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On-Farm Evaluation of Deleafing Frequency on the Severity of Black Sigatoka Disease (*Mycosphaerella fijiensis* Morelet) and Yield of Banana (*Musa* spp)

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Authors' contributions

This work was carried out in collaboration between all authors. Author KA designed the study, collected the data, performed the statistical analysis and wrote the protocol. Authors FDE and KA managed the analyses of the study. Authors TDN and FDE managed the literature searches and did the write up. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

Bananas are susceptible to the highly damaging black Sigatoka disease (BSD) caused by the fungus (*Mycosphaerella fijiensis).* The objective of this study was to evaluate the effect of leaf pruning frequency on the control of the BSD and the yield of banana. The study was carried out at Njombe (Lat 4º 36' N, Long 9º 40' E, 170 m above sea level) in a randomized complete block design with four treatments (3-day, 6-day, 9-day and 12-day pruning frequencies) and three replications. Data were collected on the different stages of evolution of the disease, percentage infection rate, weekly rate of leaf loss, number of leaves at harvest, yields (bunch weight and mid finger circumference and the monetary value of the yields. The results show that the highest maximum percentage rate of infestation of the disease (54.00 % and 50.53 %) was recorded in the 12-day and 9-day frequencies respectively. The lowest weekly rate of leaf loss (0.82 and 0.85 leaves/week) was recorded in the 6-day and 3-day frequencies which differ significantly from 1.90 and 1.38 leaves/week in the 12-day and 9-day frequencies. A statistically significant difference was recorded in the number of leaves at harvest with the highest of 4.20 leaves recorded in the 6-day frequencies. The highest average bunch weight of 32 kg (26.10 %) estimated at 57.36 t/ha was recorded in the 6 day frequency, while 36.8 cm average mid finger

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circumference was recorded in the 3-day frequency. The 6-day frequency registered the highest monetary value of USD 52,184 /ha, which does not differ significantly from that of the 3-day frequency of USD 52, 021 /ha. The lowest monetary value was recorded in the 12-day frequency of USD 45, 878. From the results of the study, the 6-day pruning frequency could be recommended for practice to accompany the chemical control.

Keywords: Banana; black Sigatoka disease; economic analysis; leaf pruning; deleafing; Mycosphaerella fijiensis.

1. INTRODUCTION

Banana (*Musa* spp) is cultivated in more than 120 countries in five continents. In terms of world production, banana is the fourth food commodity after rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) and rank first among fruits. In West and Central Africa, banana plays an important role in food security, employment, income generation in rural and urban areas. Cameroon produces about 1.4 million tonnes of banana a year ranking fourth in world production and first in Africa. The banana sector in Cameroon contributes about 6% the Gross National Product and over 50 000 permanent jobs [1].

Diseases are among the most important factors in banana production worldwide [2]. Black Sigatoka disease (BSD) is the most important of these diseases. It causes significant reduction in leaf area, yield losses of 50% or more and premature ripening, a serious defect in exported fruits [3]. It is more damaging and difficult to control than the related yellow Sigatoka disease, and has a wider host range that include the plantains, desert and ABB cooking bananas that are usually not affected by yellow Sigatoka [4].

In commercial fields, BSD is controlled by the aerial application of fungicides and cultural practices, such as the removal of affected leaves, and adequate spacing of plants and efficient drainage within the plantation [5]. Mourichon et al [6], observed that fungicides application includes the use of air planes, permanent landing strips and facilities for mixing and loading the fungicides, and the high recurring expense of the spray themselves. It has been estimated that the cost of controlling the BSD is ultimately responsible for 15-20% of the final retail price of these fruits in the importing countries [4]. Yet, as fungicides continue to lose their effectiveness against the disease, the dose of application is being increased leading to pesticide residues which is a serious health hazard [7, 8] and environmental pollution, due to the unavailability of resistant cultivars. The annual cost of fungicide application in export plantation is about USD 1,000 /ha [3]. Resistance is the cheapest, safest and most effective means of disease management but resistant cultivars are not readily available both for subsistence and commercial cultivations. Cultural practices (deleafing, planting density, drainage) may therefore, be a good alternative to the application of synthetic fungicides. The general objective of this study was to increase banana yield through deleafing.

2. MATERIALS AND METHODS

The study was carried out at the Njombe production unit of the PHP industrial banana plantation situated at Njombe (Latitude 4º 36' North and Longitude 9º 40' East, 170 m above sea level) in the Littoral region of Cameroon. The climate of the area is of the Equatorial humid type with long rainy season (March - October) and a short dry season that extend

from November to February. The climate is hot and humid, resulting to high temperatures (25º to 30ºC) and high relative humidity (80%). The average annual rainfall is at 3472 mm, while the average annual rate of evapo-transpiration (ET) is 1055.6 mm. Soils are deep, gravelly and permeable Andosols of baltic pyroclastes origin with low pH (4.5 – 6.5).

The study was conducted on a plot in production of 1.33 ha with first cycle plants of the variety Grand Nain. It was conducted on the double linear cropping pattern plot having a dimension of 1.75 x 2 x 3.8 m giving a density of 1,800 plants/ha. A randomized complete block design with four treatments and three replications was used. A mixture of fungicides of the family of benzimidazoles and triazoles with additional mineral oil and an emulsifier was used. To reduce other pests such as insects (*Cosmopolites sordidus Germar*, l824) and nematode (*Radopholus similis* Cobb, 1893), thiamethoxam (Actara®) and terbufos (Counter®) were used. Contact herbicides (paraquat: Gramoxone®, 1.5 litre/100 litre of water/ ha) and systemic herbicides (glyphosate: Roundup-360, 2 litres/100 litres of water/ha) were used to manage weeds. Dolomite was used as soil improver. Five fertilizers used were fractioned in a well defined calendar: KCI (792 kg / Ha / year), Urea (405 kg/ha / plant), NPK (23-0-24) (144 kg/ ha / yr), Ammonium Sulphate (162 kg/ ha /year) and Ammonium Diphosphate (270kg/ha /yr).

2.1 Observation of Black Sigatoka Disease

Observations of the disease were based on the methods proposed by Granry and Meyer [9, 10], readapted by Foure [11] and Cohan et al, [12]. Ten (10) flowered plants of the same age and vegetative stage were randomly selected in a plot on a surface area of about 300 m^2 [13]. Observations were made on a surface area of 80 m^2, divided into four blocks of 20 m^2. For each treatment, 10 plants having an average of 13 leaves were selected randomly.

The study was conducted on first cycle banana plants of the variety Grand Nain at the first week of inflorescence and leaves were pruned in the following frequency: 3-day, 6-day, 9-day and 12-day. The experiment was laid out in a randomized complete block design with four treatments and three replications. All the other treatment and farming operations including the normal frequency of aerial spraying (twice a month) of fungicides were maintained.

At the end of the pruning, the severity of BSD infection in the plots was determined from the percentage infection rate (PIR) of the disease. The effect of leaf pruning frequency on the control of the black sigatoka disease was determined from the number of leaves at harvest (NLH) and the weekly rate of leaf loss (WRLL) for the different frequencies.

The effect of leaf pruning frequencies on the yields was determined from the quantitative aspect of yields (bunch weight (kg), and fruit mid finger circumference (mm)). The monetary value of the yield was estimated from the price of a kilogram of banana estimated at USD 1.00.

2.2 Data Analysis

The data collected were subjected to the analysis of variance (ANOVA), and the means were compared using the Fisher's Least Significant Difference (F-LSD) at 5% level. The economic value of banana bunch weight was also calculated.

3. RESULTS AND DISCUSSIONS

3.1 Effect of Leaf Pruning on the Control of the Black Sigatoka Disease

The maximum, minimum and mean percentage infection rate of necrotic BSD is presented in Fig. 1.

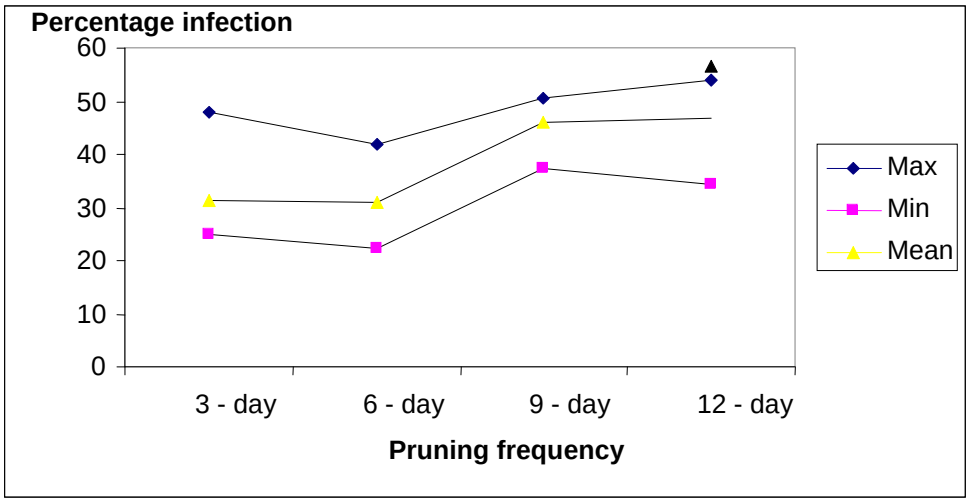


Fig. 1. Influence of leaf pruning frequency on percent black sigatoka infection

In Fig. 1, the maximum percentage rate infection (PIR) of the disease with respect to the different pruning frequencies indicated that the highest rate of necrosis (54.00 %) was recorded in the 12-day frequency, followed by 50.53 % in the 9-day frequency), 48 % in the 6-day frequency and 42 % in the 3-day frequency.

The minimum PIR of the disease with respect to the different pruning frequencies shows that the minimum rate of necrosis (22.33 %) was recorded in the 6-day frequency, followed by 25 % in the 3-day, 34.29 % in the 12-day and 37.50 % in the 9-day frequencies.

The mean PIR of necrosis recorded were as follows: 31.23 % for the 3-day frequency, 30.79% for the 6-day, 45.87 % for the 9-day and 46.83 % for the 12-day frequencies. The reduction in the rate of infestation with frequent pruning falls in line with the findings of Cote et *al* [14] which shows that management techniques that prevent the build-up of banana pathogens and also eliminate them; non-chemical techniques, such as cultural practices and biological control, and resistant cultivars will reduce the pesticide application on banana by 65.00 %.

The maximum, minimum and mean percentage infection rate of large necrosis of the black Sigatoka disease is presented in Fig. 2.

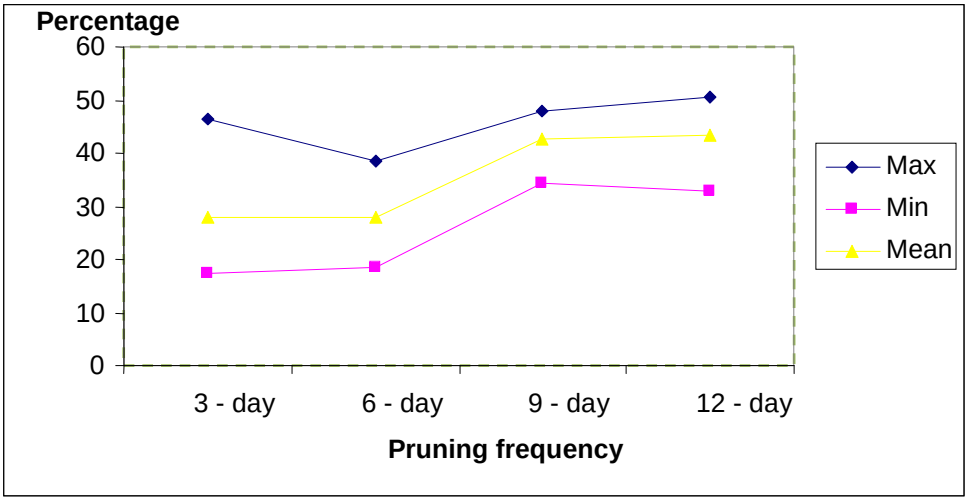


Fig. 2. Influence of leaf pruning frequency on large necrotic percent black Sigatoka infection

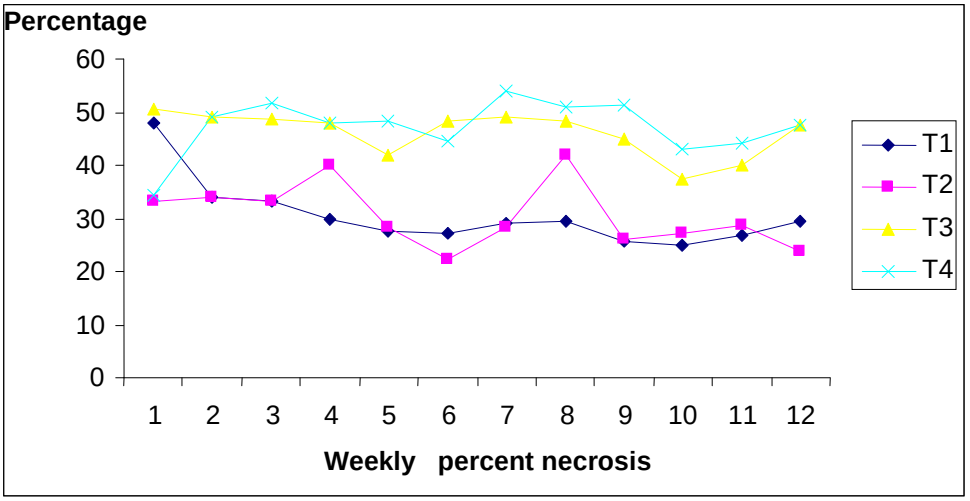
Fig. 2 presents the maximum PIR of the disease with respect to the different pruning frequencies. The figure indicates that the highest rate of large necrosis (50.50 %) was recorded in the 12-day frequency, followed by 49.09 % in the 9-day, 46.4 % in the 6-day and 38.33 % in the 3-day frequencies.

The minimum PIR of the disease with respect to the different pruning frequencies shows that the minimum rate of large necrosis (17.43 %) was recorded in the 6-day frequency, followed by 18.6 % in the 3 day, 32.74 in the 9-day and 34.43 % in the12-day frequencies.

The mean PIR of large necrosis recorded were as follows: 28.02 % for the 3-day frequency, 27.95 % for the 6-day, 42.58 % for the 9-day and 43.39 % for the 12-day frequencies.

The reason for the high rate of evolution of the BSD in the 12-day and 9-day frequency is partly due to higher rate of leaves intersection that creates a favorable micro climate for the propagation of the inoculums. Under such conditions, Robinson [15]) explained that, the fungal disease becomes more pronounce and more and more difficult to control.

The maximum weekly percentage infection rate of necrosis is presented in Fig. 3.

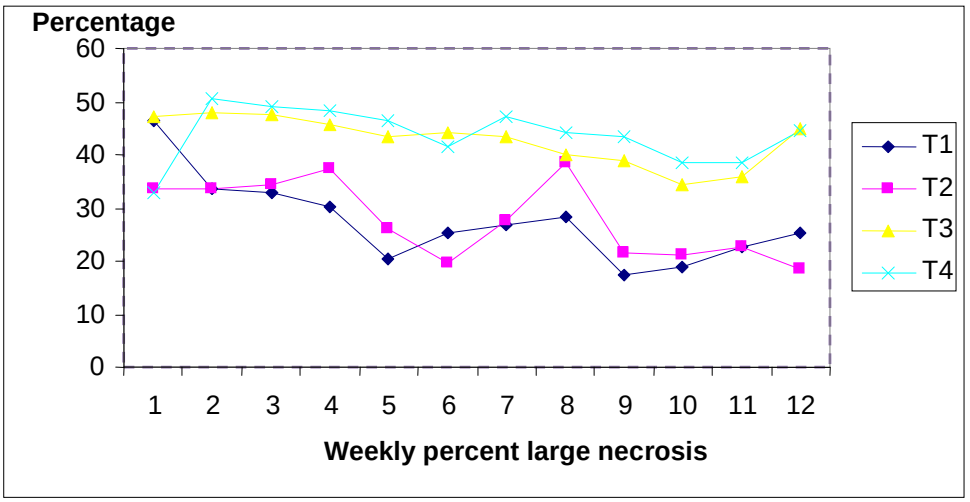


Where T1=3-day; T2= 6-day; T3=9-day and T4 = 12-day pruning frequencies respectively

Fig. 3. Weekly percentage infection rate of necrosis

Maximum weekly PIR of necrosis (54.00 %) was recorded in the 12-day frequency at the eighth (8th) week of pruning, followed by 50.53 % in the 9-day frequency at the first (1st) week, 48.00 % in the 3 day frequency at the first (1st) week and 42.00 % in the 6-day frequency at the eight (8th) week. The minimum PIR of necrosis was recorded in the 3-day frequency at the seventh (7th) week, in 6-day frequency at the tenth (10th) week, in the 9-day frequency at the eleventh (11th) week and in the 12-day at the first (1st) week of pruning.

The maximum weekly percentage infection rate of large necrosis is presented in Fig. 4.



Where T1=3-day; T2= 6-day ;T3=9-day and T4 = 12-day pruning frequencies respectively

Fig. 4. Weekly percentage infection rate of large necrosis

Fig. 4 shows that the maximum weekly PIR of large necrosis (50.50 %) was recorded in the 12-day frequency at the second (2^{nd}) week of pruning, followed by 49.09 % in the 9-day frequency at the second (2^{nd}) week, 46.4 in the 3 day at the first (1^{st}) and 38.33 in the 6-day frequency at the eight (8^{th}) of pruning. The minimum PIR of large necrosis (17.43 %) was recorded in the 3-day frequency at the ninth (9^{th}) week of pruning, followed by 18.60 % in the 6-day at the twelfth (12^{th}) week, 32.73 % in the 12-day at the first (1^{st}) week and 34.43 % in the 9-day at the tenth (10^{th}) week of pruning.

However, as leaf removal increased, black Sigatoka severity decreased at the 6^{th}, 9^{th}, 10^{th} and 11^{th} weeks for the 6-day pruning frequency, the disease severity decreased at the 5^{th}, 9^{th} and 10^{th} weeks for the 3-day frequency. The disease severity decreased from the 8^{th} to the 11^{th} weeks for both the 9-day and 12 day frequencies. Tarla et al, [16] showed that it takes 21-28 days for streaks to appear on banana.

3.2 The Effect of Leaf Pruning Frequency on the Control of the Black Sigatoka Disease

The effect of the different leaf pruning frequencies on the control of the BSD was determined from the number of leaves at harvest and from the weekly rate of leaf loss.

3.3 Number of Leaves at Harvest

Table 1 shows the number of leaves at harvest for four leaf pruning frequencies.

Table 1. Number of leaves at harvest for four leaf pruning frequencies

Pruning frequency	Mean number of leaves at harvest
3-day	3.00b
6-day	4.20a
9-day	3.00b
12-day	2.30b

$F\text{-}LSD_{0.05}$ =1.20; CV % = 23.6

**Means within a column followed by the same letters are significantly the same according to Fischer's LSD (P=0.05)*

The highest NLH (4.20 leaves) was recorded in the 6-day frequency which showed statistically significant difference from all the other frequencies. However, there was no statistically significant difference between the 3-day and the 9-day frequencies having 3 leaves at harvest respectively.

The percentage rate of infestation of the BSD did show a statistically significant difference with respect to the different leaf pruning frequencies (LPF). The PIR did not show statistically significant difference between the 3 day and 6 day frequencies. However, the 3-day and the 6-day frequencies were significantly different from the 9-day and the12-day frequencies. The highest PIR was recorded in the 12-day frequency, followed by the 9-day frequency.

The rate of infection of the BSD did not have any statistically significant effect on the maturity period of the fruit because the fruits were all harvested between the eleventh and twelve weeks of age. Abadie et al., [17], proposed that new cultivars must be selected if fungicides must be reduced. In Cameroon, most cultivars that have few leaves at harvest produce small

bunches and low quality banana. New cultivars are being selected based on this criterion [16]

3.4 The Weekly Rate of Leaf Loss (WRLL)

The results of the analysis of variance for the comparison of means on treatment variation and block variation for the weekly rate of leaf loss is presented in Table 2

Table 2. Comparison of variance on treatment variation for the weekly rate of leaf loss

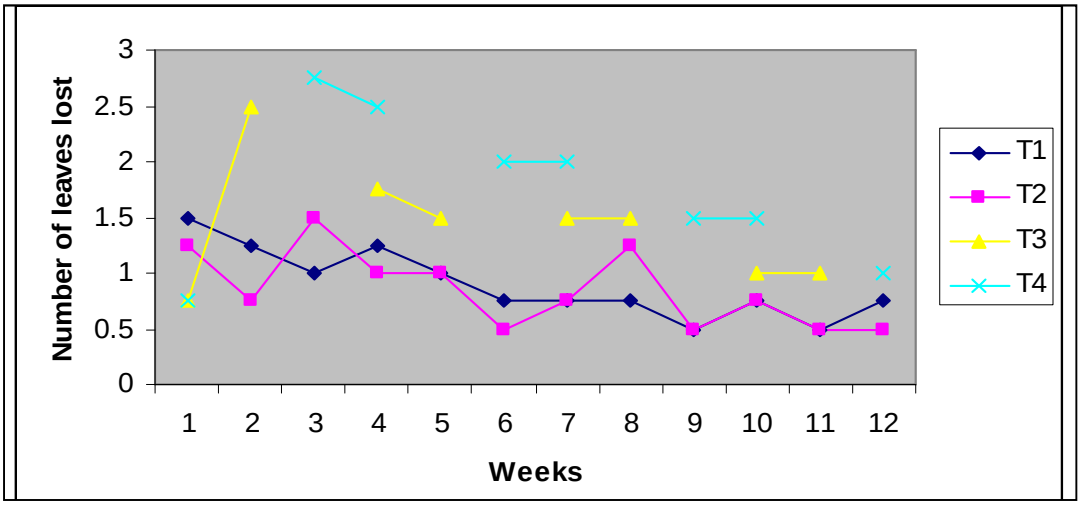
Pruning frequency	Weekly rate of leaf loss
3-day	0.85 c
6-day	0.82 c
9-day	1.38 b
12-day	1.90 a

F-LSD$_{0.05}$ = 0.13, CV % = 7.3

**Means within a column followed by the same letters are significantly the same according to Fischer's LSD (P=0.05)*

Table 2 shows that, the highest weekly rate of leaf lost (1.90 leaves/week) was recorded in the 12-day frequency, which was statistically significant different from all the other frequencies. This was followed by 1.38 leaves/week for the 9-day frequency which also differed significantly from 0.85 leaves/week recorded in the 3 day and 0.82 leaves/week recorded in the 6 day frequencies. Thus, the different leaf pruning frequencies had a statistically significant effect on the weekly rate of leaf lost. The lowest WRLL of 0.82 leaves/week was recorded in the 6-day frequency which did not show any statistically significant difference with the 0.85 leaves/week recorded in the 3-day frequency.

The weekly number of leaf loss with respect to the different leaf pruning frequencies is presented in Fig. 5.



Where T1=3-day; T2= 6-day; T3=9-day and T4 = 12-day pruning frequencies respectively

Fig. 5. Weekly number of leaf loss

The highest number of leaf lost (2.75 leaves) was recorded in the 12-day frequency at the 3rd week. This was followed by 2.5 leaves in the 9-day at the 1st week, 1.5 leaves in the 3-day at the 1st and 1.5 leaves in the 6-day frequencies at the 3rd and 8th weeks of pruning. Regular removal of leaves is laborious and reduces the photosynthetic capacity of the plant. This leads to low banana yields [18].

3.5 Yield Evaluation

3.5.1 Bunch weight

The analysis of variance for the comparison of means for treatment variation and block variation on bunch weight is presented in Table 3.

Table 3. Comparison of means on treatment variation for bunch weight (BW)

Means	12-day: 28.20	9-day: 30.30	3-day: 31.90	6-day: 32.00
6-day: 32.00	3.80*	$1.70^{n.s}$	$0.10^{n.s}$	0.00
3-day: 31.90	3.70*	$1.60^{n.s}$	0.00	
9-day: 30.30	$2.10^{n.s}$	0.00		
12-day: 28.20	0.00			

$F\text{-}LSD_{0.05}$ for the treatment mean = 2.60
CV % = 30.20
**: Significant difference at 5% level of probability*
n.s: Non significant difference

The highest average bunch weight (32.00 kg) was recorded in the 6-day frequency, followed by 31.90 kg in the 3-day frequency which did have a statistically significant difference from 28.20 kg recorded in the 12-day frequency. However, the 6-day frequency did not show any statistically significant difference from the 30.30 kg and 31.90 kg recorded in the 9-day and 3-day frequencies respectively. There was no statistically significant difference recorded between the 9-day and 12-day frequencies. Deleafing increases yields [19] but soil amendments can also be tried due to the labour involved in deleafing technology [20].

3.6 Average Mid Finger Circumference

The average mid finger circumference (mm) for four leaf pruning frequencies is presented in Table 4.

Table 4. Average mid finger circumference (mm) for four leaf pruning frequencies

Pruning frequency	Average mid finger circumference (mm)
3-day	36.50 ab
6-day	36.30 b
9-day	36.80 a
12-day	36.70 a

$F\text{-}LSD_{0.05}$= 0.35, CV = 3.7
**Means within a column followed by the same letters are significantly the same according to Fischer's LSD (P=0.05)*

Table 4 shows that, the highest average mid finger circumference of 36.8 mm was recorded in the 9 day frequency, which did not show any statistically significant difference from 36.50

mm and 36.70 mm, recorded in the 3-day and the 12-day frequencies respectively. However, the 9-day frequency (36.80 mm) did have a statistically significant difference from 36.30 mm recorded in the 6-day frequency. The 12-day frequency (36.70 mm) is not statistically significantly different from 36.50 mm recorded in the 3-day frequency. The 12-frequency did show a statistically significant difference from 36.30 mm recorded in the 6 day frequency. All the fruits were harvested at an average mid finger circumference ranging from 36 to 39 mm, which is the required standard for harvesting in PHP.

3.7 Economic Value of Banana

According to the results, the 6-day frequency registered the highest monetary value of USD 52,184 /ha, which does not differ significantly from that of the 3-day frequency of USD 52,021 /ha. The lowest monetary value was recorded in the 12-day frequency of 45,878 /ha. Ayodele & Ikotun (19) had earlier reported that deleafing increases banana bunch yields and consequently, farm income. For over two decades, BSD has been the major constraint to banana production worldwide.

4. CONCLUSION AND RECOMMENDATION

The 6-day leaf pruning frequency registered the lowest percent infection rate of necrosis, the highest number of leaves at harvest of 4.20 leaves/plant, the lowest rate of leaf loss, the highest bunch weight of 32.00 kg, the highest average mid finger circumference, the highest estimated yields of 57.60 t/ha and consequently, the highest monetary yields value estimated at USD 52,021 /ha. Thus, the result of the study suggests that, the 6-day leaf pruning of banana for the management of BSD should accompany chemical control. It will be interesting to carry out this study on younger plants and other banana varieties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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