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Plantain (*Musa* spp. AAB) bunch yield and root health response to combinations of physical, thermal and chemical sucker sanitation measures.

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Abstract

Plantain is an important staple in West and Central Africa and the Congo basin, yet it is low yielding due to its high susceptibility to a complex of root and corm pests and diseases. Farmers are unaware of nematodes, banana weevil eggs and fungi and there is virtually no pest and disease control. This study evaluated the effects on plantain bunch fresh yield of factorial combinations of a simple physical sanitation method, paring, followed by five different treatments (control, ash-coating, hot-water treatment, boiling-water treatment and nematicide application). Paring reduced plantain establishment, had no effect on fresh bunch yields but reduced uprooting and improved root health status. Without previous paring, bunch yields after traditional ash-coating (5.7 Mg ha^{-1}) and nematicide application (6.3 Mg ha^{-1}) were not different from control (4.6 Mg ha^{-1}). Hot-water treatment (12.0 Mg ha^{-1}) and boiling-water treatment (14.2 Mg ha^{-1}) increased yield significantly. Boiling-water treated plantains attained 90% of the final yield earlier than any other treatment. Yield losses were mainly caused by pseudostem break. Uprooting caused only minor losses. Yield losses can not be attributed to a particular group of pests or diseases but all factors contributing to water deficiency leading to low turgor permitting pseudostem break. Root health parameters were positively related to bunch yield and to bunch mass per producing plant. Due to its simplicity, flexibility, low cost, absence of negative environmental consequences and the accelerated production boiling-water treatment is the most labour efficient and profitable sucker cleaning method.

Introduction

Crop yield losses due to pest and disease attack are one of contributing factors to declining food production and the worsening of poverty in sub-Saharan Africa. Plantain is the most important food cash crop in southern Cameroon. Smallholder farmers could use this demand to generate income but face the problem of a high proportion of plantains failing to produce due to uprooting and pseudostem break. The major cause of these losses is a complex of pests and diseases of the roots and the corm. Traditional plantain planting does not include pest and disease control measures. There are several cleaning methods ranging from paring, through heat treatment to the use of nematicide with a wide range of costs, labour input, and environmental risks. None of these treatments, but hot-water treatment, have been tested in West and Central Africa. In this trial capital and labour costs were estimated and the yield response of plantains determined of combinations of paring and non-paring, followed by 5 different further treatments: (1) no further treatment, i.e., control, (2) nematicide application into the planting hole, (3) rolling of suckers in wood ash, (4) hot-water treatment, (5) boiling-water treatment, to determine the best option of efficient, affordable and adoptable plantain sucker sanitation for farmers.

Materials and methods

The trial was established in a farmer's field on land manually cleared from secondary forest (>18 years), at Nkolmetet (11^{O}45' E, 3^{O}25' N) in southern Cameroon. The biomass was not burned. Plots had 16 plants at 2.5 x 2.25 m distance resulting in a space allocation of 5.625 m^2 $plant^{-1}$ and 1778 plants ha^{-1}. The trial was a 2x5 factorial complete randomised block design with 6 replicates. First factor was sucker paring, i.e., all roots and about 5 mm of the outer corm layer and all discoloured (not white) tissue, were peeled off, versus traditional preparation, i.e., only rotten parts of the corm are crudely removed. The 2nd factor was sucker 'follow-up treatment': (1) no treatment, i.e., control (2) nematicide application, carbofuran 3g active ingredient into the planting hole, (3) rolling of the sucker in wood ash, (4) hot-water treatment, 20 minutes in 52°C hot water (5) boiling-water treatment, 30 seconds in boiling water. Suckers of variety "Essong" (French type) were treated and planted between 2 and 7 April 1999. Labour and capital costs were estimated while conducting the various treatments. The cost of general items in farm households such as cutlasses, knives, baskets, fire wood, and ash were not considered (Table 1).

Table 1: Labour requirement in person hours (h) and capital and operational costs in US $ of different plantain sucker cleaning methods of planting material for 1 ha.

		Control	Ash-Coating	Hot-water	Boiling-water	Nematicide
Labour (h)	Paring	60	62.5	85.6**	70.8*	66.5
	No-paring	0	2.5	25.6**	10.8*	6.5
Capital	US $	0	0	63[a]	10[b]	0
Operation	US $	0	0	10	0	430

* two persons conducting boiling-water treatment, ** 4 persons conduction hot-water treatment, [a] 10% depreciation, [b] 50% depreciation.

Soil was sampled and organic C, Total N, exchangeable K^+ and available P were determined. Harvested, uprooted and plants with broken pseudostem were evaluated for the number of living leaves, plant height, circumference of the pseudostem at 0.5 m height, number and size of suckers and the number of roots. Root damage was assessed on 5 randomly selected living. Nematode damaged tissue is dark purple compared with unaffected white tissue. A "root necrosis index" (RNI) was derived as:

RNI = (surface of necrotic tissue / total surface of tissue) x 100%

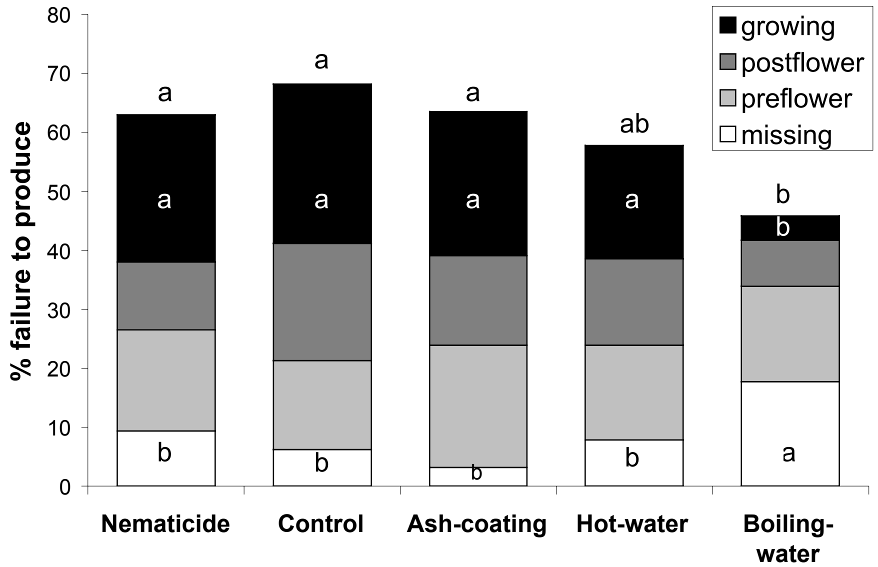
To consider both the number of living roots and the RNI, the "non-damaged root index" (NDRI) was calculated as: NDRI = number of living roots x (100 – RNI)

Bunch harvest was terminated end of May 2002 at 1148 days (38 months) after planting. Bunch yield and plant parameters data were analyzed on untransformed data, percentages were 'arcsine' transformed using the GLM procedure in SAS version 8. Least square means were calculated and the levels of significance of differences between means determined for pair-wise comparisons (p diff).

Results

Plantain establishment was significantly higher from non-pared suckers (97.3%) than from pared suckers (83.3%, p<0.001). Follow-up treatment with boiling water had the lowest establishment rates. Pre-flower losses (Figure 1) were 17.1%, largely caused by pseudo-stem break (11.9 %), yet unaffected by paring and follow-up treatments. Death through fungal rot was less after paring (0.8%) than without paring (2.7%, p = 0.05). Pre-flower uprooting (3.4%) was not affected by paring. Control and ash-coating had 6.0% losses, more than the other treatments (1.7%, p<0.05). Post-flower losses were 13.8% (11.5% by pseudo-stem break), unaffected by treatments. Post-flower uprooting was less after paring (0.6%) than when not pared (3.5%, p<0.003). Follow-up control had significantly higher losses than any other treatment. Post-flower losses due to fungal corm rot were marginal (0.2%). At 38 MAP, 4.2% to 27.1% of the plants had not flowered. Paring had no effect, boiling-water treatment had a significantly lower rate of failure to flower than any other follow-up treatment (p<0.004). Between 45.8 and 68.2% of plants did not produce a bunch. Paring had no effect. Boiling-water treatment had a significantly lower rate of failure to produce a bunch than control, ash-coating and nematicide application.

Figure 1: Relative contribution (%*) of non-establishment (missing), pre- and post- flowering



uprooting or pseudostem break and failure to reach flowering (growing), to the total proportion of plantains that failed to produce an edible bunch, Nkolmetet, southern Cameroon.
Column section 'missing' labelled with the same letters are not significantly different at p<0.024. Column section 'growing' labelled with the same letters are not significantly different at p<0.004. * re-transformed to % after statistical analysis of ARC SINE transformed data.

Between 31.8 and 54.2% of plants produced an edible bunch. Paring had no effect. Boiling-water treatment had a significantly higher proportion of plants producing a bunch than control, ash-coating and nematicide application. Proportions of plants harvested standing, broken or uprooted were unaffected by follow-up treatments. Mean bunch mass per plant was 10.5kg, unaffected by paring. Bunch mass in control (8.4kg) was significantly lower than in boiling-water treatment (12.4kg, p=0.004) and hot-water treatment (11.4kg, p=0.029). Ash-coating (10.1kg) and nematicide (10.1kg) were not different from other follow-up treatment. After paring total fresh bunch yield (Table 1) was not affected by follow-up treatments. Within non-pared, the two thermal follow-up treatments out-yielded all other follow-up treatments significantly. It is noteworthy that in control, ash-coating and nematicide treated plots, plantain yields increased after paring compared to non-paring. Contrary to that higher yields were attained in boiling-water and hot-water treated plots when the suckers had not been pared.

Table 1: Fresh bunch yield (Mg ha^{-1}) of the plant crop of local plantain (*Musa* spp. AAB subgroup French), Nkolmetet, southern Cameroon.

	nematicide	control	ash-coating	hot-water	boiling-water
Pared	8.50	6.05	6.90	7.43	10.20
Non pared	6.18	4.54	5.68	11.47	13.69
Mean	7.34	5.29	6.29	9.45	11.95
P diff for Mean only					
nematicide	--	ns	ns	ns	0.013
control	--	--	ns	0.024	<0.001
ash-coating	--	--	--	0.083	0.003

Fresh bunch yield was closely correlated with the proportion of plants that produced an edible bunch ($r^2 = 0.87$, $p < 0.0001$) and less closely, yet significantly with the mean bunch mass per producing plant ($r^2 = 0.4$, $p< 0.0001$). Bunch production was earliest in boiling-water treated plots, followed by hot-water treated plots (Figure 2). The time taken after planting to attain 90 and 95% of the final plant crop yield was shortest in boiling-water treated plots and the longest in nematicide treated plots.

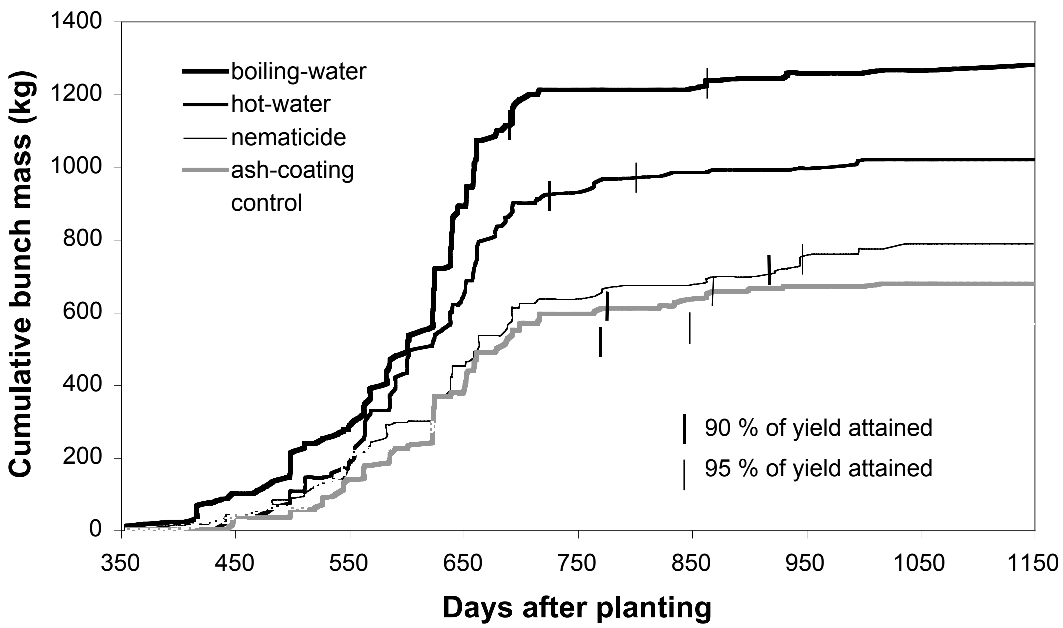


Figure 2: Cumulative bunch mass production over time of local plantain (*Musa* spp. AAB) after five different sucker cleaning treatments. Nkolmetet, southern Cameroon. Mean of non-pared and pared.

The number of live roots and the Non-Damaged Root Index (NDRI) were higher after paring, and the Root Necrosis Index (RNI) was significantly lower on pared plants. After both thermal treatments plants had significantly more living roots than the control plants. The control and the ash-coated treatment had significantly higher RNI and lower NDRI than hot- and boiling-water treated plants. Nematicide treated plants had a lower RNI and a higher NDRI than the control. In the non-pared plots RNI increased with the time elapsed between planting and evaluation at harvest or when fallen (RNI = 0.076 DAP + 0.13; $r^2 = 0.16$; $p = 0.026$). When pared no such relationship was found.

Relationships between root health and yield parameters

The mean fresh bunch yield was correlated with the number of living roots, the RNI and the NDRI found at harvest. In all cases these correlations were less strong when suckers were pared than when not pared. Similar, yet weaker correlations were found between the bunch mass per producing plant and the number of living roots, the RNI and the NDRI.

Economic assessment

The economic assessment was done on the basis of the yield gains over the non-pared control in terms of the extra labour and the extra expenses. Across the follow-up treatments paring had a much lower yield gain per extra working hour than non-paring (Table 8). Boiling-water treatment produced close to 0.9 Mg ha^{-1} more per hour extra work when not pared. Yield gain per extra expense was the lowest when nematicide was applied and the highest when boiling-water treatment was used.

Table 3**.** Yield advantage (Mg ha^{-1}) of paring and follow-up treatments per extra hour of labour and per extra US $ of investment and operational cost for sanitation of local plantain suckers at Nkolmetet, southern Cameroon.

Mg ha^{-1} $hour^{-1}$	Control	Ash-coating	Hot-water	Boiling-water	Nematicide	Mean
Pared	0.029	0.037	0.044	0.081	0.059	0.050
Non-pared	na	0.440	0.290	0.892	0.260	0.470
Mg ha^{-1} US $\$^{-1}$						
Pared	na	na	0.052	0.573	0.009	0.211
Non-pared	na	na	0.102	0.963	0.004	0.356

na = not applicable due to no extra labour or no extra cost.

Discussion

Plantain establishment of 97.3 % when suckers were not pared is high. Failure to establish were reported between 3 to 15% (Hauser 2000, Norgrove & Hauser 2002). Paring caused 16.7 % failure to establish, thus at the upper end of the reported range.

Bunch production rates ranging from 45.8 % in untreated control to 68.2 % after boiling-water treatment, were higher than those reported by Norgrove & Hauser (2002) ranging from 22 to 44%, yet, were lower than those reported by Hauser (2000) ranging from 50% in control to 71% after hot-water treatment and fertilizer application. Achard & Sama Lang (1999) reported 10 to 77% bunch production in south-western Cameroon. The proportion of plants that do not produce is generally relatively high as even in the best situation more than 20% of the yield was not realized. Reasons for failure to produce and plant status at harvest are often not reported. Norgrove & Hauser (2002) reported 49.7% pre-flowering losses, of which 9% were failure to establish and 39.3% were caused by uprooting. Post-flowering losses in the same study were as well dominantly caused by uprooting, in clear contrast to losses dominantly caused by pseudostem break in this study.
Boiling-water treatment significantly reduced the proportion of plants that did not reach flowering, while pre- and post-flowering losses were unaffected. This indicates that root health

related problems caused by nematodes, which can be eliminated at planting, may not have been the major factor reducing yields. However, the reduction of losses caused by uprooting, which is considered a consequence of nematode infestation shows that paring and the thermal treatments can reduce the effects of nematodes. The high proportion of plants with broken pseudostems indicates that water supply to maintain the turgor of the pseudostem may have been the limiting factor, which can be caused by root and corm health related problems due to nematodes, weevils and fungal attack but could as well be independent of the health status of the sucker at planting. The thermal treatments apparently removed some of these constraints, yet the data do not allow identification of these factors.

The plantain yield of the farmer typical combination of non-paring without follow-up treatment (control) of 4.58 Mg ha^{-1}, was low compared to yields attained with the same treatment in researcher managed trials in the same area of 10.2 Mg ha^{-1} (Hauser 2000) and 9.94 Mg ha^{-1} (Norgrove & Hauser 2002) and compared to the average of the Cameroon Center Province of 14.45 Mg ha^{-1} (Ngalani 1996). There are no other plantain yield data available from experiments on Ultisols and Oxisols of southern Cameroon and other parts of the Congo basin. Most agronomic research on plantain was done in Nigeria, yet none of those studies was conducted without the use of nematicide and fertilizer. In Ghana, (Banful et al. 2003) reported bunch yields ranging from 3.3 to 4.7 Mg ha^{-1} when no nematode control was applied. Achard & Sama Lang (1999) reported bunch yields in south-western Cameroon ranging from 0.6 to 7.4 Mg ha^{-1} at planting densities of 500 to 1000 ha^{-1} and 6.9 to 11.2 Mg ha^{-1} at densities of 1000 to 1400 ha^{-1}. No information on sucker sanitation was given.

Boiling-water treatment contributed to faster growth, however the cause of this effect cannot entirely be attributed to pest and disease control and a larger and healthier root system as hot-water treatment and nematicide application had similar root health, yet, not similar yields. Boiling-water treatment may have reduced incidence and severity of other unspecific pests and diseases or caused physiological stimulation of the growth.

Conclusion

Due to its low capital investment and the high yield advantage per extra labour hour, boiling-water treatment is the most efficient sucker cleaning method. It has furthermore no negative environmental effects as even the fire wood used is a renewable resource. The earlier start of production and the earliest attainment of 90% of the total production can further save on weeding time or permit the earlier use of the land for other purposes. The standard treatment in commercial banana production, nematicide application, performed very poorly both in terms of returns to labour and capital and the time required to attain 90% of production. Considering its environmental effects it cannot be recommended and even commercial banana producers may be well advised to use alternative treatments such as hot-water or boiling-water treatment for their initial sucker sanitation.

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