1980). The fungi were pure-cultured and Mycelium pieces of each fungus was mounted on slides covered with slip and observed under microscope for identification of the fungus.

To fulfil Koch's postulates for pathogenicity, a test was carried out in the greenhouse in pots. The salt-free sea sand and peat were sterilised for 30 min at 120 ° C in an autoclave. They were then mixed at the rate of 0.25% peat moss and 75% sea sand. The mixture was placed in polyethylene jars (12 cm x 18 cm). Seeds of Bambara groundnut

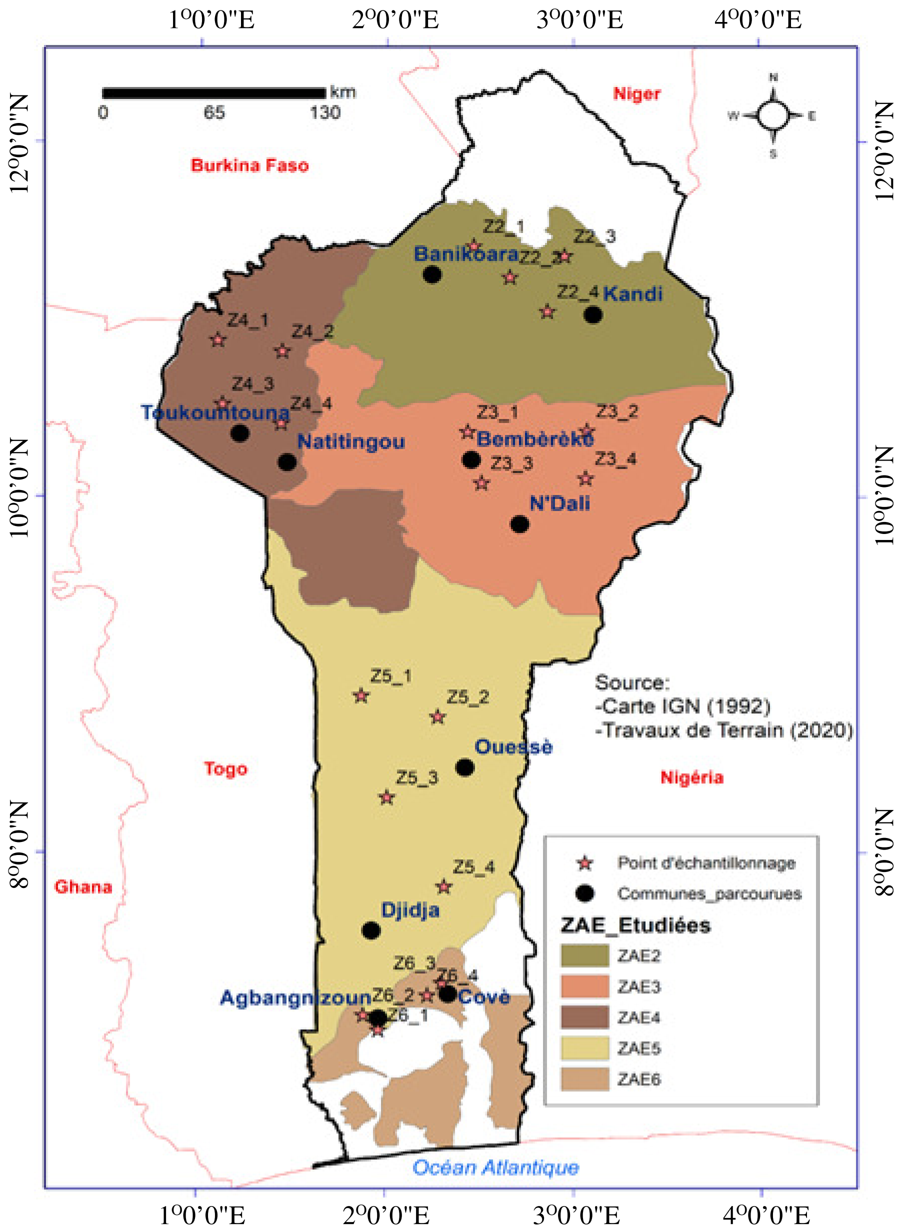



Figure 1. Map of Benin showing the study sites. AEZ = Agroecological zone; AEZ 2 = Cotton zone of North Benin; AEZ 3 = South Borgou food zone; AEZ 4 = West Zone-Atacora; AEZ 5 = Cotton zone in Central Benin, AEZ 6 = Zone of "bar lands".

previously surface sterilised were sown at the rate of 2 seeds per pot.

One week after Bambara groundnut planting, a portion of 4-day growing culture media containing mycelium and sclerotia of the microorganism were used to inoculate Bambara groundnut seedlings in each pot. This inoculum was deposited at the collar of the seedling (Adandonon *et al*., 2005; PANE *et al*., 2007; Sikirou *et al*., 2011). It was then covered with a light layer of soil and regularly watered. The experiment was followed and the number of plants showing symptoms of the disease (damping-off, root rot with mycelia and/or sclerotia on the crown and withered plants) was recorded every 4 days and this for 28 days after seedling inoculation. The re-isolated fungus was observed in the laboratory and the culture media compared to the original ones.

**Soil analysis.** Soil samples (500 g) were taken at different sites to a depth of 20 cm. Composites were made after a homogeneous mixing of the sub-samples. Total nitrogen was determined by the Kjeldahl 1883 method (Houngnandan *et al*., 2020). Available phosphorus was determined using the Bray method (Menage and Pridmore, 1973). The water pH of the soil was measured by the potentiometric method and organic carbon by calorimetry at a wavelength of 600 nm following method of Walkley and Black (1934). The exchangeable bases extracted by the Metson method (Metson 1956).

**Statistical analysis.** Analysis of variance was performed using the SAS General Linear Model (GLM) procedure for the damping-off incidence. Student Newmann Keuls test (SNK) was used to separate the means (p d" 0.05). Pearson correlation coefficients and a simple linear regression were established between effects of damping-off, climatic and chemical parameters of the AEZs.

## RESULTS

Soil chemical characteristics of the study sites The soils sampled at the different study areas had an acidic pH regardless of the year of prospecting (Table 1). The highest pH level was obtained in AEZ 2. All the different AEZ soil samples were very rich in assimilable phosphorus. In AEZs 4, 5 and 6, soil samples had a high level of mineralisation; while the level was moderate in the soils of AEZ 2 and 3. Nitrogen content was the highest in AEZs 5 and 6, as compared to that in AEZs 2, 3 and 4.

**Symptoms of the disease in the field.** In the field, the symptoms observed were wilting of the plants (Figs. 2 and 3) and rot at the collar of the plants with white mycelia. Sclerotia were observed (Figs. 2 and 3) around the plants and were white at the base of some plants and light brown or brown-black of other plants observed in the surveyed fields. Some collar rot diseased plants were dead fallen on the ground.

**Greenhouse pathogenicity test.** Four days after inoculation, 15% of the Bambara groundnut plants showed symptoms of wilt and collar rot, with white mycelia and sclerotia around the plants. These symptoms were characteristic of damping-off disease recorded in the field during the survey (Fig. 3). Eight days after inoculation, 33.75% of the plants had white mycelia and/or sclerotia at their collar and 2.5% of the plants withered and died (Table 2). The inoculated pathogen was re-isolated each time from the diseased seedling samples plated in culture media in the greenhouse. After 28 days of inoculation, it was observed 6.25% of healthy plants without visible symptoms of the disease; 18.75% of the plants were characterised by the presence of mycelia and brownish sclerotia; and 56.25% of the plants wilted and died with the presence of brown-blackish sclerotia. Overall, 93.75%

TABLE 1. Soil chemical parameters in the different AEZ surveyed for occurrence and distribution of damping-off in Benin

| 2019 | pH ($H_20$) | Total N (%) | Organic carbon (%) | Available P (ppm) | Exchangeable (cmol. $kg^{-1}$) | | | Mg (cMol $kg^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| | | | | | $Na^+$ | $K^+$ | $Ca^{2+}$ | |
| **AEZ2** | 6.27±0.08a | 0.05±0.01b | 1.24±0.08a | 30.97±2.02a | 2.31±0.74a | 0.85±0.19a | 4.16±0.26a | 1.27±0.18a |
| AEZ3 | 5.94±0.07ba | 0.05±0.01ba | 1.77±0.14a | 31.37±1.81a | 0.84±0.25a | 0.98±0.31a | 1.94±0.26a | 0.83±0.09a |
| AEZ4 | 5.70±0.15b | 0.06±0.01ba | 1.59±0.24a | 35.79±3.33a | 1.50±0.39a | 0.58±0.13a | 3.44±0.41a | 1.06±0.16a |
| AEZ5 | 5.97±0.10ba | 0.08±0.01a | 1.26±0.25a | 33.52±2.10a | 1.41±0.27a | 0.99±0.33a | 4.03±0.60a | 1.23±0.15a |
| AEZ6 | 5.93±0.10ba | 0.08±0.01a | 1.76±0.21a | 32.75±3.82a | 1.57±0.30a | 0.83±0.16a | 3.27±0.85a | 0.81±0.21a |
| **2020** | | | | | | | | |
| AEZ2 | 6.01±0.07a | 0.05±0.01a | 1.41±0.11a | 22.22±2.26a | 2.70±0.92a | 1.06±0.23a | 4.83±0.30a | 1.91±0.29a |
| AEZ3 | 5.77±0.04ba | 0.05 ±0.01a | 1.15±0.13a | 20.08±2.14a | 1.21±0.27a | 1.06±0.25a | 2.40±0.33b | 1.36±0.15a |
| AEZ4 | 5.85±0.10ba | 0.06±0.01a | 1.65±0.17a | 20.58±1.60a | 1.69±0.44a | 1.03±0.33a | 4.26±0.51ba | 1.32±0.19a |
| AEZ5 | 5.73±0.04ba | 0.06±0.01a | 1.53±0.21a | 20.85±0.74a | 1.58±0.35a | 1.16±0.4a | 4.33±0.34ba | 2.03±0.31a |
| AEZ6 | 5.59±0.12b | 0.07±0.01a | 1.60±0.16a | 22.17±2.03a | 1.62±0.24a | 1.03±0.21a | 4.06±1.05ba | 1.18±0.27a |

Means followed by the same alphabetical letters are not significantly different (P> 0.05) according to the test of Student Newman-Keuls. AEZ = agroecological zone; Na = sodium; K = Potassium; Ca = calcium and Mg = magnesium of the Bambara groundnut plants tested showed symptoms of damping-off disease, similar to what was observed in the surveyed fields.

**Identification of the causal agent.** The symptoms observed were wilting of the plants with a silky white causative mycelium at the level of the crown of septate hyaline hyphae under the microscope. The pathogen's sclerotia were visible in culture medium and on soil infected with the pathogen. The sclerotia were small in size with a rounded shape and were initially white in colour, which over time evolved into light brown and subsequently brown-black. These symptoms were characteristic of damping-off caused by *S. rolfsii* (Fig. 4).

**Distribution of the incidence of damping-off.** Distribution of the damping-off incidence from diseased plants observed during the various surveys (2019 and 2020) through the AEZs is presented in Figures 5 and 6. Bambara groundnut damping-off disease was present in three out of five AEZs during the 2019

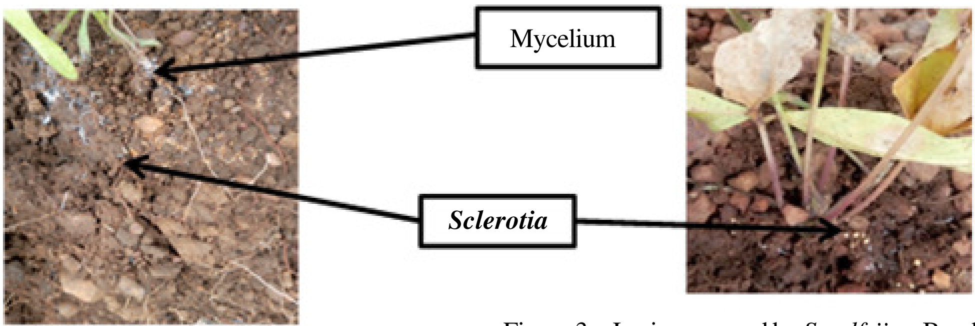



Figure 2. Mycelium and white sclerotia of *S. rolfsii* on Bambara groundnut plants.

Figure 3. Lesions caused by *S. rolfsii* on Bambara groundnut plants.

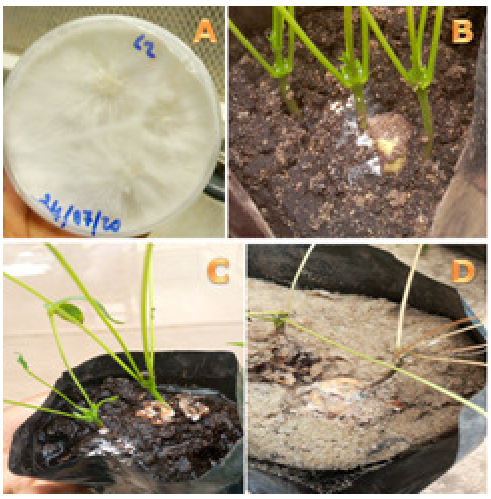



Figure 4. Symptoms observed on the plants after inoculation. (A) Culture of the pathogen, *Sclerotium rolfsii*, isolated on culture medium; (B) Bambara groundnut plants containing sclerotia at the plant collar; (C) Bambara groundnut plants with white mycelium at the collar; (D) Bambara groundnut plants with collar rot and wilting of the whole plant.

TABLE 2. Symptoms observed on the plants during the test

| Days after inoculation | Observed symptoms | | | |
|---|---|---|---|---|
| | Plants with no symptoms of damping-off (%) | Presence of mycelium and/or sclerotiaon the substrate and at the collar of plants (%) | Presence of mycelium, sclerotia and collar rot of plants (%) | Wilting and dead plants (%) |
| 00 | 100 | 0 | 0 | 0 |
| 4 | 85 | 15 | 0 | 0 |
| 8 | 51,25 | 33,75 | 12,5 | 2,5 |
| 12 | 18,75 | 37,5 | 25 | 18,75 |
| 16 | 15 | 18,75 | 33,75 | 32,5 |
| 20 | 10 | 15 | 31,25 | 43,75 |
| 24 | 8,75 | 16,25 | 25 | 50 |
| 28 | 6,25 | 18,75 | 18,75 | 56,25 |

survey while it was observed in 2020 on four out of five AEZs. Figure 5 shows that there was a significant difference (P<0.0006) between the different AEZs in terms of disease incidence (P<0.0006). The highest incidence (Fig. 6) was observed in AEZ4 in 2019 (23.33%), followed by AEZ3 (17.22) and AEZ2 (16.12%). Regarding the survey in 2020, the highest incidence was recorded in AEZ3 (18.33%) followed by AEZ4 (14.00%), AEZ2 (10.55) and AEZ5 (5.17%), respectively. Incidence recorded was zero in AEZ5 and 6 during the 2019 survey. Similar result was observed in AEZ6 in 2020. This means that the pathogen is generally present in these different AEZs and that Bambara groundnut is attacked by damping-off disease in Benin.

**Effect of cropping history.** The different cropping history recorded during the survey was as follows: maize as sole crop, maize + cowpea and maize + peanut combinations. The cultivation of Bambara groundnut was also sown on plots set aside. A comparative analysis of the means of the incidence of the disease according to the cropping history (Fig. 7) shows the existence of a highly (P<0.001) significant difference between the AEZs. From this figure, it could be observed that the fields with maize/cowpea and maize/peanut cropping history had high incidence rate of the disease during the two-year survey.

**Effect of environmental conditions.** Table 3 shows that there was a strong positive correlation between rainfall and damping-off incidence during the two-year survey. There was also a strong negative correlation between minimum temperature, minimum humidity and incidences recorded in 2019 and 2020. These correlations were highly significant (P<0.001). On the other hand, a weak significant positive correlation (P<0.05) was observed between maximum humidity and damping-off incidence in 2020. There was a strong positive correlation between the maximum humidity on the one hand, and weak correlation between number of rainfall, maximum temperature and

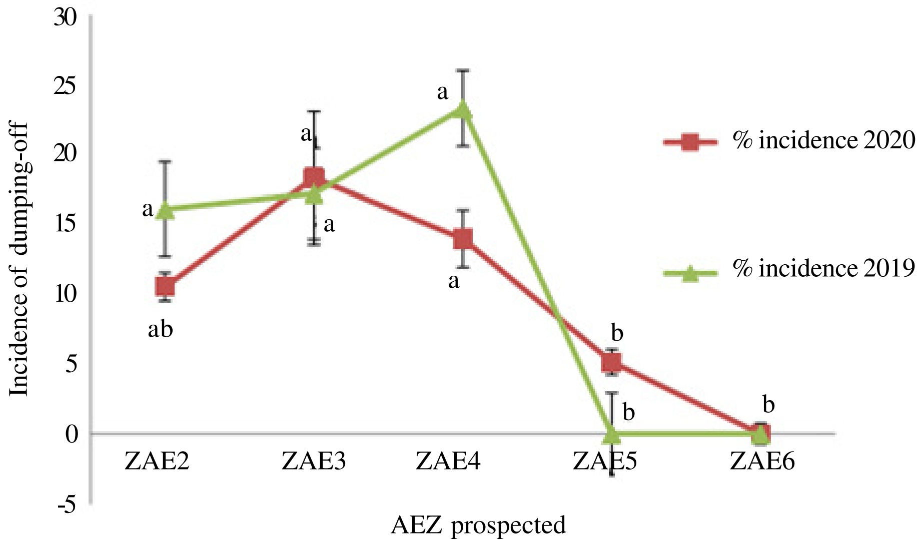



Figure 5. Distribution and incidence of damping-off during the two years, 2019-2020, per AEZ in Benin.

incidence of damping-off in 2019 (Table 3). The correlation of damping-off incidence with the number of rainfall and maximum humidity was highly significant ($P<0.001$) and that with the maximum temperature was significant ($P<0.05$).

**Relationship between soil chemical properties and damping-off incidence.** Graphs A, B, C, D and (Fig. 8) show respectively the existence of a highly significant relationship ($P = 0.0000$) between the pH water, nitrogen, assimilable phosphorus, potassium level, soil organic carbon and incidence of damping-off in Bambara groundnut. These relationships strongly affected the incidence. Also, the regression equation (mean incidence = -7.6 + 44.77 pH water) shows that when the pH water increased by one unit, the incidence underwent an increase of 44.77. Likewise, the incidence increased by 571.4 when nitrogen increased by one unit (average incidence = -22.70 + 571.4N). An increase in the incidence of damping-off is also observed at the level of the Pass (average incidence = -51.07 + 2.963Pass), K (average incidence = -8.482 + 18.82K) and Corg (average incidence = -9.58 + 31.37 Corg).

On the other hand, there was a very weak relationship ($R^2 = 14.2$) between the incidence and the calcium level (Graph F). This relationship was significant ($p = 0.023$). Virtually no relationship was established between incidence and magnesium level (Fig. 8, E).

## DISCUSSION

The pH values of the soils recorded under cultivation of Bambara groundnut indicate the low acidity of these soils (AFES, 1995). According to Baize (2000), the pH determines the assimilability of the main nutrients and trace elements. High nitrogen and organic carbon levels were observed during the two years of survey. The phosphorus levels of the different soil samples for the two years are high and therefore rich in phosphorus which is favorable to the crop (Brink and Belay, 2006).

Observation of diseased Bambara groundnut plants in the fields and the fungus isolated and identified indicate that the various fields were infected by the fungus *S. rolfsii*,

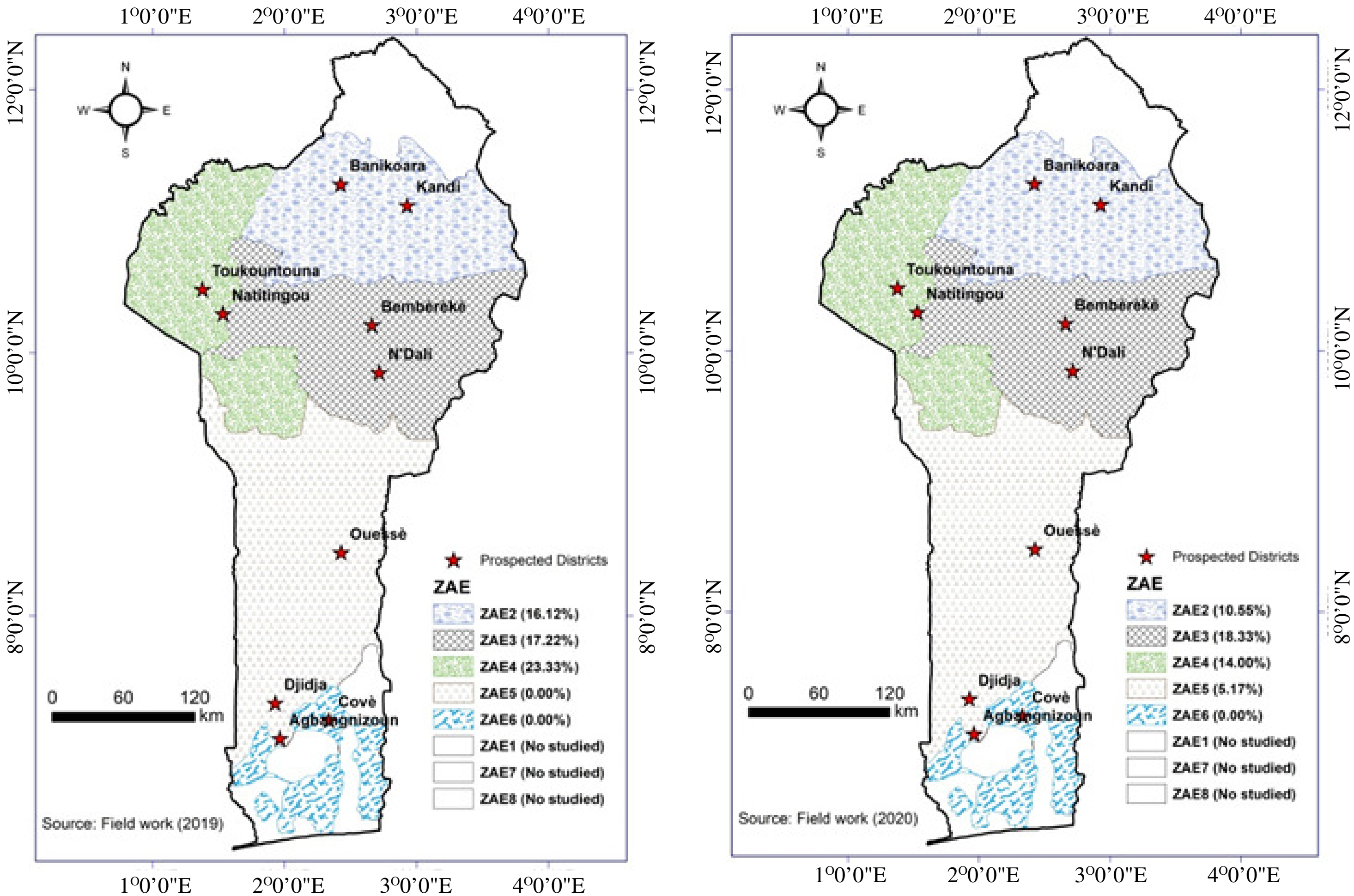



Figure 6. Distribution of the incidence of damping-off by Agroecological Zone in Benin. AEZ = Agroecological zone. AEZ 1 = Zone of the extreme north of Benin; AEZ 2 = Cotton zone of North Benin; AEZ 3 = South Borgou food zone; AEZ 4 = West Zone-Atacora; AEZ 5 = Cotton zone in Central Benin, AEZ 6 = Zone of "bar lands"; AEZ 7 = Depression zone; AEZ 8 = Fisheries zone.

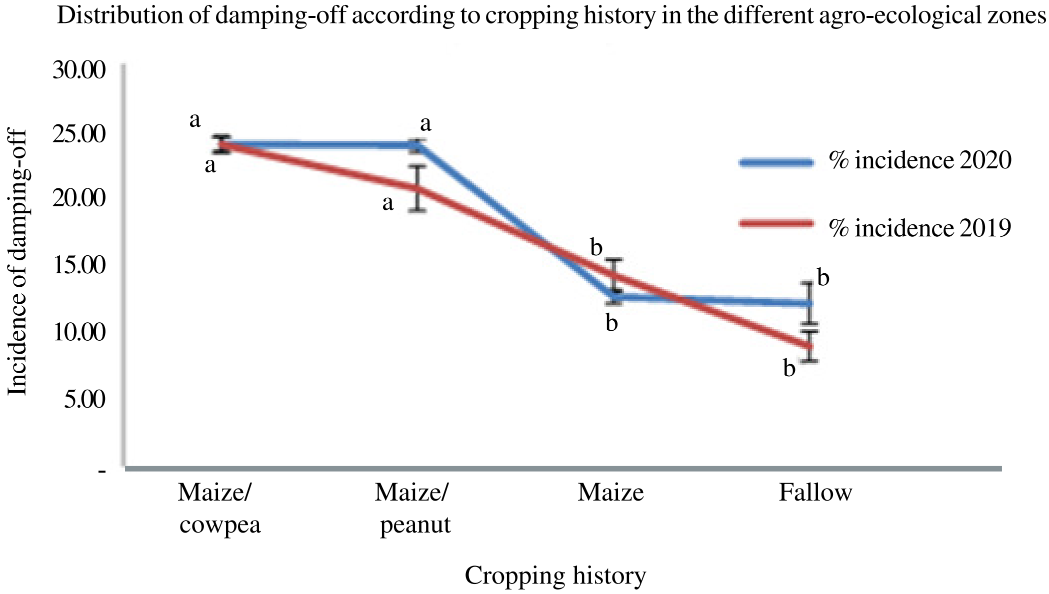



Figure 7. Damping-off incidence in relation to cropping system history in Bambara groundnut growing AEZs in Benin.

causal agent of this damping-off disease. The pathogenicity test carried out by inoculating seedlings with the isolated fungus resulted in symptoms characteristic of the damping-off disease symptoms observed in the field during the survey. This test revealed that 93.75% of the Bambara groundnut plants tested showed symptoms of *S. rolfsii*. Moist-looking lesions have also been observed developing in the collar area. According to Kossou *et al*. (2001), Sikirou *et al*. (2011) and Adandonon *et al*. (2017), this fungus is characterised by presence of white, silky mycelium at the plant collar with partitioned hyaline hyphae with loops of anastomoses. It also produces sclerotia on hosts and typically infects the collar region or stems near the soil surface (Mullen, 2001; Mahadevakumar *et al*., 2016).

This result is consistent with that obtained by Adandonon *et al*. (2005) during his work on damping-off of cowpea. The results of the study showed that damping-off is present in three out of five AEZs in 2019 and in four of five AEZs in 2020. These are AEZ 2; 3 and 4 in 2019 and AEZ 2; 3; 4 and 5 in 2020. The incidence values also varied from one AEZ to another, regardless of the year. It varies from 0.00% (AEZ 5 and 6) to 23.33% in 2019 and from 0.00% (AEZ 6) to 18.33% in 2020.

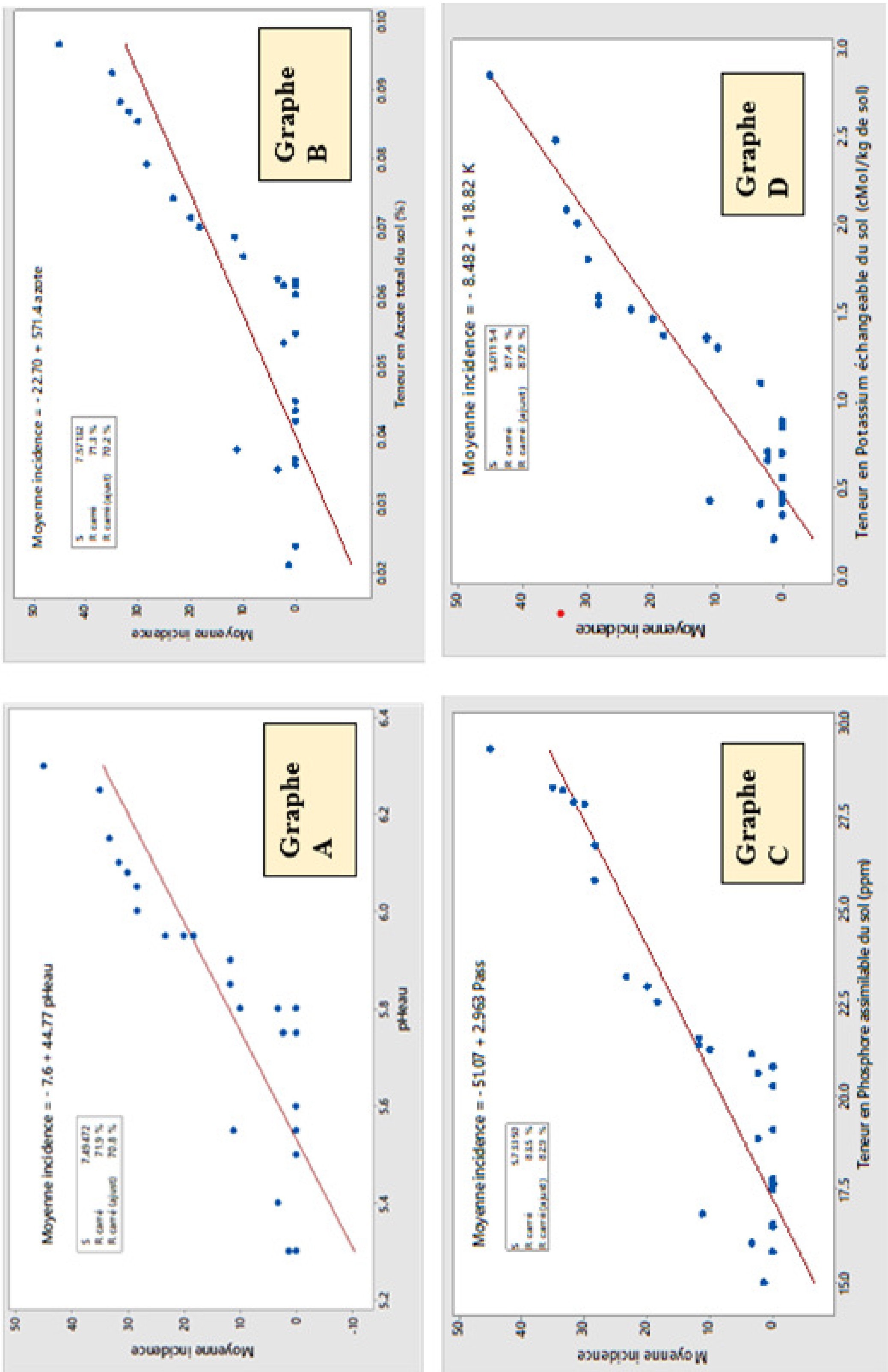
The highest incidence values in both years were obtained in the West-Atacora zone (AEZ 4) and the South Borgou food zone (AEZ 3). This means that the pathogen is present on these sites and that the Bambara groundnut is attacked by damping-off. The magnitude of the incidence values up to 20.83% showed that damping-off of Bambara groundnut caused by *S. rolfsii* could become an important disease of the Bambara groundnut crop in Benin.. Indeed, this fungus is a very polyphagous pathogen and due to its wide host range, it is considered one of the most destructive pathogens in the world (Paul *et al.,* 2017). *Sclerotium rolfsii* attacks around 500 plant species from 100 different families (Punja, 1985; Blancard, 1988).

This study has made it possible to determine the incidence of damping-off taking into account the cropping history. Fields with maize/cowpea and maize/groundnut cropping history were found to have high disease incidence rates. This is because cowpeas and

TABLE 3. Correlation coefficients between the different climatic parameters and incidence of damping-off disease in Bambara groundnut producing AEZs in Benin

| Variables | Incidence 2020 | Incidence 2019 | Pluviometry | Number of precipitations | Maximum temperature | Minimum temperature | Maximum humidity | Minimum humidity |
|---|---|---|---|---|---|---|---|---|
| Incidence 2020 | 1 | | | | | | | |
| Incidence 2019 | 0,67*** | 1 | | | | | | |
| Pluviometry | 0,56*** | 0,61*** | 1 | | | | | |
| Number of precipitations | 0,34 | 0,46*** | 0,48*** | 1 | | | | |
| Maximum temperature | 0,27 | 0,44* | -0,02 | 0,0500 | 1 | | | |
| Minimum temperature | -0,59*** | -0,75*** | -0,69*** | -0,73*** | -0,57*** | 1 | | |
| Maximum humidity | 0,41* | 0,70*** | 0,59*** | 0,56*** | 0,66*** | -0,91*** | 1 | |
| Minimum humidity | -0,64*** | -0,62*** | -0,87*** | -0,18 | -0,2900 | 0,67*** | -0,57*** | 1 |

*** = Very highly significant (P<1%); ** = Highly significant (P<1%); * = Significant (P<5%); ns = Not significant at 5%


Graphe A
Moyenne incidence = - 7.6 + 44.77 pHeau
Moyenne incidence
pHeau
Graphe B
Moyenne incidence = - 22.70 + 571.4 azote
Moyenne incidence
Teneur en Azote total du sol (%)
Graphe C
Moyenne incidence = - 51.07 + 2.963 Pass
Moyenne incidence
Teneur en Phosphore assimilable du sol (ppm)
Graphe D
Moyenne incidence = - 8.482 + 18.82 K
Moyenne incidence
Teneur en Potassium échangeable du sol (cMol/kg de sol)

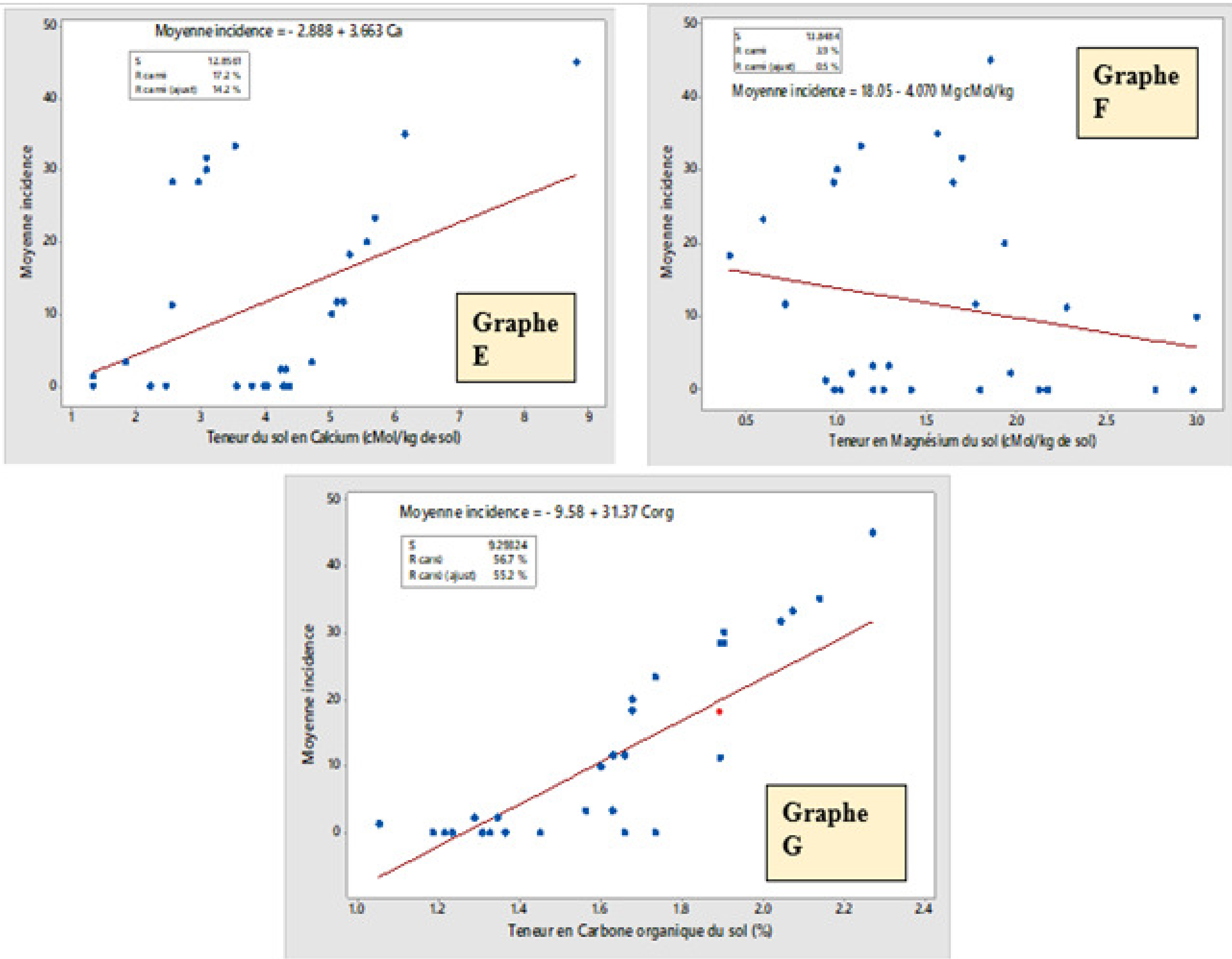



Figure 8. Relationships between sol parameters and incidence of damping-off on Bambara groundnut in different producing AEZs in Benin.

peanuts are host plants of the pathogen as reported by previous work (Adandonon *et al*., 2005; Ozgonen *et al.,* 2010). Damping-off is a disease caused by *S. rolfsii* which is prevalent on farms in Benin and especially on leguminous crops (Adandonon *et al*., 2017). Sclerotia of *S. rolfsii* can live in soils and on plant debris for several years (Adandonon *et al*., 2005) and are means of propagation of the species in nature, either for primary infection at the onset of a new season, or for secondary infections. Germination occurs through mycelial filaments which attack the host by rapidly invading healthy tissue, most often in the vicinity of the soil. This pathogen is considered to be the main causal agent of stem and root rot in peanuts (Ozgonen *et al*., 2010).

Most of the regression equations have shown that climatic conditions were favourable for the development of damping-off of Bambara groundnut in Benin. Soil parameters such as: water pH, assimilable phosphorus, potassium and organic carbon in the soil, which were among the limiting elements in the production of Bambara groundnut, influenced the average incidence of damping-off. Indeed, soils rich in phosphorus and potassium are favourable to the production of Bambara groundnut, but also increase the average incidence since when its elements increase by one unit the value of the incidence increases. This implies that *S. rolfsii* could be present on soils rich in nutrients.

## CONCLUSION

This study determined the presence, distribution and incidence of damping-off in Bambara groundnut crop caused by *S. rolfsii* in Benin. Damping-off is present in most of the fields surveyed in the agroecological zones of crop production. The West-Atacora zone (AEZ 4) and the South-Borgou food zone (AEZ 3) have the highest incidence values on average. A high incidence was also observed in relation to the maize / cowpea and maize / peanut crop history. There is a strong relationship between climatic and soil parameters and the different damages of damping-off in the studied AEZs. This study shows the presence of damping-off of Bambara groundnut crop in AEZs in Benin with *S. rolfsii* as the causal agent of the disease. This is the first report of damping-off disease and *S. rolfsii* as the causal agent of the disease in Bambara groundnut in Benin.

## REFERENCES

Adandonon, A., Aveling, T.A.S. and Tamo, M. 2005. Occurrence and distribution of cowpea damping-off and stem rot and associated fungi in Benin. *Journal of Agricultural Science* 142:561-566.

Adandonon, A., Momma, N., Hoshino, Y.T. and Makino, T. 2015. Bacterial populations concomitant with *Sclerotium rolfsii sclerotia* in flooded soil, as estimated by 16S rRNA gene, PCR-DGGE and sequence analyses. *Journal of Applied Biosciences*, 93:8696-8712.

Adandonon, A., Regnier, T. and Aveling, T.A. 2017. Phenolic content as an indicator of tolerance of cowpea seedlings to *Sclerotium rolfsii*. *European Journal of Plant Pathology* 149(2):245-251. doi: https://doi.org/10.1007/s10658-017-1178-9.

Amarteifio, J., Tibe, O. and Njogu, R. 2006. The mineral composition of bambara groundnut (*Vigna subterranea* (L) Verdc) grown in Southern Africa. *African Journal of Biotechnology* 5(23);2408-2411.

Ayandoo, A.J., Demuyakor, B., Badii, K.B. and Sowley, E.N.K. 2003. Storage systems for Bambara groundnut and their improvements for bruchid pest management in Talensi Nabdam District, Upper East Region, Ghana. *International Journal Scientific & Technology Ressource* 3(4):181-186.

Brink, M. et Belay, G. 2006. PROTA (‘Ressources végétales de l’Afrique tropicale 1: céréales et légumes secs'). *Wageningen, Pays Bas*.

Brink, M., Sibuga, K., Tarimo, A. and Ramolemana, G. 2000. Quantifying photothermal influences on reproductive development in bambara groundnut (*Vigna subterranea*): models and their validation. *Field Crops Research* 66(1):1-14.

Bamshaiye, O.M, Adegbola, J.A. and Bamishaiye, E.I. 2011. Bambara groundnut: An under-utilized nut in Africa. *Advances in Agricultural Biotechnology* 1:60-72.

Blancard, D. 1988. Maladies de la tomate; observar, identifier, lutter. 04; SB608. T75, B53.

Basu, S., Mayes, S., Davey, M., Roberts, J.A., Azam-Ali, S.N., Mithen, R. and Pasquet, R.S. 2007. Inheritance of 'domestication' traits in bambara groundnut (*Vigna subterranea* (L.) Verdc.). *Euphytica* 157 (1-2):59-68.

Dansi, A., Vodouhè, R., Azokpota, P., Yedomonhan, H., Assogba, P., Adjatin, A., Loko, Y.L., Dossou-Aminon, I. and Akpagana, K. 2012. Diversity of the neglected and underutilized crop species of importance in Benin. *The Scientific World Journal* 2012:932-947.

Domsch, K.H., Gams, W. and Anderson, T. H. 1980. Compendium of Soil Fungi. Academic Press, London, UK. pp. 1365-1389.

Dwivedi, S. and Prasad, G. 2016. Integrated management of *Sclerotium rolfsii*: An overview. *European Journal of Biomedical and Pharmaceutical Sciences* 3:137-146.

Mahadevakumar, S., Yadav, V., Tejaswini, G. and Janardhana, G. 2016. Morphological and molecular characterization of *Sclerotium rolfsii* associated with fruit rot of *Cucurbita maxima*. *European Journal of Plant Pathology* 145(1):215-219. doi: https://doi.org/10.1007/s10658-015-0818-1.

Mbaiogaou, A., Hema, A., Ouedraogo, M., Pale E., Naitormbaide, M., Mahamout, Y. et Nacro, M. 2013. Etude comparative des teneurs en polyphénols et en antioxydants totaux d'extraits de graines de 44 variétés de voandzou (*Vigna subterranea* (L.) Verdcourt). *International Journal Biologycal Chemical Sciences* 7(2):861-871. http://dx.doi.org/10.4314/ijbcs.v7i2.41.

Mkandawire, C. 2007. Review of bambara groundnut (*Vigna subterranea* (L.) Verdc.) production in Sub-Sahara Africa. *Agricultural Journal* 2(4):464-470.

Kossou, D.K., Gbèhounou, G., Ahanchédé, A., Ahohuendo, B., Bouraïma, Y. et van Huis A. 2001. Indigenous cowpea production and protection practices in Benin. *International Journal of Tropical Insect Science* 21(2):123-132.

Minka, S.R. and Bruneteau, M. 2000. Partial chemical composition of bambara pea [*Vigna subterranea* (L.) Verde]. *Food Chemistry* 68(3):273-276.

Mullen, J. 2001. Southern blight, southern stem blight, white mold. *The Plant Health Instructor* 10(1):104-111.

Niba, A.S. 2011. Arthropod assemblage dynamics on cowpea (*Vigna unguiculata* L. Walp) in a subtropical agro-ecosystem, South Africa. *African Journal of Agricultural Research* 6(4):1009-1015.

Nitiema, L.W., Traoré, F., Nebie, K., Soalla, R.W., Ouedraogo, T.Y., Sanon, B.S. et Ouattara K. 2019. Effet du fertilisant minéral NPK et du biofertilisant BioDeposit® sur les insectes ravageurs et les maladies du niébé (*Vigna unguiculata* L. Walp.) au centre-ouest du Burkina Faso. *Journal of Applied Biosciences* 143: 14649-14658. doi: https://dx.doi.org/10.4314/jab.v143i1.4.

Okabe, I. and Matsumoto, N. 2000. Population structure of *Sclerotium rolfsii* in peanut fields. *Mycoscience* 41(2):145-148.

Onwubiko, N., Odum, O., Utazi, C. and Poly-Mbah P. 2011. Studies on the adaptation of Bambara Groundnut [*Vigna Subterranea* (L.) Verdc] in Owerri Southeastern Nigeria. *New York Science Journal* 4(2):60-67.

Ozgonen, H., Akgul, D.S. and Erkilic A. 2010. The effects of arbuscular mycorrhizal fungi on yield and stem rot caused by *Sclerotium rolfsii* Sacc. *In peanut. African Journal of Agricultural Research* 5(2):128-132.

Pane, A., Raudino, F., Adornetto, S., Proietto, G. and Cacciola, S.O. 2007. Blight of English Ivy (*Hedera helix*) caused by *Sclerotium rolfsii* in Sicily. *Plant Disease* 91: 635-642.

Paul, N.C., Hwang, E.-J., Nam, S.-S., Lee, H.-U., Lee, J.-S., Yu, G.-D., Kang, Y.-G., Lee, K.-B., Go, S. and Yang, J.-W. 2017. Phylogenetic placement and morphological characterization of *Sclerotium rolfsii* (Teleomorph: *Athelia rolfsii*) associated with blight disease of *Ipomoea batatas* in Korea. *Mycobiology* 45(3):129-138.

Punja, Z.K. 1985. The biology, ecology, and control of *Sclerotium rolfsii*. *Annual Review of Phytopathology* 23(1):97-127.

Sikirou, R., Assogba-Komlan, F., Tosso, F. et Agassounon, T. 2011. Efficacité de la sève du pseudo-tronc du bananier contre le champignon *Sclerotium rolfsii*, un agent causal du flétrissement de la tomate. *Bulletin de la Recherche Agronomique du Bénin* 70:47-59.

Talukder, M. R., Sarkar, A. and Rashid, H. 2019. The role of arbuscular mycorrhizal fungi in the bioprotection of ash gourd (Benincasa hispida) against damping off disease. *Fundamental and Applied Agriculture* 4(1) :704-712 : 2019 doi : 10.5455/faa.6098.

Touré, Y., Koné, M., Silué, Y.S. et Kouadio, J. 2013. Prospection, collecte et caractérisation agromorphologique des morphotypes de voandzou [*Vigna Subterranea* (L.) Verdc. (Fabaceae)] de la zone savanicole en Côte d'Ivoire. *European Scientific Journal* 9(24):308-325.

Xie, C., Huang, C.-H. and Vallad, G.E. 2014. Mycelial compatibility and pathogenic diversity among Sclerotium rolfsii isolates in the southern United States. *Plant Disease* 98(12):1685-1694. doi: https://doi.org/10.1094/PDIS-08-13-0861-RE.