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Effects of different levels of source-sink ratio on yield and susceptibility to crown rot in Cavendish banana plants

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ABSTRACT

Banana crown rot is caused by a parasitic complex of fungal origin, with symptoms most often appearing after harvest. The source-sink ratio has an impact on disease development that could be deleterious with a high Black Leaf Streak Disease pressure. The aim of this work was to assess the effects of hand removal as a lever to rebalance this ratio to control crown rot in a production context. The results confirmed a significant effect of hand number and functional leaf area on banana susceptibility to crown rot. A high source-sink ratio resulting from hand removal enabled the fruit to better resist disease with limited impact on yield.

Keywords: Sigatoka, fungicide, drone, banana, phytosanity.

INTRODUCTION

Crown rot represents the most significant postharvest disease affecting the quality of exported bananas (Krauss & Johanson, 2000). This disease is caused by a fungal parasitic complex; whose most common pathogen appears to be the fungus Colletotrichum musae (Berk. & Curt.) (Lassois et al., 2010b). Various pre-harvest factors related to the pedoclimatic context or plant physiology are known to influence fruit susceptibility to crown rot (Ewané et al., 2013). It has been demonstrated, in particular, that a high source-sink (So-Si) ratio is associated with larger fruit size and enhanced tolerance of bananas to crown rot (Ewané et al., 2020; Lassois et al., 2010a). In banana plantations affected by Black Leaf Streak Disease (BLSD), the functional leaf surface can be significantly impacted by the development of necrotic areas and the associated deleafing practice. In cases of substantial epidemic pressure, functional leaves losses can therefore lead to a noticeable imbalance in the So-Si ratio, which can, in turn, greatly affect banana size and susceptibility to crown rot.

Reducing the number of hands at flowering in order to rebalance the So-Si ratio could be one way to restore the fruit quality potential. However, this practice has never been evaluated under production conditions for a range of ablation levels acceptable to the sector. Therefore, the aims of this work were to assess, in a climatic context conducive to disease development, i) the impact of BLSD and deleafing on fruit susceptibility to crown rot; ii) the extent to which moderate levels of ablation at 5, 6 and 7 hands enable rebalancing of the So-Si ratio and improve fruit resistance to crown rot and iii) the impact of these ablation levels on yield (bunch weight) and fruit weight.

MATERIAL AND METHODS

The trial was conducted in Martinique from August to October 2022 (during the wet season) at two banana (Musa acuminata [AAA group, Cavendish subgroup]) conventional farms located in areas under medium and high BLSD pressure. At each farm, three plots were selected, within which 21 randomly chosen banana plants at the flowering stage had their bunches pruned to 5, 6 or 7 hands (7 plants per treatment). Two fingers were let on the first false hand, and the bunches were covered with polyethylene bags. BLSD was managed using a reasoned chemical control strategy guided by biological forecasting (Fouré & Ganry, 2008), combined with weekly leaf cutting to remove necrotic surfaces.

Various indicators were measured at the flowering stage, including pseudostem circumference at 1 m, banana plant height, total leaf number and hand number. The BLSD severity was assessed visually by estimating, for each leaf, the area affected by necrosis using Gaulh's scale (Gaulh, 1994). Total leaf number and the necrotic leaf area for each leaf rank was monitored biweekly until harvest. The quantity of green, photosynthetically active leaves was calculated by subtracting the necrotic area from the total leaf number. The area under the curves of the quantity of green leaves (AUC_GL) was also calculated. The bunches were harvested at a consistent physiological age of 925±10°C, and the bunch weight was measured without a stalk.

The third hand of each bunch was collected before the fruits entered the rinse tank and then processed in the laboratory using a sterile knife. A cluster of four fruits was used to conduct crown rot sensitivity tests following the protocol of de Lapeyre de Bellaire et al. (2008). Inoculations were performed by depositing 50 µL of a spore suspension at 104 conidia mL-1 of a strain of Colletotrichum musae isolated at the Caribbean Agro-Environmental Center (Cirad, Quartier Petit Morne, Le Lamentin, Martinique). The length and width of the crown and of the necrotic area were measured using callipers to estimate their respective surfaces, and then the internal necrotic surface (INS) was calculated (Ewané et al., 2013). An external median finger was used for pomological measurements (size, grade and weight).

All statistical analyses were conducted with the R software (RStudio 2022.07.2). The lmer function from the R package lme4 (Bates et al., 2015) was used to build linear mixed models to test the effect of the quantity of green leaves and the number of hands (Hand_Number) on the response variables INS, bunch weight and fruit weight. A Log10 transformation was first performed to normalise the distribution of INS. The models selected were:

(1) Log10 (INS) ~ AUC_GL + Hand_Number + AUC_F_V: Hand_Number + (1| Field)

(2) Bunch_weight ~ AUC_GL + Hand_Number + AUC_F_V: Hand_Number + (1| Field)

(3) Fruit_weight ~ AUC_GL + Hand_Number + AUC_F_V: Hand_Number + (1| Field)

The model's residuals were tested for independence and normality using Shapiro's test and graphical analyses. Fixed effects were tested using an ANOVA with a Type III sum of squares. The package emmeans was used to calculate the size of the effects. Post-hoc tests were performed to compare modalities 5, 6 and 7 hands using the pairs function.

RESULTS AND DISCUSSION

For each farm, marked differences in fruit susceptibility to crown rot (INS) were observed according to the number of hands remaining on the bunch (Figure 1).

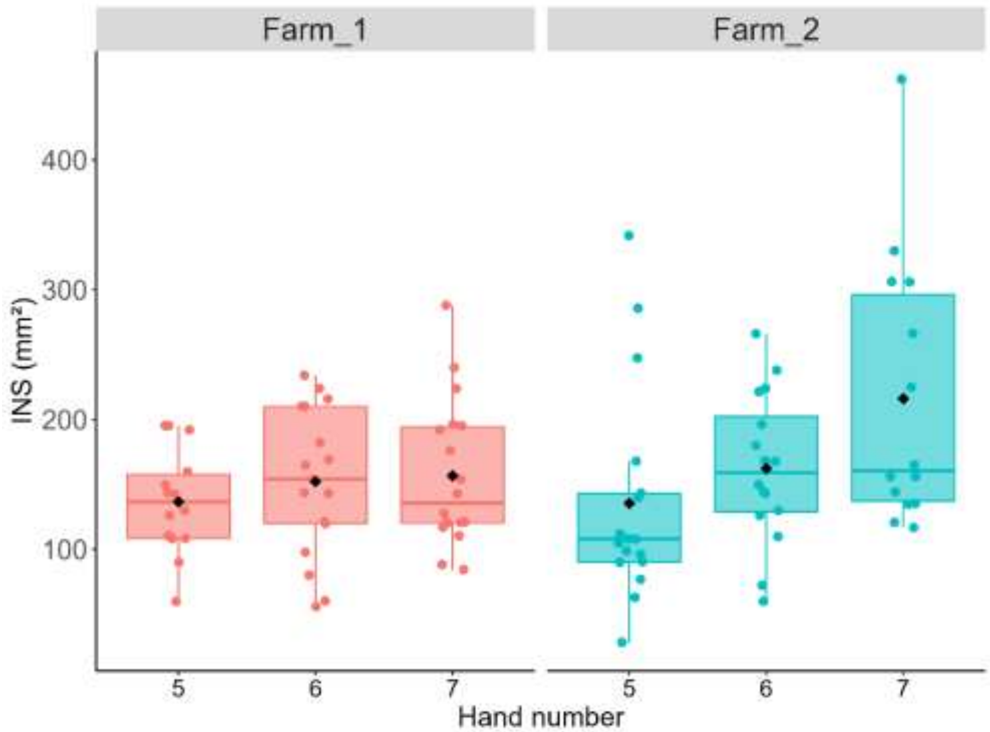

Figure 1. Boxplot representation of INS for each farm as a function of the number of hands. The coloured dots represent the INS values obtained from the tested crown samples, and the black dots represent the arithmetic means.

The results of the mixed-effect model show that the quantity of functional leaves from flowering to harvest (represented by the variable AUC_GL), the number of hands left after removal (represented by the variable Hand_Number), as well as their interactions (AUC_GL * Hand_Number), have a significant effect on the size of crown rot (represented by the variable INS) obtained after inoculation with C. musae ($p < 0.05$; Table 1 and 2). Also, the INS is negatively correlated with the quantity of green leaves and positively correlated with the number of hands left on the bunch (Table 1).

Table 1. Estimated parameters with standards errors and quality criterion summary of the linear mixed models.

Parameter	Dependent variable		
	log10(INS) (mm²)	Bunch weight (kg)	Fruit weight (g)
(Intercept)	2.11 (0.03)	24.1 (1.2)	250.6 (6.8)
AUC_GL	−0.10 (0.03)	1.9 (0.7)	12.0 (5.1)
Hand_Number6	0.04 (0.05)	1.3 (1.1)	-21.9 (7.9)
Hand_Number7	0.12 (0.05)	1.6 (1.1)	-32.7 (8.0)
AUC_GL × Hand_Number6	0.05 (0.05)	0.8 (1.3)	8.9 (9.2)
AUC_GL × Hand_Number7	0.18 (0.04)	1.5 (1.0)	1.0 (7.6)
Num.Obs.	96	98	98
R^2 Cond.	0.21	0.43	0.34
Akaike Inf. Crit.	1096.7	566.9	930.6
Bayesian Inf. Crit.	1117.2	587.6	951.3

Table 2. Results of the test of fixed effects (ANOVA with a Type III sum of squares).

Fixed effect	Dependent variable								
	log10(INS)			Bunch weight			Fruit weight		
	Chisq	df	Pr(>Chisq)	Chisq	df	Pr(>Chisq)	Chisq	df	Pr(>Chisq)
(Intercept)	3966.49	1	< 2.2e-16 ***	380.20	1	< 2.2e-16 ***	1449.56	1	< 2.2e-16 ***
AUC_GL	11.47	1	0.001***	7.89	1	0.004 **	6.02	1	0.014 *
Hand_Number	6.63	2	0.036 *	2.12	2	0.346	19.80	2	5.006e-05 ***
AUC_GL:Hand_Number	6.99	2	0.030*	1.88	2	0.390	0.86	2	0.650

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' df: degree of freedom

In this experiment, the quantity of "source" leaves was not fixed but was modulated by the pressure linked to BLSD and the deleafing practised on each farm. There is therefore a strong interest in maximising the number of green leaves between flowering and harvesting to limit the development of crown rot.

The effect size was significantly different between 7 and 5 hands on the bunch ($p = 0.017$), decreasing from 169.8 mm² to 125.9 mm², or 25.9%, on average (Table 3).

Table 3. Effect size for the different levels of ablation.

	Hand_Number	Estimate	SE	df	lower.CL	upper.CL
log10(INS) (mm²)	5	2.10	0.033	26.4	2.03	2.17
	6	2.14	0.036	32.3	2.07	2.22
	7	2.23	0.034	27.9	2.16	2.30
Fruit weight (g)	5	252	6.68	14.1	237	266
	6	231	7.06	16.8	216	246
	7	219	6.73	14.6	205	233
Bunch weight (kg)	5	24.3	1.21	9.00	21.6	27.1
	6	25.7	1.25	10.18	22.9	28.5
	7	26.1	1.21	9.15	23.4	28.8

SE: standard error; df: degree of freedom; CL: confidence level of 0.95

However, the effect size trend is not significant when measured with only a one-hand difference. Going from 7 to 6 hands ($p = 0.170$) and from 6 to 5 hands ($p = 0.66$) offers better resistance to crown rot, but not in a significant way, with the value at 6 hands having an intermediate mean effect size of 138.0 mm². These results suggested that sufficient removal of the hands would give the banana plants enough resources to synthesise secondary metabolites with properties that would make the fruit more resistant to crown rot, such as phenolic compounds (Ewané et al., 2020). Although this phenomenon had already been observed for very strict ablations (1 or 2 hands on the bunch), the effect at 5 hands proves to be interesting for its significant reduction in susceptibility.

However, this level of ablation is acceptable to the sector only if yields are not too severely reduced by the loss of additional hands. The impact of hand number on bunch weight was therefore studied. As shown in Figure 2 and Table 1, there was no significant difference in bunch weight between bunches with 5 hands and the ones with 6 or 7 hands (Figure 2-A).

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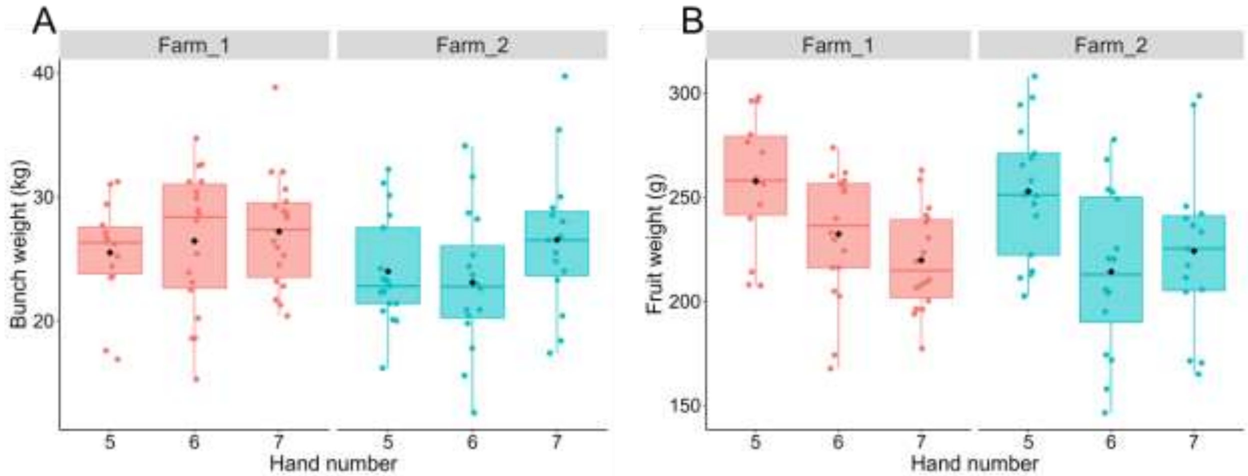

Figure 2. Boxplot representation of bunch weight (A) and fruit weight (B) as a function of ablation level. The coloured dots represent the INS values obtained on the tested crown samples, and the black dots represent the arithmetic means.

This lack of difference within bunch weight is explained by the significantly higher fruit weight on the 5-hand bunches ($p < 0.05$; Table 2 and 3; Figure 2-B) which compensates for the loss of hands. In addition, the increase in fruit weight and size also leads to more valuable fruits. From 7 hands upwards, assimilates from photosynthetic activity could be limited and might be unavailable to make the fruit grow.

CONCLUSIONS

The results of this study confirm the effect on susceptibility to crown rot of the cumulative number of functional leaves from flowering to harvest and of the number of hands left on the bunch after removal. The originality of this study lies in the demonstration of this type of effect within an experiment carried out with a range of ablation levels acceptable to the profession (5, 6 and 7 hands). It reveals that the ablation level at 5 hands is the most effective among the three levels tested for obtaining a fruit that is more resistant to crown rot. Importantly, the yield analysis shows that the impact on bunch weight remains limited. This is due to an improvement in the fruit weight, which compensates for the decrease in number resulting from the removal of hands.

With increasing restrictions on use of fungicides in the field and post-harvest, these results argue in favour of surgical leaf removal in order to preserve the functional leaf area as effectively as possible during the fruit-filling phase. The results also indicate the benefits of more severe hand removal at flowering in order to compensate, to some extent, for the defoliation caused by BLSD and deleafing. The implementation of these practices by farmers appears to be a viable solution, especially during periods favourable to the onset of these diseases, such as the rainy season. These practices could potentially be extended to organic banana farms, which are particularly affected by storage diseases and the lack of curative means of intervention provided by fungicides.

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