Original Research Article

Study of the effects of cailcedrat (*Khaya senegalensis*) on late blight, the main onion disease (*Allium cepa* L.) in the Department of Diamare (Far North, Cameroon)

Abstract

Objective : Onion (*Allium cepa* L.) is a vegetable crop with an important economic asset for Cameroonian farmers. The objective of this study is to evaluate the effects of different formulations of *K. senegalensis* on late blight, the main onion disease (*Allium cepa* L.) in the department of Diamaré, (Far North, Cameroon).

Methodogy and results : For this purpose, an experimental split-splot device consisting of three blocks (repeats), comprising three varieties (Chagari, Goudami and Blanc de galmi) of onion and eight treatments (TtN, Ttp, THK1, THK2, TEFK1, TEFK2, TEEK1 and TEEK2) was used in two study sites (Gayak and Wouro-Mayo) and during two agricultural seasons (2020 and 2021). After data collection and analysis, the results obtained show that the mean value of the highest incidence was obtained with Ttn treatment (34.44) in Gayak in 2020, and the lowest value was obtained with THK2 (0.00) in Wouro-Mayo. In 2021, the highest mean value was recorded in Gayak with TtN (32.03) and the lowest incidence is observed with TEEK2 (0.37) in Wouro-Mayo. Moreover, the highest severity was obtained with TtN (17.58) in Wouro-Mayo in 2020, and the lowest with THK2 (0.00) at the same site. In 2021, the lowest severity was observed with THK2 (0.18) in Gayak and the highest with TtN (14.90) in Gayak. The highest yields were recorded with THK2 (160.27 t/ha) at Wouro-Mayo in 2020 and THK2 (169.46 t/ha) in 2021 at the same study site. On the other hand, the lowest yields were obtained in Gayak with TtN (79.6 t/ha) in 2020 and in 2021 with TtN (92.26 t/ha) at the same site.

Conclusion and application of findings : The oil and aqueous extracts of *Khaya senegalensis* bark could therefore constitute an alternative to synthetic pesticides in the context of integrated onion disease management in the Diamare department (Far North, Cameroon).

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Keywords : *Allium cepa, Khaya senegalensis,* late blight, incidence, severity, yield.

INTRODUCTION

Food security is a major concern for all countries in the world, especially developing countries where agricultural activity is still rudimentary and extensive (Miassi *et al.,* 2018). Agriculture is one of the main sectors of activity that contributes to the socioeconomic development of populations. It employs more than 40% of the world's workforce, including more than 52% in Africa and Asia (MOMAGRI, 2016). This sector is the development base of all emerging countries, including Cameroon. In this sector, market gardening occupies an important place for human food. Considered as a food sovereignty activity (FAO, 2016), vegetable crops play a key role in most nutrition and poverty alleviation programmes and contribute significantly to family incomes (Yolou *et al.,* 2015). Among the most important vegetable crops, we can mention: cucurbits, nightshades and alliaceae etc. Thus, onion cultivation is considered to be a vegetable crop with an important economic asset for Cameroonian farmers (Dinissia *et al.,* 2021). The onion (Allium cepa) is a herbaceous monocot belonging to the family Alliaceae whose domestication has been accompanied over time by a selection of cultivars with significant bulb development in the first year of cultivation (Frist and Frisen 2011). Over the past decade, global onion production has increased significantly. Indeed, onion (*Allium cepa)*, the second most cultivated vegetable in the world after tomatoes (Sakatai *et al.,* 2019) is one of the most important and consumed vegetable crops in the world because of its suitability at any time of the year (Mollavali *et al.,* 2016). World production of this vegetable crop amounted to 82.85, 106 tons per year with China, India and the United States as the top three producing countries (Abdou *et al.,* 2015). In Africa, the main onion producing countries are Egypt, Algeria, Morocco and Nigeria (FAOSTAT, 2016). Of all the crops cultivated, onion (*Allium cepa* L.) has become an important cash crop for these producers, after cotton and groundnuts. Thus, it covers more than 965 ha and employs 13600 producers, for an annual production of more than 38.72 t/ha and the potential yield varies between 30 and 60 t/ha depending on the variety (Alium *et al.,* 2021). Onion cultivation provides more than 6 billion CFA francs each year to producers in the Far North region (Agristat, 2012). Today, this sector represents an economic lung of great importance for the northern and far-northern regions, which account for about 85% of Cameroonian production (Essang *et al.,* 2003 ; Moutsavara *et al.,* 2021). However, despite a fairly high rate of production and the importance it plays on the socio-economic level, Cameroon does not always manage to meet the annual needs of consumption of this highly prized commodity. This is because of cumulative factors related to the seasonality of its production, its very high perishability, the low availability of improved seeds, poor cultural practices, post-harvest losses, declining soil fertility and especially fungal diseases (Mamadou, 2012 ; FAO, 2016). Among the fungal diseases, late blight is considered a limiting factor to onion cultivation in the far north. According to Maude *et al.* (2016), yield losses associated with this disease range from 30 to 70% when environmental conditions are favorable. These pest problems lead to field losses of up to 30 to 40% of crops (Kaboré, 2012). Indeed, onion downy mildew is caused by the fungus, Peronospora destructor, which develops throughout cultivation. Its development is characterized by particular climatic conditions (rainy and very humid weather) with optimal temperatures of 11 to 13 °C (FREDON, 2005). This fungus is preserved in the soil in plant debris. The first sign of the presence of late blight is the appearance of velvety felting on the leaves that remain green. Early in the morning, felting appears purplish due to the pigmentation of spores (sporangia) formed overnight on the surface of the leaf. Subsequently, most of the spores are dispersed in the air and whitish felting remains on the leaf. Over the next two to four days, infected leaves turn pale green, then yellow, and finally collapse and die (Jesperson *et al.,* 1987). Several strategies are used to control late blight, namely cultural control. These are measures to minimize factors that predispose the crop to infection or infestation, such as selecting healthy seeds with a high germination rate from a reliable seller; seed treatment to control pathogens; inspection of seedlings at source: crop association; the selection of appropriate rotation crops; seeding and transplanting only when the temperature and humidity are adequate. Mukerji *et al.* (1975) reported that primary inoculum can be reduced by crop rotation with carrots, lettuce, celery and other crops not related to onions, onion waste can be destroyed, and waste piles cannot be left near onion fields. But in general, this method of struggle gives unsatisfactory results. Genetic control using late blight-resistant seeds or varieties is effective, however, resistant varieties are not available. As for chemical control, despite its effectiveness, it is expensive, restrictive and also has harmful effects on the environment and is toxic for consumers. The misuse of pesticides induces the selection of resistant strains, environmental pollution and numerous poisonings on the part of both vegetable producers and consumers (Son *et al.,* 2017). In addition, synthetic insecticides have a detrimental effect on useful entomofauna (Sigrist *et al.,* 1994) including natural enemies of pests, hence the need to seek alternatives to control by botanical insecticides. Several botanical control alternatives have been developed, including the use of plants with insecticidal, anti-appetizing and repellent properties, respectful of the environment (Megueni *et al.,* 2011 ; Ngakou *et al.,* 2012 ; Déla *et al.,* 2014). The current trend is the formulation of natural substances by using aqueous extracts and essential oils like that of Khaya senegalensis as biopesticides is necessary (Ngakou *et al.,* 2014). It is in this context

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that this study on the effect of different formulations of *K. senegalensis* against late blight, the main onion disease in the department of Diamaré (Far North, Cameroon) is situated.

MATERIALS AND METHODS

Description of the study site

This study was conducted in two sites (Gayak and Wouro-Mayo) and in two agricultural seasons on 2020 and 2021. The locality of Gayak (10°37', 25'' North, 14°22'07'' East) and the locality of Wouro-Mayo (10°36'47'' North, 14°19',39'' East) are located respectively in the district of Maroua 1st and 2nd, Departement of Diamre.

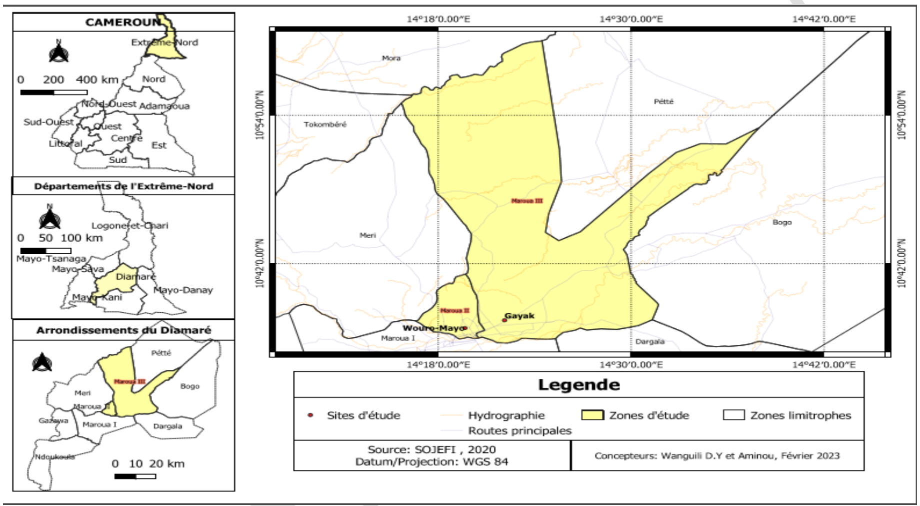

Figure 1 : Study Site Location Map

Material

The plant material consists of the three commercial varieties of onion : the Chagari and Goudami ecotypes collected from local producers in Gazawa and Mora and the improved white variety of Galmi purchased from the Technician stores in the city of Ngaoundere. These are widespread and adapted cultivars in the study areas. The aqueous extracts of the leaves, bark and oil of Khaya senegalensis have been used as formulations to control Peronospora destructor, a mildew pathogen of the onion. Liquid soap, NPK chemical fertilizer formulation 20-10-10, urea and insecticide Conquest C176 EC were used in this study.

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Experimental set-up

The experimental device used is a split-splot with an area of 271.8 m² (45.3×6 m) consisting of three blocks (corresponding to three repetitions) separated by 2m. Each of the blocks consists of three varieties that have received eight (8) distinct treatments, i.e. 24 elemental plots per block. Each plot unit of 1.2 m2 has 60 plants divided into 5 rows and 12 plants per line with a spacing of 10 cm between the planes and 20 cm between the lines, an elevation of 5cm per ridge thickness to avoid light flooding and increase yield (Sanon *et al.,* 2001).

Setting up trials

A total of 4320 plants were transplanted per site divided into 1440 plants per block. Two experimental sites dislocated into two agricultural seasons for two years (2020 and 2021) were the subject of our study. The different treatments (8) consist of a negative control (TtN) ; a positive control treatment based on Conquest C176 EC (TtP), a treatment based on *K. senegalensis* oil 60 ml diluted in 1 L of water (THK1) ; a treatment based on *K. senegalensis* oil 80 ml diluted in 1L of water (THK 2), a treatment based on aqueous extract of *K. senegalensis* leaf powder of 90 g diluted in 2 L of water (TEFK 1); a treatment based on aqueous extract of *K. senegalensis* leaf powder of 100g diluted in 2 L of water (TEFK2), a treatment of aqueous powder extract of the bark of *K. senegalensis* of 90g diluted in 2 L of water (TEEK1) and an aqueous extract of powder of the bark of *K. senegalensis* of 100g diluted in 2 L of water (TEEK2). These treatments were applied using a 1.5 L trigger sprayer two weeks after transplanting and then repeated every 30 days in the elemental plots up to two weeks before the onion harvest. A fertilizer application (NPK 14 - 23 -14) was carried out respectively on the 14^{th} and 44^{th} days after transplanting at a rate of 18g/1.2 m². An application of urea was carried out at a rate of 18 g/1.2 m² from the 60^{th} day after transplanting. The same methodology was used in each experimental site.

Data collection

Data collection included height (assessed using one tape measure) and leaf count (by count) estimated at 90 days after transplanting, bulb diameter (cm), bulb weight (kg/bulb) and yield (t/ha) were assessed 02 weeks post-harvest. Sampling was done by removing border plants to reduce the risk of contamination (one line on either side). The data were taken on five (05) plants among the (60) that counted the elementary plots or (15) plans per treatment. The selection of plants was made randomly during sampling. The incidence (Singh *et al.,* 1999) and severity (Tchoumakov *et al.,* 1990) were assessed at 105 days after transplanting by the following formulas to assess the development of onion downy mildew in each treatment.

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$I(\%) = np \times 100/N$ With I : incidence, *np : Number of feet attacked*, N: total number of feet

$S\ (\%) = \frac{\sum n * I}{N} \times 100$ With S : severity, *n : Number of feet attacked*, I : severity index with estimate 0 = no symptoms ; ¼ = 25% ; 2/4 = 50% ; ¾ = 75%; 4/4 = 100% diseases.

DATA ANALYSIS

The data collected were analyzed using XLSTAT 2007 software, which allowed us to perform the analysis of variance (ANOVA). The DUNCAN test compared the means of the measured parameters at the 5% threshold when the difference was significant.

RESULTS AND DISCUSSION

Effects of treatments on the incidence of onion downy mildew at the Gayak site

Figures 2 and 3 present the effects of treatments on the incidence of onion downy mildew at the Gayak site in 2020 and 2021. The analysis of variance performed at 105 days after transplanting shows that TtN, TEFK2, THK2 and THK2 treatments significantly influenced (P<0.0001) disease incidence during the two years of evaluation. The highest mean incidence values were observed in plots treated with TtN (34.44), TEEK1 (19.41) in 2020 and TtN (32.03), THK1 (24.62) in 2021, respectively. In contrast, the smallest incidences were obtained with Ttp (1.46), TEFK2 (2.03) in 2020 and THK2 (0.37), TtP (1.66) in 2021. The most sensitive variety to late blight is the Chagari variety with an average incidence of 14.72 and the least susceptible is the white variety of Galmi with an average incidence of 9.78 for all treatments in 2020. On the other hand, in 2021 the variety most sensitive to late blight is the Blanc de Galmi 15.76 variety and the most resistant is the Goudami 12.7 variety.The TEEK2, THK2 treatments proved very effective with the Blanc de Galmi and Gougami varieties in 2020 in which the absence of the disease was found. In addition, onion downy mildew appears in all treatments in 2021. Indeed, the significant decrease in the incidence of the disease after treatment with *K. senegalensis* oil could be explained by the existence of compounds such as flavonoids and alkaloids causing inhibition of the development of *Peronospora destructor,* pathogen responsible for onion downy mildew. The results obtained are similar to those of Sagitov *et al.* (2011) who also obtained a 100% reduction in the incidence of fusarium wilt after soaking of seedlings followed by foliar spraying with successively garlic and pepper extracts at 4% and note an increase in the weight and yields of treated plants. In the same vein, it has been shown that the essential oil of X. aethiopica fruits strongly inhibits the mycelial growth of S. rolfsii, resulting in a considerable reduction in the incidence of the disease on treated tomato plants compared to untreated plants (Bolou *et al.,* 2015).

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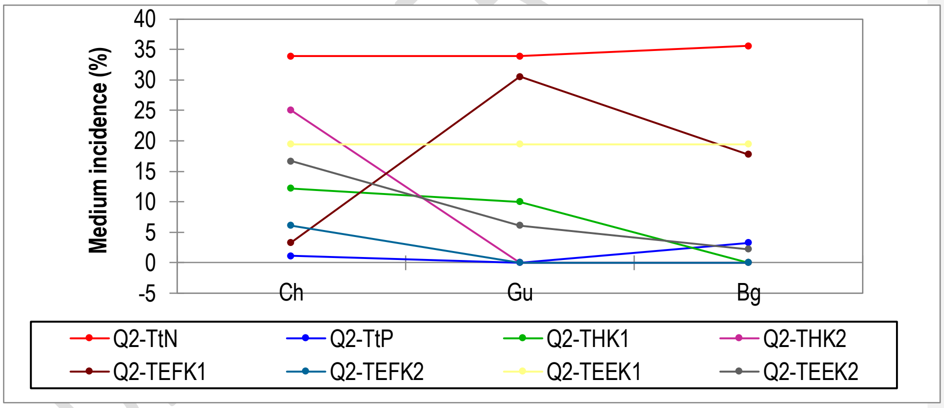

Figure 2 : Incidence of onion downy mildew in 2020

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2: treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

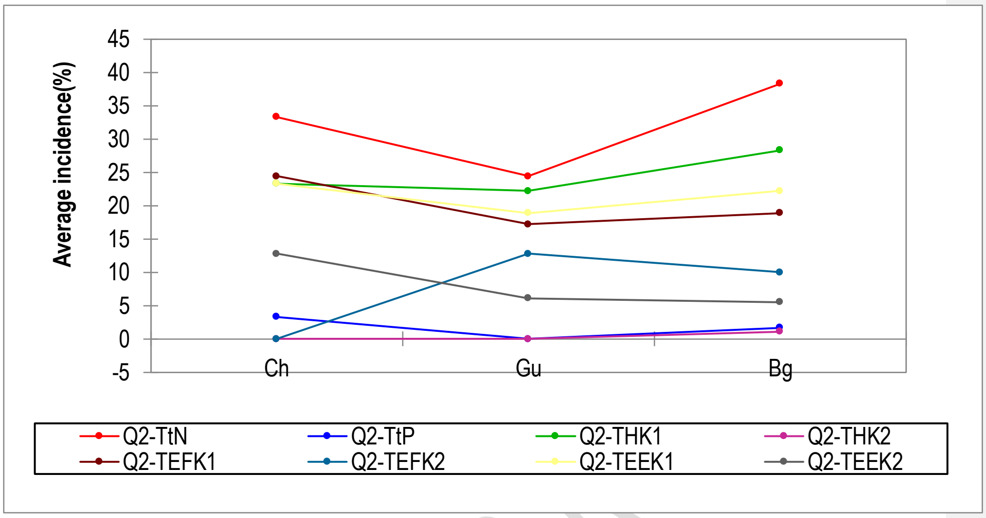

Figure 3 : Incidence of onion downy mildew in 2021

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2: treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

Effects of treatments on the incidence of onion downy mildew at the Wouro-Mayo site

Figures 4 and 5 present the effects of treatments on the incidence of onion downy mildew at the Wouro-Mayo site in 2020 and 2021. The analysis of variance performed 105 JAR shows that TtN, TEFK2, THK2, THK1 and THK2 treatments showed a significant difference (P <0.0001) in disease incidence during both years. The highest mean incidence values were obtained with TtN (29.06) and TEFK1 (11.66) in 2020 and with TtN (27.22) and TEEK1 (17.21) in 2020 respectively. In contrast, the smallest incidences were obtained with THK2 (0.00) and TEFK2 (0.74) in 2020 and with TEEK2 (0.37) and TtP (1.41) in 2021. In 2020, the most sensitive variety to late blight is the Chagari variety with an average incidence of 10.69 and the least susceptible is the Galmi White variety with an average incidence of 3.74. On the other hand, in 2021 the most sensitive variety to late blight is the Chagari variety with an average incidence of 12.98 and the least sensitive is the Goudami variety with an incidence of 8.19 for all treatments. TEFK2, THK2 treatments have proven to be very effective with the Blanc de galmi and Goudami 2020 varieties, and there is also zero incidence with THK2 on the Chagari variety hence the absence of the disease. In 2021, it is found that the disease was observed in all treatments. Indeed, the presence of polyphenolic compounds and saponins in extracts of the leaves and bark of *K. senegalensis* could be responsible for the decrease in the incidence of downy mildew in onions. The results obtained are similar to those of Kulimushi *et al.* (2014) who also revealed the reduction in the population density of black bean aphids on plants treated with garlic extract and the combination of garlic extract and papaya leaves. Garlic and onion extracts kill the aphid Myzus persicae by preventing it from landing and feeding on its host plant (Hori 1996).

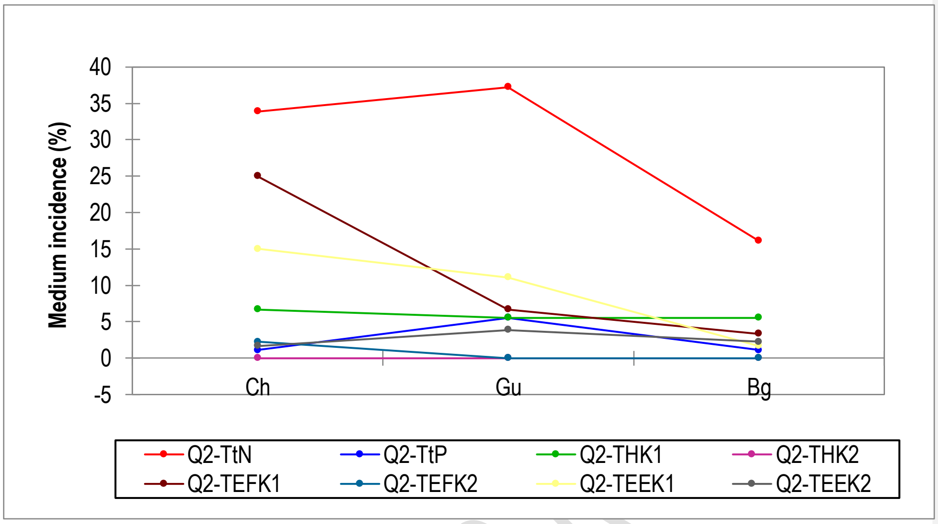

Figure 4 : Incidence of onion downy mildew in 2020

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2: treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

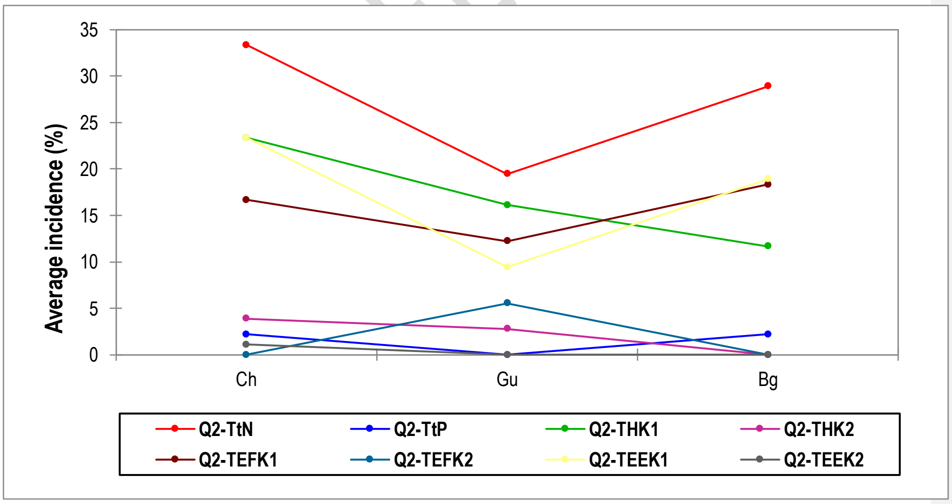

Figure 5 : Incidence of onion downy mildew in 2021

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2 : treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

Effects of treatments on onion mildew severity at the Gayak site

Figures 6 and 7 present the effects of treatments on the severity of the Gayak site in 2020 and 2021. The analysis of variance performed 105 JAR shows that TtN, TEFK2, THK2, and THK2 treatments showed a significant difference (P<0.0001) in disease severity during the two years of study. The highest mean severity values were obtained with TtN (16.66), TEEK1(11.8) treatments in 2020 and TtN (14.9), THK1(10.91) treatments in 2021, respectively. In contrast, the smallest severities were achieved with TtP (0.97), TEFK2 (2.45) treatments in 2020 and THK2 (0.18), TtP (0.55) treatments in 2021. The most sensitive variety to late blight is the Goudami variety with an average severity of 9.75 and the least susceptible to late blight is the Blanc de galmi variety with an average severity of 5.47 in 2020. Moreover, in 2021 the most sensitive variety to late blight is the Blanc de galmi variety with an average severity of 7.11 and the least sensitive is the Goudami variety with a severity of 6.04 for all treatments. TEFK2 and TtP treatments have proven to be very effective against late blight with Blanc varieties in 2020. In addition, zero severity is observed with THK2, TtP and TEFK2 treatments on the Goudami variety hence the absence of the disease. Indeed, chemical compounds such as tannins, quinones and steroids present in *K. senegalensis* leaf and oil extracts may be unfavorable to the development of champions spores and cause a significant decrease in onion downy mildew pathogen. Abakar *et al.* (2020) reports that, H. suaveolens extract reduced the density of *H. armigera* on cotton which is consistent with the work encountered in the literature. Fall *et al.* (2017) and Biao *et al.* (2018) report that *H. suaveolens* extract reduces infestation rates of *Sitophilus* spp. a pest of corn and green pepper variegated potato virus vectors respectively.

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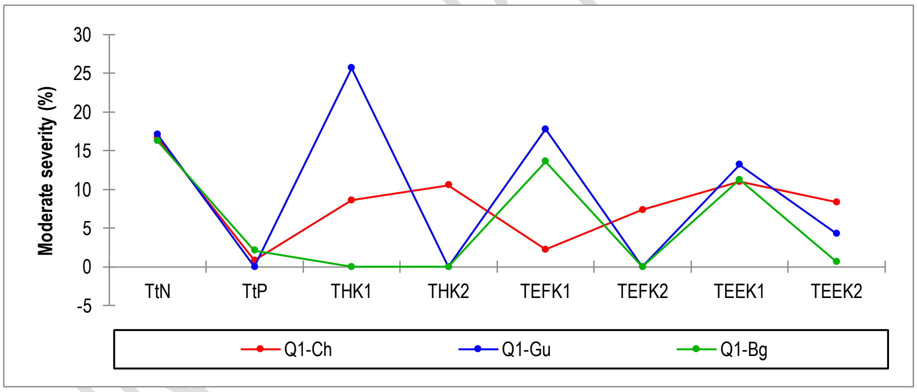

Figure 6 : Severity of onion downy mildew in 2020

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2 : treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

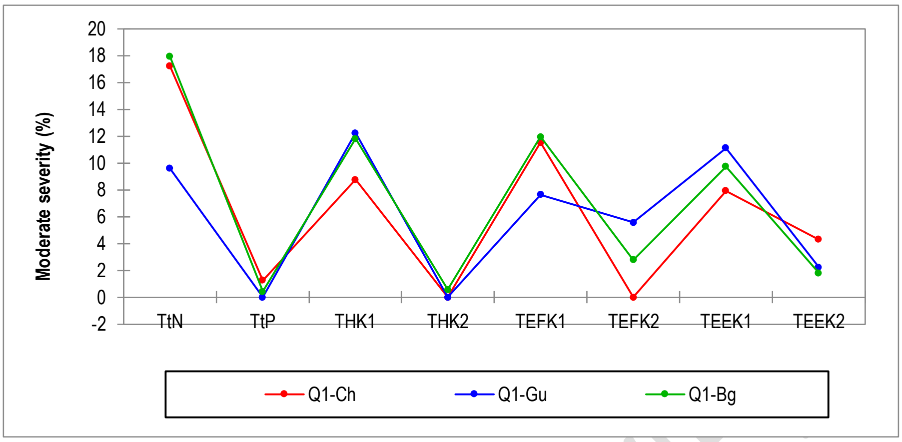

Figure 7 : Severity of onion downy mildew in 2021

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2 : treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

Effects of treatments on onion mildew severity at the Wouro-Mayo site

Figures 8 and 9 present the effects of treatments on onion downy mildew severity at the Wouro-Mayo site in 2020 and 2021. The analysis of variance performed 105 JAR shows that TEFK2, THK2, TEEK2 treatments, showed a significant difference (P <0.0001) on the severity of the disease. The highest mean severity values were obtained with TtN (17.58), TEFK1 (6.06) in 2020 and TtN (14.62), TEEK (8.28) in 2021, respectively. On the other hand, the smallest severities are observed with THK2 (0.00), TEEK2 (0.78) in 2020 and with TEEK2 (0.37), THK (0.73) in 2021. The variety most susceptible to onion downy mildew is the Chagari variety with an average severity of 6.04 and the least susceptible to onion downy mildew is the white galmi variety with an average severity of 2.72 in 2020. In addition, in 2021 the Chagari variety remains the most sensitive to onion downy mildew with an average severity of 7.23 and the Goudami variety recorded an average severity of 4.12 for all treatments. TEEK2, THK2 treatments proved to be very effective with the Goudami and Blanc de galmi variety in 2020. On the other hand, in 2021 there are zero severities with THK2, TtP and TEEK2 on the Goudami and Blanc de galmi varieties, thus leading to the absence of the disease. Plant extracts have chemicals that are active against insect pests of crops. These results corroborate those of Gnago *et al.* (2010) who proved the effectiveness of aqueous extracts of neem seed against okra and cabbage aphids in Côte d'Ivoire. Déla *et al.* (2014) also demonstrated in the laboratory that the aqueous and hydroethanolic extract of neem leaves led to 95% mortality of Myzus persicae nymph and decreased adult survival and fecundity.

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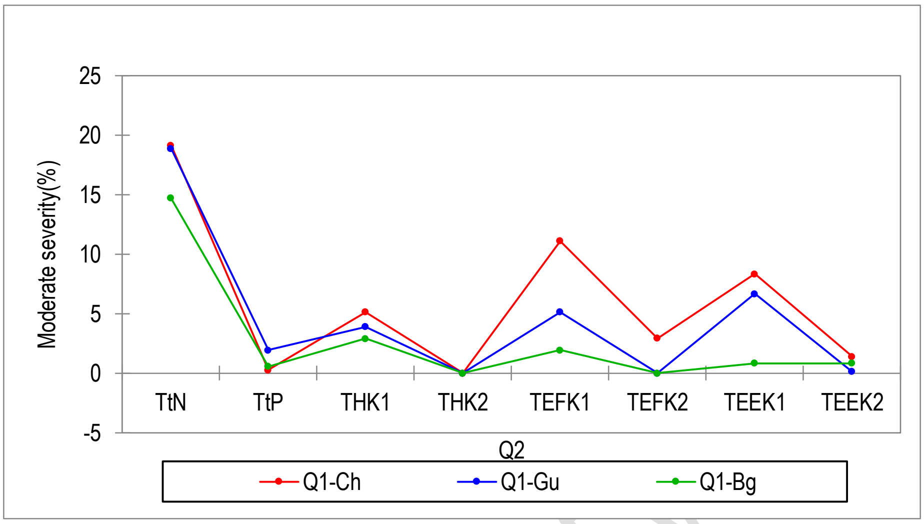

Figure 8 : Severity of onion downy mildew in 2020

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2 : treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

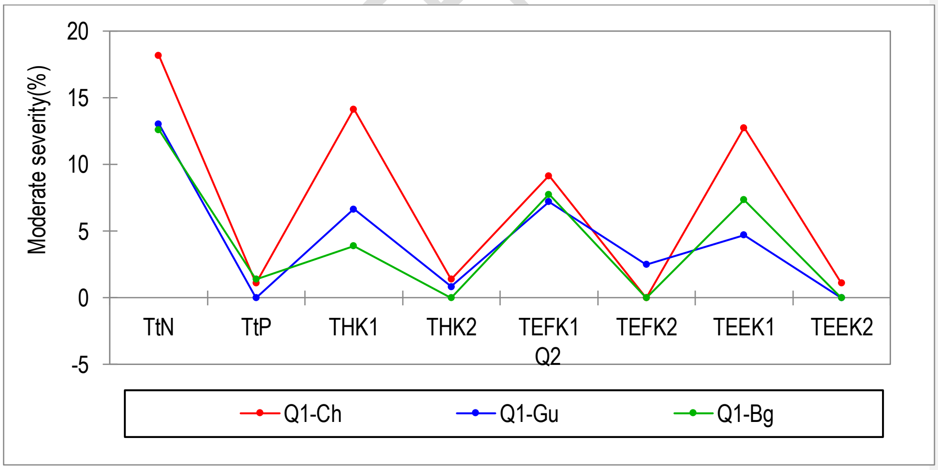

Figure 9 : Severity of onion downy mildew in 2021

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2 : treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

Effects of treatments on onion bulb yield in t/h at the Gayak site

Figures 10 and 11 present the effects of treatments on onion bulb yield (t/h) at the Gayak site in 2020 and 2021. The different treatments applied had a significant effect (P<0.0001) on the average yield of onion bulbs over the two years of study. Indeed, average yields varied from 79.6t/ha to 143.86 t/ha in 2020 and from 92.66t/ha to 151.6t/ha in 2021. In 2020 the highest average yields were obtained with THK2 (143.86t/ha) and TEEK2 (138.86 t/ha) in 2020, and THK2 (151.6 t/ha), TEEK2 (144.8 t/ha) in 2021. On the other hand, the lowest values were obtained with Tt (79.6t/ha), TEEK1 (113.86 t/ha) in 2020, and TtN (92.66 t/ha), TEEK1 (121.46 t/ha) in 2021. In addition, the Goudami variety has the highest average yields during the two years of studies, i.e. 153.5 t/ha in 2020 and 163.7 t/ha in 2021, unlike the Chagari variety which gave the lowest yields, i.e. 85.25 t/ha in 2020 and 82.5t/ha in 2021. As a result, the increase in bulb yield of plots that received THK2 and TEEK2 is explained by the fact that the components of these treatments would have allowed the plants to be less attacked, resulting in a good sanitary and productive status. The results obtained are similar to those of Mondedji *et al.* (2014) who investigated the efficacy of the aqueous extract of *Azadirachta indica* against cabbage pests and obtained the highest masses of marketable apple cabbage on plots treated with hydroethanolic extract of neem leaves.

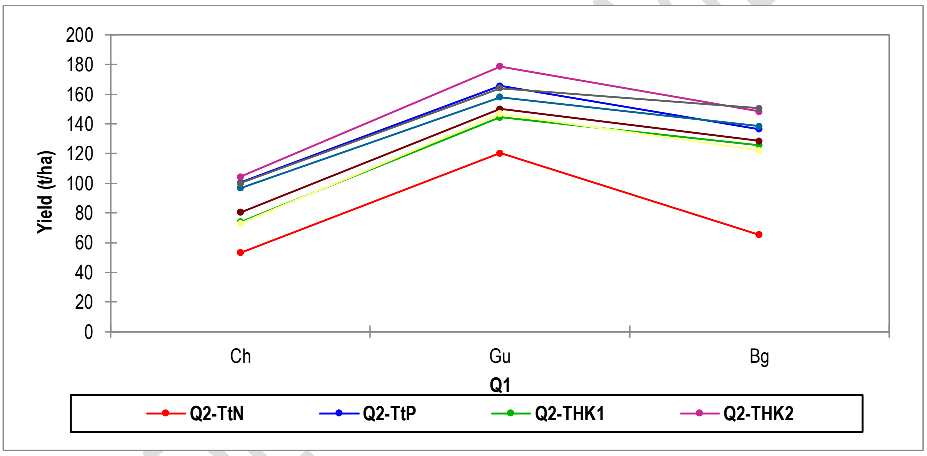

Figure 10 : Onion bulb yield in 2020

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2 : treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

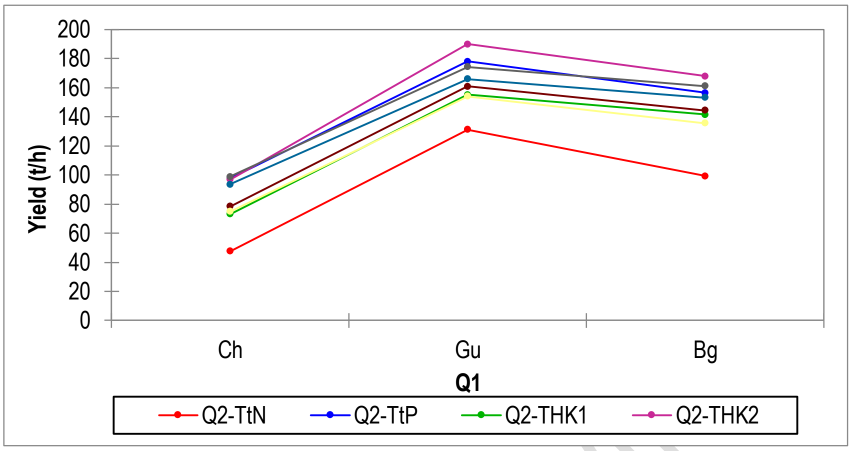

Figure 11 : Onion bulb yield in 2021

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2 : treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

Effects of treatments on the t/h yield of onion bulbs at the Wouro-Mayo site

Figures 12 and 13 present the effects of treatments on onion bulb yield (t/h) at the Wouro-Mayo site in 2020 and 2021. The different treatments applied had a significant effect (P<0.0001) on the average yield of onion bulbs during the two years of study. Indeed, average yields varied from 88.26t/ha (with TtN) to 160.26 t/ha (with THK2) in 2020 and from 97.33 t/ha (with TtN) to 169.46 t/ha (with THK2) in 2021. However, the highest average yields were obtained with the treatments THK2 (160.26 t/ha) and TEEK2 (154.94 t/ha) the lowest values were obtained with the treatments TtN (88.26 t/ha) and THK1 (118.26 t/ha) in 2020. In 2021, and 97.33 t/ha and 125.86 t/ha in 2021. In addition, the Goudami variety has the highest average yields during the two years of studies with values of 176.6 t/ha in 2020 and 184.85 t/ha in 2021, unlike the Chagari variety which gave the lowest yields of 95.55 t/ha in 2020 and 96.85 t/ha in 2021. Mondedji *et al.* (2014), report that the significant presence of Auxiliary insects combined with the effects of neem appear to be the basis for the higher yields provided by plots treated with the botanical extract. Ngakou *et al.* (2014) also showed that improving plant mineral nutrition and adding biopesticides increase plant yield.

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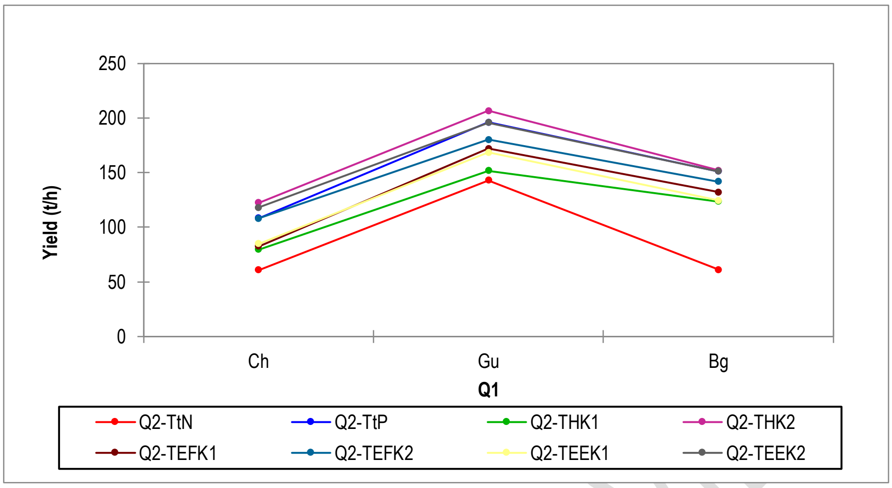

Figure 12 : Onion bulb yield in 2020

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2 : treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

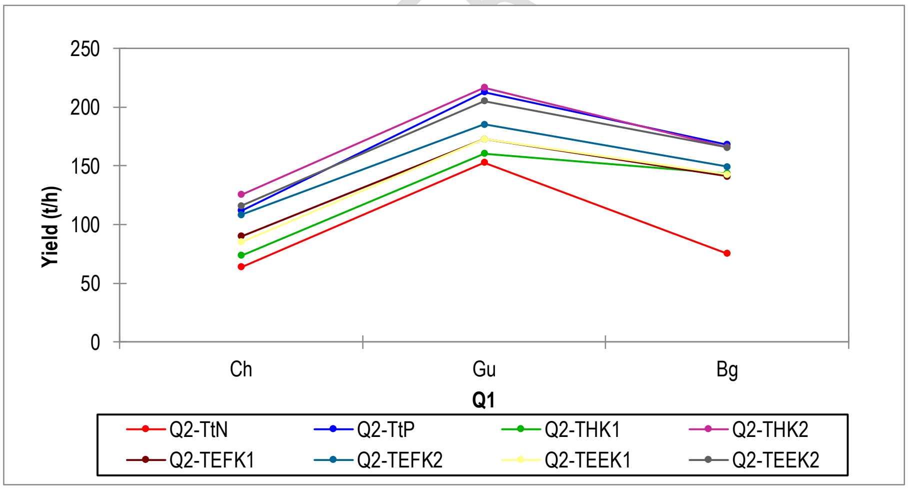

Figure 13 : Onion bulb yield in 2021

TTN : negative control, TTP : positive control treatment having received Conquest C176 EC, THK1 : treatment with *K. sengalensis* oil at a dose of 60ml, THK2 : treatment with *K. sengalensis* oil at a dose of 80ml, TEFK1 : treatment with *K. sengalensis* leaf extract at a dose of 90g/2l ; TEFK2 : treatment with *K. sengalensis* leaf extract at a dose of 100g / 2l, TEEK1: treatment with K. senegalensis bark extract at a dose of 90g / 2l, TEEK2 : treatment with *K. senegalensis* bark extract at a dose of 100g / 2l. Q2 : treatment, Q1 : variety, Ch : Chagari, Gu : Goudami, Bg : Galmi white.

CONCLUSION

The present study allowed us to compare the effectiveness of a *K. senegalensis* based biopesticide against the main onion disease in the Department of Diamare (Far North, Cameroon). This study shows that aqueous extracts of bark and leaves at a dose of 100 g / 2l and K. senegalensis oil at a dose of 80 ml have been shown to be effective against *Peronospora destructor,* onion downy mildew pathogen at both sites in the control of onion downy mildew. These applications not only significantly reduced the incidence and severity of the disease but also contributed to a considerable increase in yield compared to the negative control. The highest values were recorded in 2020 with TEEK2 (1 38.13 t/ha), THK2 (143.86 t/ha) in Gayak and THK2 (160.26 t/ha), TEEK2 (154.93 t/ha) in Wouro-Mayo. Moreover, in 2021 the highest average yields were recorded with THK2 (151.6 t/ha), TEEK2 (144.8 t/ha) in Gayak and THK2 (169.46 t/ha), TtP (164.26 t/ha) in Wouro-Mayo. These different extracts can be used as alternatives to synthetic pesticides in the context of integrated management of onion downy mildew. Indeed, the reduction in the frequency of application of plant extracts and the development of concentrated formulations of active ingredients will promote the adoption of these different plant extracts with insecticidal properties by market gardeners. It is in this option that it is necessary to raise awareness among market gardeners about the harmful effects of synthetic pesticides on their health and their environment.

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REFERENCES

Abakar A. S., Tchuenteu, T. L., Kosma, P., Koulagna, I. H., Kaka, A. T., Megueni, C., 2020. Mycorrhizae interaction and *Hyptis suaveolens/Cyperus rotundus* extracts : Bioinsecticides suitable for the protection of cotton against *Helicoverpa armigera. Journal of Applied Biosciences,* 149 : 15270-15279.
Abdou, R., 2015. Morphological and agronomic variability of onion ecotypes (*Allium cepa* L.) identified by Niger producers. *Tropicultura,* 33 : 1-14.
AGRISTAT., 2012. Yearbook of Agricultural Sector Statistics. Directorate of Agricultural Surveys and Statistics. MINADER, Yaoundé, Cameroon. Pp. 17 : 123.
Alium, H., Haouvang, L. H., Toukam, T. S., Ngakou, A., 2021. Potential of compost, compost tea and aquerous neem leaves extract in reducing some diseased and boosting onion (*Allium cepa* L) production in the field at Gapring-Lara in the Department of Mayo Kani (Cameroon). *International Journal of Biological and Chemistry Sciences*, 15 (4) : 1524-1543.
Biao, F, Afouda, L., Koné, D., 2018. Effet des extraits aqueux à base d'ail (*Allium sativum*), de neem (*Azadirachta indica*), de *Hyptis suaveolens* et d'huile d'arachide sur les pucerons vecteurs du virus de la panachure du piment (*Capsicum chinense*) au Nord-Benin. Journal of Animal and Plant Sciences, 38 (3): 6336-6348.
Bolou, B. A., Kouakou, T. H., Kouame, G. K., Kassi, F., Tuo, S., Cherif, M., Lezin, B., Kone, D., 2015. Inhibition of *Sclerotium rolfsii* sacc. (Corticiaceae), causative agent of tomato stem crown rot (Solanaceae), by *xylopia aethiopica* (dunal) a. Rich (annonaceae) And *Trichoderma* sp. *European Scientific Journal,* 1857 – 7881.
Déla, M. A., Koffivi, K. G., Komina, A., Arnaud, A., Philippe, G., Adolfe, G. I., 2014. Evaluation of neem leaves-based preparations as insecticidal agents against the green peach aphid, *Myzus persicae* (Sternorrhyncha : Aphididae). *African Journal of Agricultural Research,* 9 :1344– 1352.
Dinissia, J., Tchuenteu, T. L., Abba, M., Hawaou, Habib, A., Nwaga, D., Megueni, C., 2021. Diagnosis of onion production in the northern part of Cameroon. *International journal of Biological and Chemical sciences,* 15(3) 923-935.
Essang T, Woin N, & Badeboga E, A., 2003. Strategies and behaviors of economic actors in the onion sector. Cirad – Prasac:10.
Fall R, Ngom S, Sembène ASM., 2017. Insecticidal activity by fumigation of essential oils of *Callistemon viminalis*, *Melaleuca leucadendron* and *Hyptis suaveolens* vs. Sitophilus spp. corn pests: 31-36.
FAO., 2018. Onion production in the world. http://www.fao.org/faostat/fr/#data/QC/visualize (accessed November 16, 2018).
FAOSTAT. FAO Agricultural Statistics Database, http://faostat.fao.org/ (10/06/2016).
FREDON.,2005. Implementation of reasoned control of onion downy mildew using the non-irrigated miloni risk forecasting model. 2005 ; 280 : 52-56.
Fritsch R. Friesen N., Chapter 1., 2002. "Evolution, Domestication, and Taxonomy". In:H.D. Rabinowitch and L. Currah (eds.) Allium Crop Science – Recent Advances. CABI Publishing, Wallinford UK, pp. 5-30.
Gnago, A. J, Danho, M., Atcham, A. T., Fafana, K. I., Kohou, G. A., 2010. Effectiveness of neem (Azadirachta indica) and papaya (Cm'lca papaya) extracts in the control of okra (Abelmoschus esculentus) and cabbage (Brassica oleracea) insect pests in Côte d'Ivoire. *J. Biol. Chem. Sci.,* 4(4), 953-966.
Jesperson, G.D, et J.e. Sutton., 1987. Evaluation of a forecaster for downy mildew of onion (*Allium cepa* L.)., 6 : 95-103.
Kabore, S. J., 2012. Study of the pathogenicity of three major fungal agents on onion (Allium cepa L.) and evaluation of the antagonistic effects of five isolates of Trichoderma spp. Against these agents in vitro. Final thesis for the obtaining of the diploma 53 of Agricultural Engineer, Centre Agricole Polyvalent de Matourkou (CAPM), Bobo Dioulasso, Burkina Faso. 55p.
Kulimushi. F, Gardiner D. M, Manners J. M, Kazan K., 2014. *Fusarium* Pathogenomics. *Annu. Rev. Microbiol.*, 67 : 399–416.

Maldangoi Y, Woin N, Cathala M., 2003. Onion producers in Northern Cameroon : the challenges of a sector in search of a place in the sun. Cirad – Prasac. 8p.
Mamadou B. S., 2012. Support for the marketing and structuring of the rice and onion sectors and Operational strategy for the implementation of the component's activities. 50p.
Maude, A., 2016. Support to the Quebec Pytosanitary Strategy in Agriculture, PRIME-VERT Qhebec. *Phyd.,*1 : 151-158.
Megueni C, Awono E. T, Ndouenkeu, R., 2011. Simultaneous effect of dilution and combination of Rhizobium and mycorrhizae on leaf production and physico-chemical properties of young leaves of vigna unguiculata (L.) Walp. *Journal of Applied Biosciences,* 41 : 2668-2676.
Miassi, Y. E. S., Dossa, F. K., Banzou, K., 2018. Onion (*Allium cepa*) Production in Urban and Peri-Urban Areas : Financial Performance and Importance of this activiy for Market Gardeners in Southern Benin. *Current Investigation in Agriculture and Current Research,* 3.
Mollavali M, Bolandnazar S.A, Rohn S, Zaare Nahandi F., 2010. Flavonol glucoside and antioxydant enzyme bio synthesis affected by mycorrhizal ungi in vaious cultivars of onion (*Allium cepa* L.). *Journal of agricultural and food local chemistry,* 64 :71-77.
MOMAGRI., 2017. Key figures of Agriculture, http:// www.momagri.org/FR/chiffres-keys-of-agriculture/With-near-40%25-of-the-world-active-population-agriculture-is-the-first-provider-of-jobs-of-the-planet 1066.html, (20/09/2017).
Mondédji, A. D., 2015. Analysis of some aspects of the vegetable production system and producers' perception of the use of botanical extracts in the management of insect pests of vegetable crops in southern Togo. *Int. J. Biol. Chem. Sci.,* 9 (1) : 98- 107.
Moutsavara, G., Philippe, K., Noubissié, T. J. B., Dounia, D., 2022. Analysis of the genotype interaction both environment and stability of some onion cultivars for the acidity and sugars of bulbs in the Sudano-Sahelian zone of Cameroon. *Sahelian journal of engeniring and applied Sciences,* 1(02) : 1-22.
Mukerji, K.G., 1975. Peronospora destructor. CMI Descriptions of Pathogenic Fungi and Bacteria, No. 456. Commonw. Mycol. Inst., Kew, Surrey, Angleterre.1 : 2.
Ngakou A, Koehler H, Ngueliaha H.C., 2014. The role of cow dung and kitchen manure composts and their non-aerated compost teas in reducing the incidence of foliar diseases of *Lycopersicon esculentum* (Mill). *Int. J. Agril. Res. Innov. & Tech.*, 4 (1): 88-97.
Ngakou A, Koundou N, Koehler H., 2012. The relative effects of compost and non- aerated compost tea in reducing disease symptoms and improvingtuberization of *Solanum tuberosum. International Journal of Agriculture Research and Review.* 504-512.
Sagitov A. O, Ell-Habbaa G. M, Ell-Fiki I. A., 2011. Studies on tomato wilt caused by Fusarium oxysporum f.sp. Lycopersicum in kazachestan. 1b: effect of exogenous application of garlic and black pepper extracts as resistance inducer treatments on the wilt disease incidence and some plant growth parameters, 1(049) : 113-119.

Sakatai D.P, Chenjou R, Bassala, Sobda G, Kamga R.T. and Hamidou A.A., 2019. Characterization five varieties of onion (*Allium cepa* L) from the physical parameters of maturation of bulbs with a view to optimising their production in the extreme North of Cameroon. *Africa sciences,* 15 : 314-331.
Sigrist JC, Martin T, Renou A., 1994. Effet non intentionnels des pesticides sur l'entomofaune utile des cotonniers. Acte de la réunion phytosanitaire de coordination Cultures Annuelles Afrique Centrale, Maroua, Cameroun.: 154-175.
Singh, S. R, Jackai, L. E. N, Thottappilly, G., Cardewell, K. F., Myers, G. O., 1999. Status of research on Constraints to cowpea production. In: Biotechnology: enhancing research on tropical crops in Africa. 21-26.
Son, D, Somda, I, Legreve, A., Schiffers., 2017. Phytosanitary practices of tomato growers in Burkina Faso and risks to health and the environment. Agriculture Notebook. 26 : 25005.

TChumakov A.E., Zaharova., 1990. Influence and statistics of disease development. *In :* Disease damage to agricultural crops. Edition Agroprome, Moscow. 5-60.