Climbing bean x highland banana intercropping in the Ugandan highlands

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Putting nitrogen fixation to work for smallholder farmers in Africa

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Table of contents

Table of tables

Table of figures

1. Introduction

Monitoring of farmers participating in N2Africa adaptation trials on climbing beans in Kapchorwa, Kabale, Kisoro and Kanungu districts, Uganda, in 2014 and 2015 showed that a majority of farmers in Kapchorwa and Kanungu districts planted climbing beans in intercropping (Ronner et al., 2018). Climbing beans were mainly intercropped with banana, or coffee and banana in these districts. These results warrant more attention for climbing bean/ banana intercropping. Especially given that farmers in all districts mention a lack of land as primary reason for intercropping indicates that this practice is not likely to change soon. In addition, as only few examples on climbing bean intercropping with perennials are available in literature, this also makes the topic worthy of investigation. Ntamwira (2014) focused on the pruning of banana leaves to increase light availability for legume intercrops, including climbing bean, in DR Congo. This practice was considered worth exploring in Uganda as well.

An experiment on climbing bean x banana intercropping was conducted in the first and second rainy season of 2016 (seasons 2016A and B respectively). The study included two varieties of climbing beans (*Phaseolus vulgaris L.*) that were grown in plots with East African highland bananas (*Musa spp.*). The research question of this experiment was:

What are the effects of pruning vs non-pruning in mature banana on the yields of a local and an improved variety of climbing beans?

Hypotheses were:

1. Climbing bean grain yield is positively affected by banana leaf pruning due to improved light availability
2. Different climbing bean varieties are more or less suitable to be grown in intercropping with banana due to differences in shade tolerance.

2. Methods

2.1 Site selection

The intercropping experiment was established in the eastern and southwestern highland regions of Uganda in the districts Kapchorwa and Kanungu. The experiments took place on-farm, in banana home gardens. Banana home gardens were selected if they were relatively well-managed in terms of application of household waste and/or manure (to presume uniform management conditions), if they contained only banana plants (no coffee or other crops), and if banana plants looked healthy (i.e. not affected by nematodes or other pests or diseases). The banana plants had to be early or mid-maturing varieties older than one year to ensure flowering during the experiment. Densities of banana mats varied in the selected home gardens and this was accounted for by using mat density as a covariate in the analysis. The selected fields also had a piece of open land adjacent to it, which allowed for the establishment of two plots with sole crops of the two climbing bean varieties. No fields of sole-cropped banana were included, because it was assumed that banana yields were not affected by a climbing bean intercrop and the level of pruning (Ntamwira, 2014). Fifteen home gardens were selected per district, resulting in a total of thirty farms, each being one replicate.

2.2 Experimental design

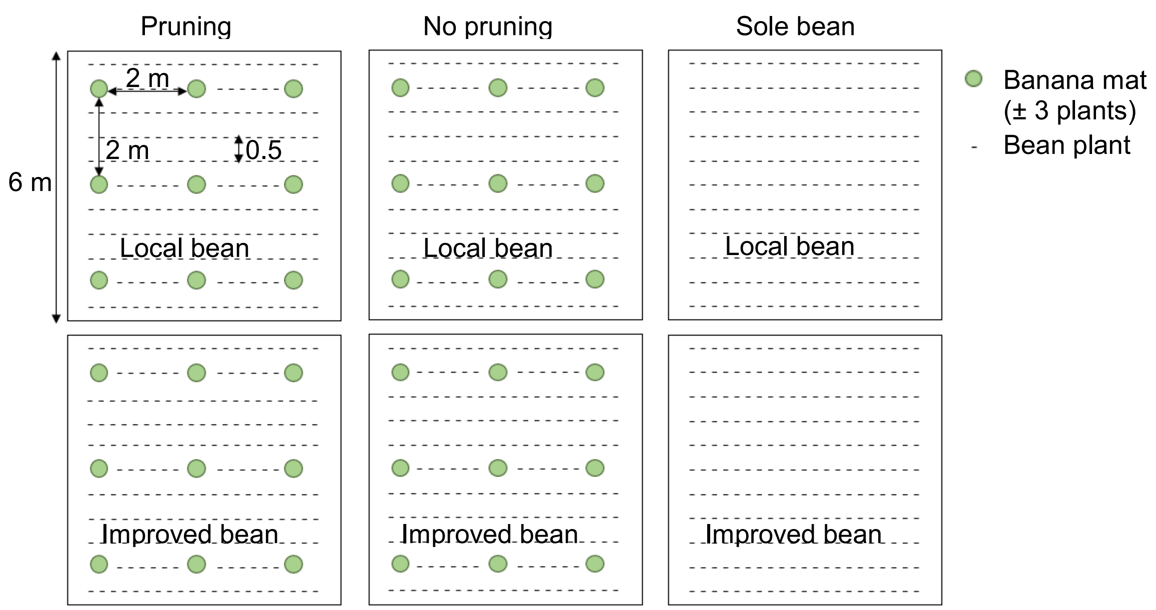
Each experimental field within a farm covered an area of approximately 12 x 12 m, consisting of four subplots of 6 x 6 m in a split-plot design with two levels of pruning and two climbing bean varieties, as shown in Table 1. Pruning implied that all leaves were removed except the eight youngest leaves from the top, under the assumption that this would not affect banana yields. No pruning implied that all leaves were retained. The local climbing bean varieties included in the experiment were Atawa in Kapchorwa and Mubano (2016A) and Kabweseri (2016B) in Kanungu. In both districts, NABE 12C was planted as the improved climbing bean variety.

Table 1. Available treatments in a split-plot design with intercropped climbing beans and banana. P = pruning, NP: no pruning, L = local bean variety: Atawa in Kapchorwa, Mubano and Kabweseri in Kanungu, I = improved bean variety; Nabe 12C, S = sole-cropped bean.

Treatment	Banana pruning	Climbing bean variety	*N*	
			Kanungu	Kapchorwa
NPL	No	Local	12	10
PL	Yes	Local	12	9
NPI	No	Improved	12	10
PI	Yes	Improved	12	9
SL	-	Local	12	No data
SI	-	Improved	12	No data

Each subplot contained about three to ten banana mats (with three plants per mat), depending on the existing banana density. Climbing beans – whether sole or intercropped – were planted at a spacing of 50 cm between rows, and 25 cm between plants. A plot accommodated eleven rows of climbing bean. Figure 1 shows the layout of the subplots – which were randomized in the actual trials.

Figure 1. Layout of the experimental field with six subplots (example of banana mats spaced at 2 x 2 m, in reality this varied).



2.3 Management of the experiment

The experiment was implemented and closely monitored by the N2Africa Field Liaison Officers with help of field assistants. On the pruning treatments, banana plants were pruned to a maximum of eight leaves at a frequency of every two weeks, starting at planting of the beans. Farmers were allowed to manage the number of banana plants per mat but were instructed not to prune bananas, as that was done by field assistants. Other management practices such as weeding were performed uniformly across all fields as instructed by field assistants.

2.4 Light interception measurements

The interception of photosynthetically active radiation (PAR) was measured with use of the AccuPAR LP-80 (Decagon Devices Inc., Pullman, Washington), shortly after planting beans and before staking, once per season in each of the subplots. Measurements were taken between 10 am and 2 pm under uniform conditions: either clear skies or uniform overcast skies.

Percent intercepted PAR (% IPAR) by the banana canopy was calculated after Gallo and Daughtry (1986) as:

$$IPAR = \left[1 - \left(\frac{It}{Io}\right)\right] * 100$$

where *It* is the PAR measured below the banana canopy – but above the bean canopy, and *Io* is the incident PAR measured above the banana canopy. In practice, *Io* was measured in a non-shaded area next to the banana field, because the banana plants were too large to bring the sensor above the canopy.

PAR measurements in between the banana and bean canopy (*It*) were taken along two straight transects per subplot (Figure 2) that covered representative parts of the field, the first transect being perpendicular to the second transect.

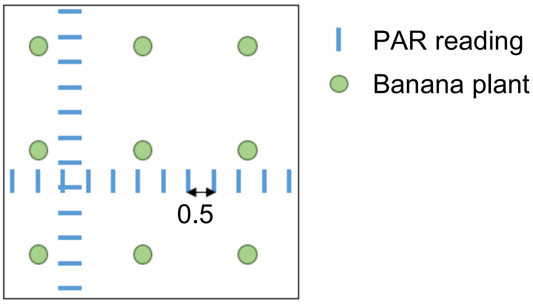


Figure 2. PAR readings below the banana canopy and above the bean canopy along two transects per subplot.

The transects were positioned such that they passed banana plants at a distance of 0.5 m from the stem. Measurements were taken at intervals of 0.5 m along the transects, holding the AccuPAR probe perpendicular to the transect. Along with each measurement, field assistants judged and recorded whether that position was fully, partly or not covered by the banana canopy. At every measurement position, five PAR readings were taken rapidly after each other. The average was recorded for that position. Incident PAR measurements outside the canopy were taken every time a new (below-canopy) transect was started.

2.5 Bean harvest

Before harvesting the whole subplot, climbing bean yields on intercropped subplots were assessed for two strips of approximately 1 x 2 m: the least and the most shaded parts of the subplot, as indicated in Figure 3. The yields on these strips were used to interpret the measurements on light interception. The exact orientation and size of those strips were determined based on the positions of banana mats in each subplot, and they always covered (parts of) two rows of beans without any banana mats in it. The sampled area was then compared to a similar area in the subplot with sole-cropped beans. On the sole-cropped bean subplots, only total yields were assessed.

The yields of the two strips and of the remainder of the subplot together established the total fresh climbing bean yield per subplot. All yields were recorded as shelled, air-dried fresh weights.

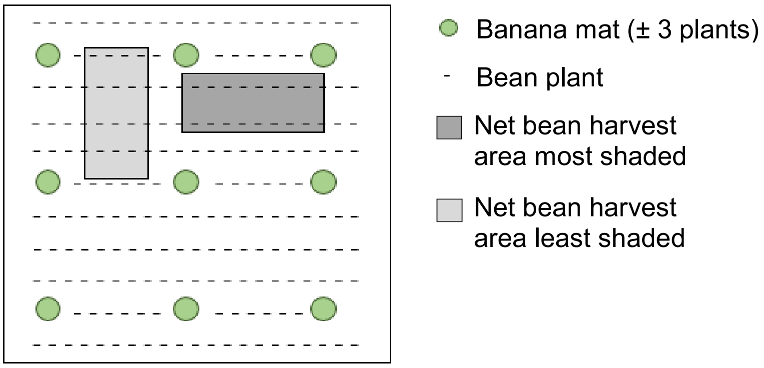


Figure 3. The least and most shaded harvest area strips in a subplot. The shape varied in reality based on the positions of the banana mats.

2.6 Banana yield estimates

Banana yields were estimated based on counts of the number of all banana plants in reproductive stage and the girth of the base of each of those plants. Nyombi et al. (2009) described the following allometric relationships between bunch weight (kg) and the girth of the banana base (cm):

At flowering ($R^2 = 0.82$): $$Bunch\ weight = 0.065\ e^{\,0.021 * girth}$$
At harvest ($R^2 = 0.97$): $$Bunch\ weight = 5.96 * 10^{-7} * e^{\,3.715 * girth}$$

2.7 Field challenges

As a result of drought, bean yields were completely destroyed in Kapchorwa in season 2016B. As a result, only PAR measurements were taken. Yield data and other agronomic measurements for 2016B were therefore only available for Kanungu district.

2.8 Statistical analysis

Linear mixed models were used to test differences in crop yield for the districts and for pruning and variety treatments, using farms as random factor. The relationships between crop yields or PAR interception and the measured variables such as the number of banana mats per plot and the distance between those banana mats were tested the same way. Software used was R Version 3.4.1 (2017).

3. Results

3.1 Light availability for beans

The mean fractions of PAR transmitted by banana – hence available for beans – over all positions and transects were significantly larger on pruned subplots than on non-pruned subplots (P<0.001). Mean fractions of PAR transmitted across seasons and districts were 0.48 (SE = 0.01, *n* = 1246) and 0.41 (SE = 0.01, *n* = 1240) on pruned and non-pruned plots respectively. Figure 4 shows the fractions of PAR transmitted per pruning treatment per district and season. Only in season 2016A in Kanungu, PAR transmitted on the non-pruned sub-plots was larger than on the pruned plots (difference not significant).

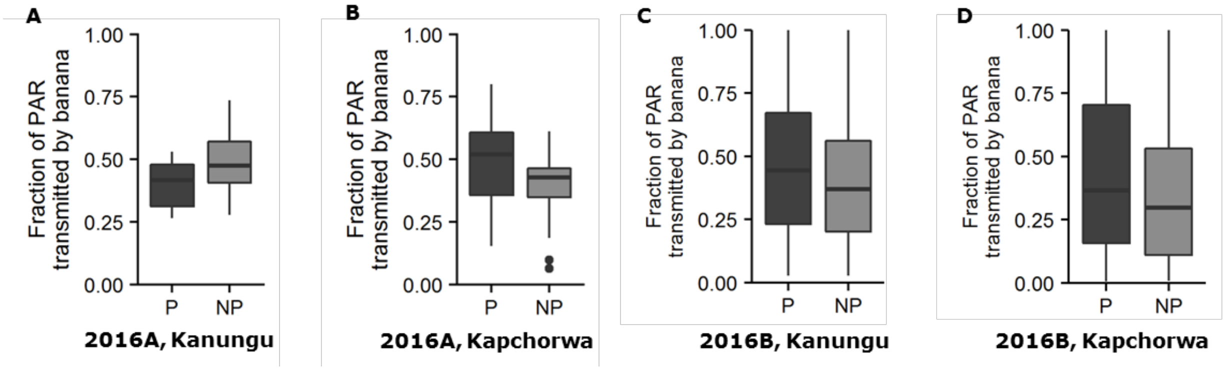


Figure 4. Fractions of incident PAR transmitted by banana canopy in pruned and non-pruned treatments in 2016A (A&B) and 2016B (C&D) in Kanungu (A&C) and Kapchorwa (B&D)

There was no significant relationship between the fractions of PAR transmitted by banana and the number of banana mats in 2016A (mean: 4.3, SE: 0.25, min: 3, max: 8), or 2016B (Kanungu only; mean: 5.8, SE: 0.30, min: 3, max: 10). The distance between banana mats (Kanungu 2016B; mean: 278 cm, SE: 9 cm, min: 75 cm, max: 631 cm) showed no relationship with PAR either.

Every position along each transect was classified as being fully, partly, or not covered by banana plants. Figure 5 shows how this classification corresponded with the actual fractions of PAR transmitted by banana, revealing a lot of variation. The mean fractions transmitted by the banana canopy were significantly different between all coverage classes in both seasons and districts (P<0.001).

Canopy cover classifications did not differ between the pruned and non-pruned plots (Table 2), except for Kapchorwa in season 2016B (X^2 test: P<0.01). The non-pruned plots had a larger percentage of full and partly covered measurement points; the pruned plots had relatively more points without cover.

The positions of the banana plants were different in all subplots, and every transect was orientated differently in relation to those banana plants. There was no difference in the level of variation in PAR transmitted for the pruned and non-pruned treatments.

The leaf angle of banana plants had been classified as being erect, horizontal, or ‘in between’, but these observations were not linked to a measure of PAR interception next to that particular banana plant. In every plot, leaf angles were variable for the different banana plants and no relation between leaf angle and PAR transmission could be identified.

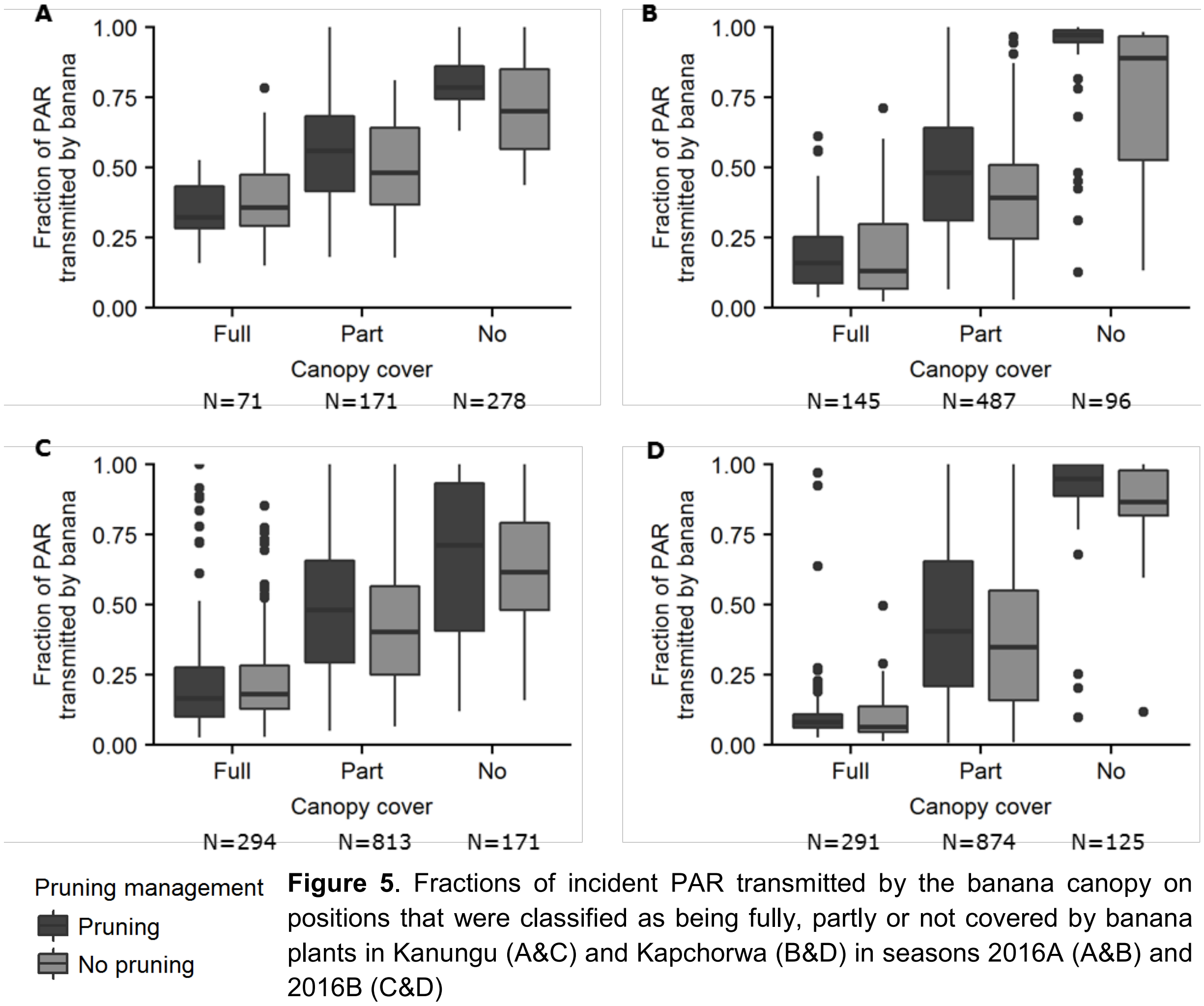


Figure 5. Fractions of incident PAR transmitted by the banana canopy on positions that were classified as being fully, partly or not covered by banana plants in Kanungu (A&C) and Kapchorwa (B&D) in seasons 2016A (A&B) and 2016B (C&D)

Table 2. Canopy cover classifications in pruned and non-pruned banana canopies in Kanungu and in Kapchorwa in 2016A and 2016B.

Pruning treatment	Banana canopy cover classifications (% of treatment N)					
	Kanungu			Kapchorwa		
	Full	*Part*	*No*	*Full*	*Part*	*No*
2016A						
Pruned	12	32	57	19	67	13
Non-pruned	15	34	50	21	66	13
2016B						
Pruned	19	67	13	14	66	20
Non-pruned	26	62	12	18	78	4

3.2 Climbing bean yields

In Kapchorwa in 2016A, climbing bean yields were significantly larger in pruned treatments than in non-pruned treatments, but this was not confirmed by the larger dataset from Kanungu in 2016A and 2016B

(Table 3). Bean yields were significantly larger in Kanungu (both seasons) than in Kapchorwa (P<0.01). The differences in bean yield in season 2016A and 2016B in Kanungu were not significant. There were also no significant yield differences between the local and improved bean varieties.

Table 3. Mean climbing bean grain yield per pruning treatment and variety in Kapchorwa (2016A) and Kanungu (2016A&B). Local = variety Mubano in Kanungu and Atawa in Kapchorwa, improved = variety Nabe 12C.

Treatment	Variety	Yield (kg ha^{-1}) *Kapchorwa 2016A* *Mean ± SE (n)*	*Kanungu 2016A* *Mean ± SE (n)*	*Kanungu 2016B* *Mean ± SE (n)*
No pruning	Improved	125 ± 32 (6)	521 ± 121 (5)	1018 ± 181 (12)
Pruning	Improved	681 ± 337 (5)	371 ± 71 (5)	1274 ± 328 (12)
No pruning	Local	134 ± 32 (6)	1051 ± 225 (5)	1050 ± 135 (12)
Pruning	Local	255 ± 101 (6)	783 ± 172 (5)	1101 ± 209 (12)
Sole cropping	Improved	165 ± 8 (8)	1157 ± 133 (5)	1676 ± 188 (10)
Sole cropping	Local	179 ± 9 (7)	1838 ± 260 (5)	1393 ± 240 (12)

In Kanungu, yields of sole-cropped beans were significantly larger than of intercropped beans (P<0.05), on both the pruned and non-pruned plots (Table 3). There were no interactions with variety, but yields of the local variety were significantly larger than the improved variety in season 2016A. In Kapchorwa differences in yield were not significant. The effect of intercropping in Kanungu could be due to the effects of shading but also to differences in plant densities as the positions of banana plants caused some bean rows to contain less bean plants than in the sole crop. However, there was no significant relationship between the number of banana mats and bean yields. We also found no relationship between climbing bean yields and the average PAR intercepted on plots.

Climbing bean yields on the least and most shaded strips that were selected on every subplot in Kanungu differed significantly in 2016A (P<0.05) and 2016B (P<0.01) (Fig.6). Yields for plants on the least shaded strips of the plots were about 1.3 times larger than on the most shaded strips. There was no interaction between shading and pruning. In 2016B, yields on non-pruned plots were significantly larger than on the pruned plots (P<0.01). There was no interaction between shading and varieties either, but in 2016B the improved bean variety had significantly larger yields than the local variety (P<0.01).

The least and most shaded strips did not contain any banana plants. The mean yield of the least and most shaded strips was larger than the sole bean yield in 2016A (P<0.01), but smaller in 2016B (P<0.01), for both the pruned and non-pruned plots (data not presented). There was no interaction with variety.

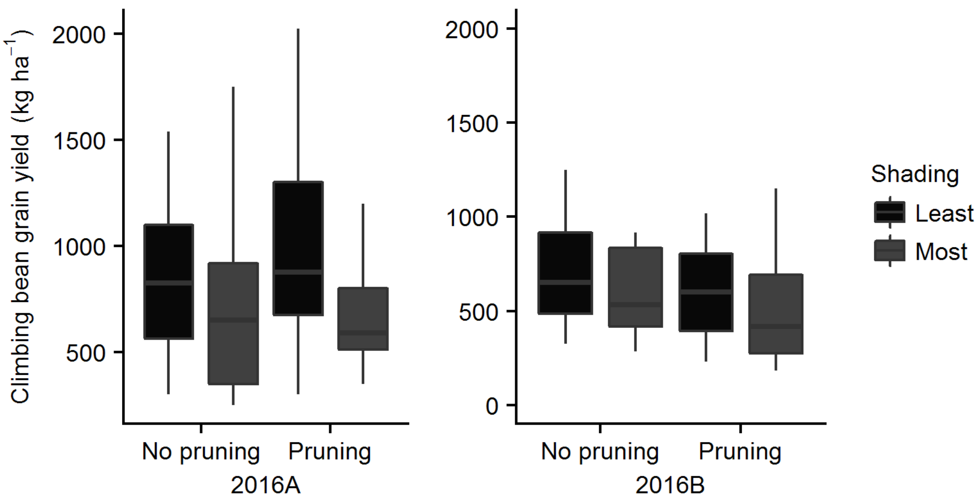


Figure 6. Climbing bean grain yields on least and most shaded parts of the non-pruned and pruned plots in Kanungu in 2016A (*n*=5) and 2016B (*n*=14).

3.3 Banana yields

Dry matter banana bunch yield estimates that were based on girth measured at flowering were significantly smaller than when measured at harvest (P=0, outliers excluded): 0.18 kg (*n*=41) versus 0.99 kg (*n*=15) in season 2016B. Figure 6 shows the estimated banana bunch yields per plant per household. The two plants with the highest estimated banana yields were selected as outliers and excluded from the yield analysis. In season 2016A the timing of girth measurements was noted per treatment and not per plant, and it was unclear whether indeed all banana plants in a plot were either flowering or harvestable. In 2016A the banana yields were estimated at 0.68 kg DM per bunch (*n*=11) when measured at flowering and at 2.88 kg DM per bunch (*n*=35) when measured at harvest. There were no significant differences in banana yield in the pruned and non-pruned subplots.

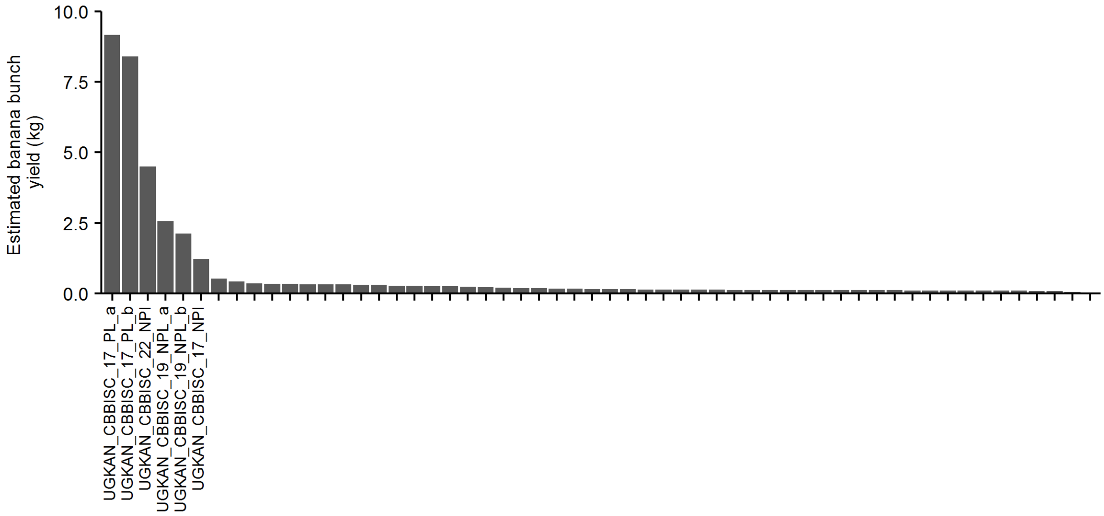


Figure 7. Estimated banana bunch yields per plant in Kanungu, season 2016B. The two leftmost plants were removed as outliers.

Mean banana base girth was 43 cm (SE = 3, *n*=41) at flowering and 45 cm (SE = 6, *n*=15) at harvest. Figure 8 shows the estimated banana bunch yields in relation to banana base girth. Different formulas were used to estimate yields depending on the timing of girth measurement, based on the allometric relations described by (Nyombi et al., 2009).

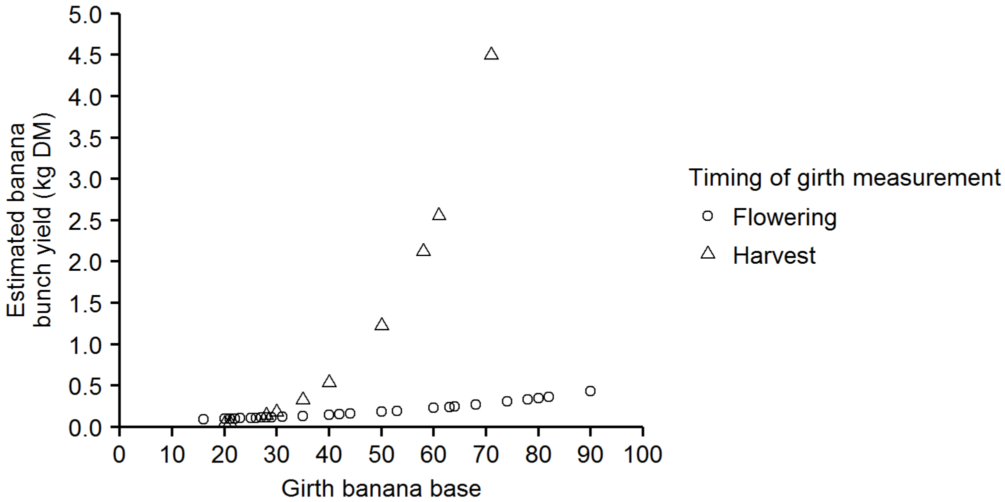


Figure 8. Relation between the girth of the banana base (cm) of fruit-bearing banana plants and the dry matter bunch yield, in season 2016B

4. Discussion

Climbing bean yields were generally larger in the sole crop than in the intercrop, confirming that bean yields were reduced by the competition with banana for light and/or nutrients. It was hypothesized that more light would be available for beans in the pruned treatments. This was indeed the case, with average 15% increase in PAR availability for beans in pruned treatments compared to non-pruned treatments. However, this did not result in increased climbing bean yields in the pruned subplots. When comparing the least shaded and the most shaded parts of each field, bean yields were larger on the least shaded areas. This supports the hypothesis and suggests that pruning was not done to an extent that influenced light availability enough.

There was also no relationship between the number of banana mats and PAR availability. This may be explained by the method for choosing the positions for the transects; which was next to a line of banana plants and not at a random position in the field. Transects were therefore rarely positioned below large gaps in the banana canopy. Although the transects provided a rich picture in terms of light availability of the plot, the differences in position of banana plants made a direct comparison between plots more difficult. Alternatively, measurements on different distances of banana plants, or random locations in the plot could be considered for future research.

It was expected that the local and improved bean varieties would differ in their shade tolerance, but they were equally suitable to be grown in intercropping, based on their yields.

In 2016A, data on net plots without any bananas in them were collected, and in 2016B on the least and most shaded parts of the field. The net plots were meant to compare sole climbing bean yields with intercropped climbing bean yields. The yields on the least and most shaded parts of the field were taken together as the average 'net' bean yield, but it is questionable if this average is the best representation of the whole plot. Moreover, because the net plots only measured 2 to 6 m^2, their conversion to kg ha^{-1} risks large error margins, which makes the comparison between sole and intercropping less reliable. Future research could base this comparison on bean yields per plant rather than an area.

There was considerable variation in PAR availability across transects through subplots (see ANNEX I). This was a result of shading by banana trees, but also of fluctuations in incoming PAR. Some measurements of below-canopy PAR were larger than the value of incident PAR measured outside of the canopy. These values were set to 1, but they indicate that the incident PAR had sometimes increased during the taking of measurements below the canopy. If incident PAR increased or decreased during the below-canopy measurements, PAR availability would be over- or underestimated, respectively.

Ideally, PAR measurements above and below the canopy should be taken simultaneously, with use of two sensors. However, the height of the banana canopy made this practically impossible. Similarly, PAR measurements in this study were taken during varying weather circumstances although the field assistants strove to work under clear skies. On overcast days, diffuse light becomes relatively more important. Weather conditions were only noted per farm, not per transect.

In this research, every position along a transect was classified as being fully, partly, or not covered by banana plants. In Kanungu and in Kapchorwa, the fractions of PAR transmitted by banana were in accordance with their assigned coverage class, but there was a lot of variation. In Kanungu, the level of variation in the fractions of PAR transmitted when there was no canopy cover was surprisingly large and this may be the result of variations in weather conditions and differences in direct and diffuse incident light. Most positions were classified as being partly covered. Figure 5 suggests that slightly more PAR was transmitted in the pruned treatments than in the non-pruned treatments in the partial cover class, and Table 2 that pruning increased the measurement spots with no or partial cover.

Mean girths of the base of flowering banana plants were 43 cm at flowering an 45 cm at harvest. Girths as small as 16 cm were measured, which seems improbable for a fruit-bearing banana plant. Nyombi et al. (2009) described mean a mean banana base girth of 68 cm at flowering and a girth reduction of 12% from flowering to harvest, which is very different from the measured girths in this study. Estimated yields based on the girths measured at flowering were smaller than 200 g per banana plant, which is unrealistic for a banana bunch. Nyombi et al. (2009) measured mean bunch DM yields of 2.5 kg. It seems likely that the girths of the banana bases were not measured correctly.

5. Conclusions

Climbing bean yields were reduced when intercropped with banana compared with sole cropping. Banana leaf pruning to a maximum of eight leaves made more PAR available for intercropped beans, but this did not result in a yield benefit compared to non-pruned treatments. Local and improved bean varieties performed similarly in terms of yield to the pruning and intercropping treatments. The number of banana mats and the distance between them did not influence PAR availability and bean yields.

References

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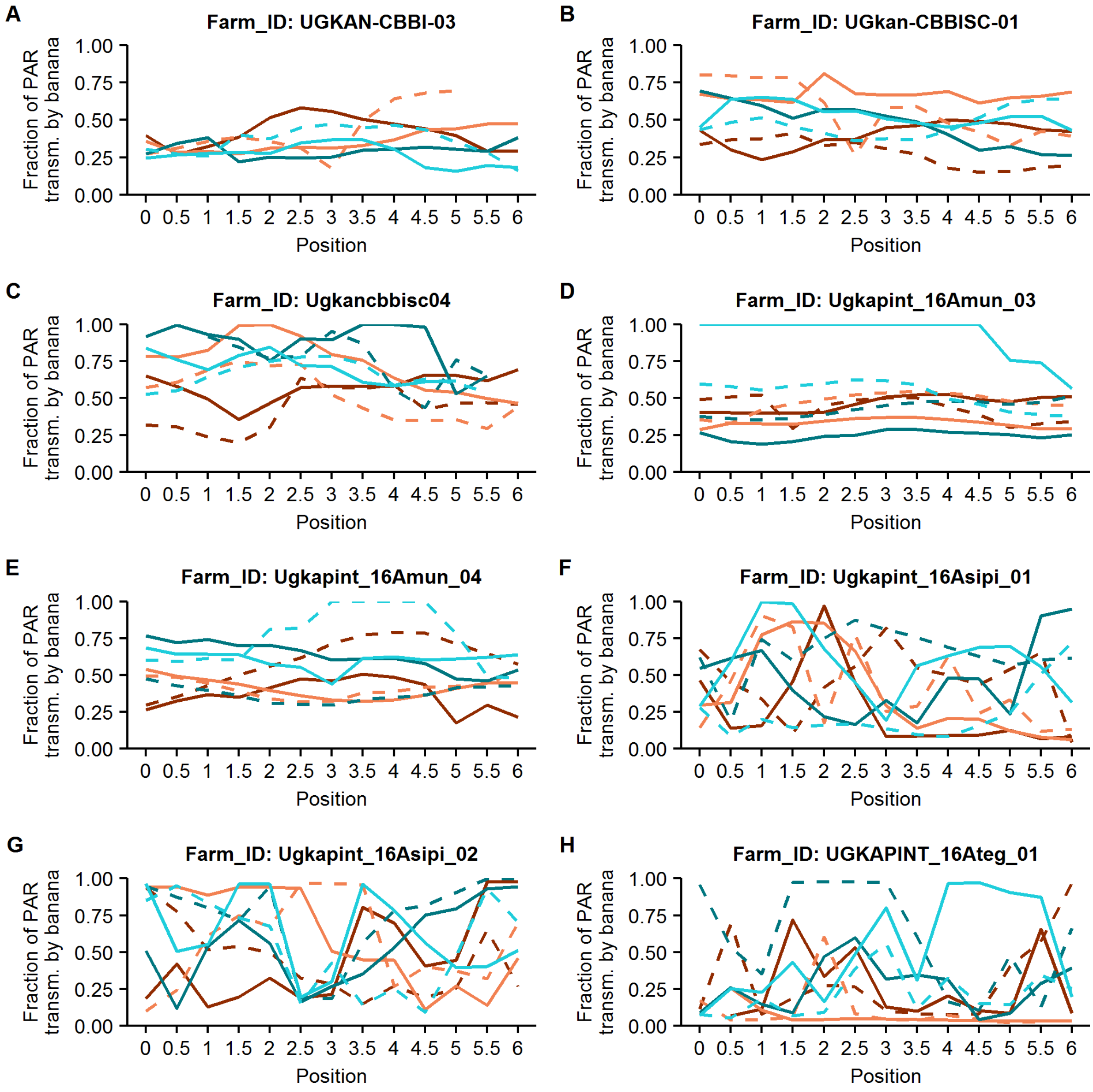
Appendix I – Light transmission profiles per farm



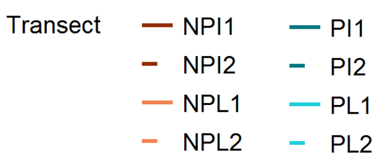


Figure I.1. Fractions of incident PAR transmitted by the banana canopy and available for intercropped beans at thirteen positions on six-meter transects (two per treatment) in **Kanungu** and **Kapchorwa** in season **2016A**. P = pruning, NP = no pruning, L = local bean variety Mubano, I = improved bean variety Nabe 12C.

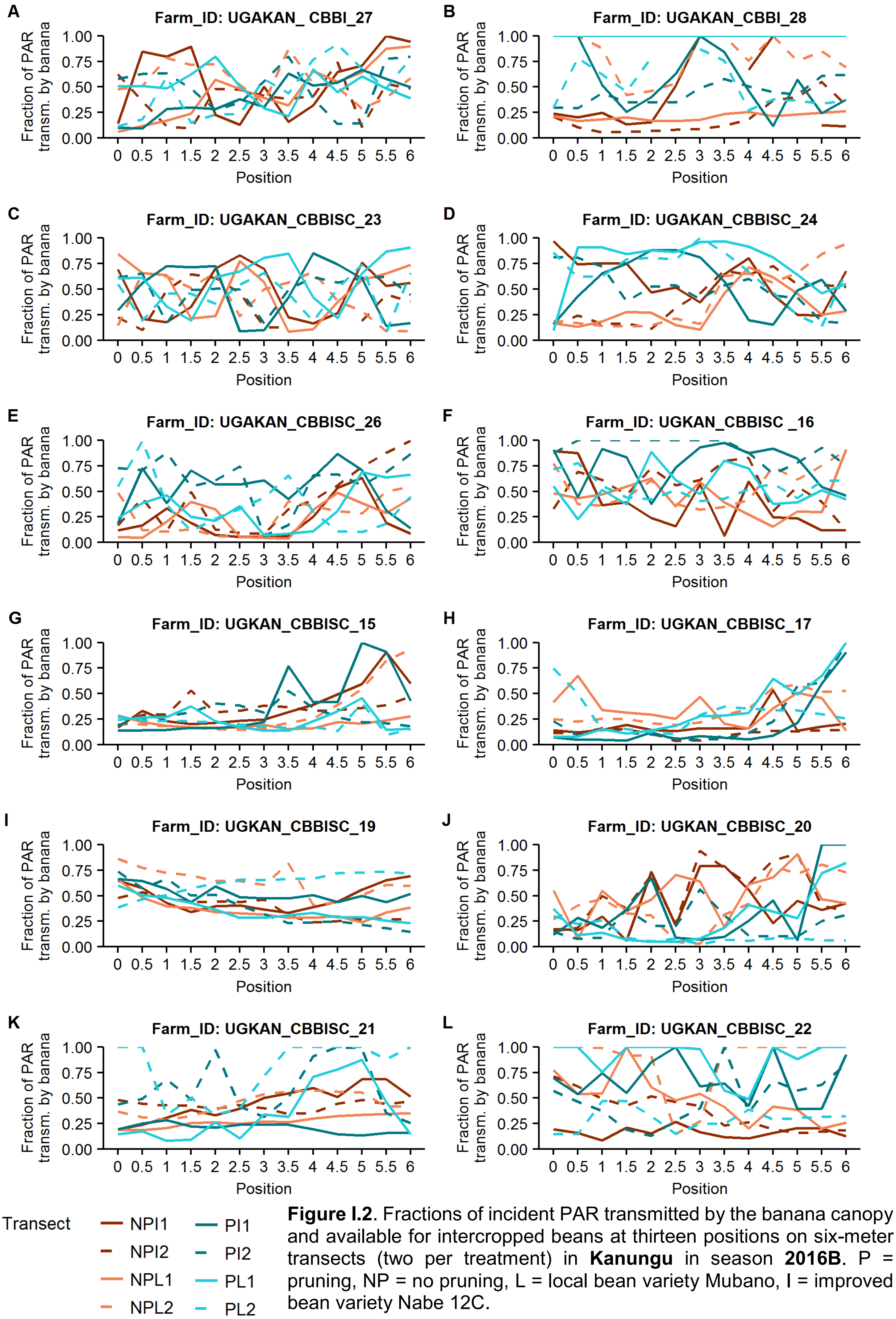
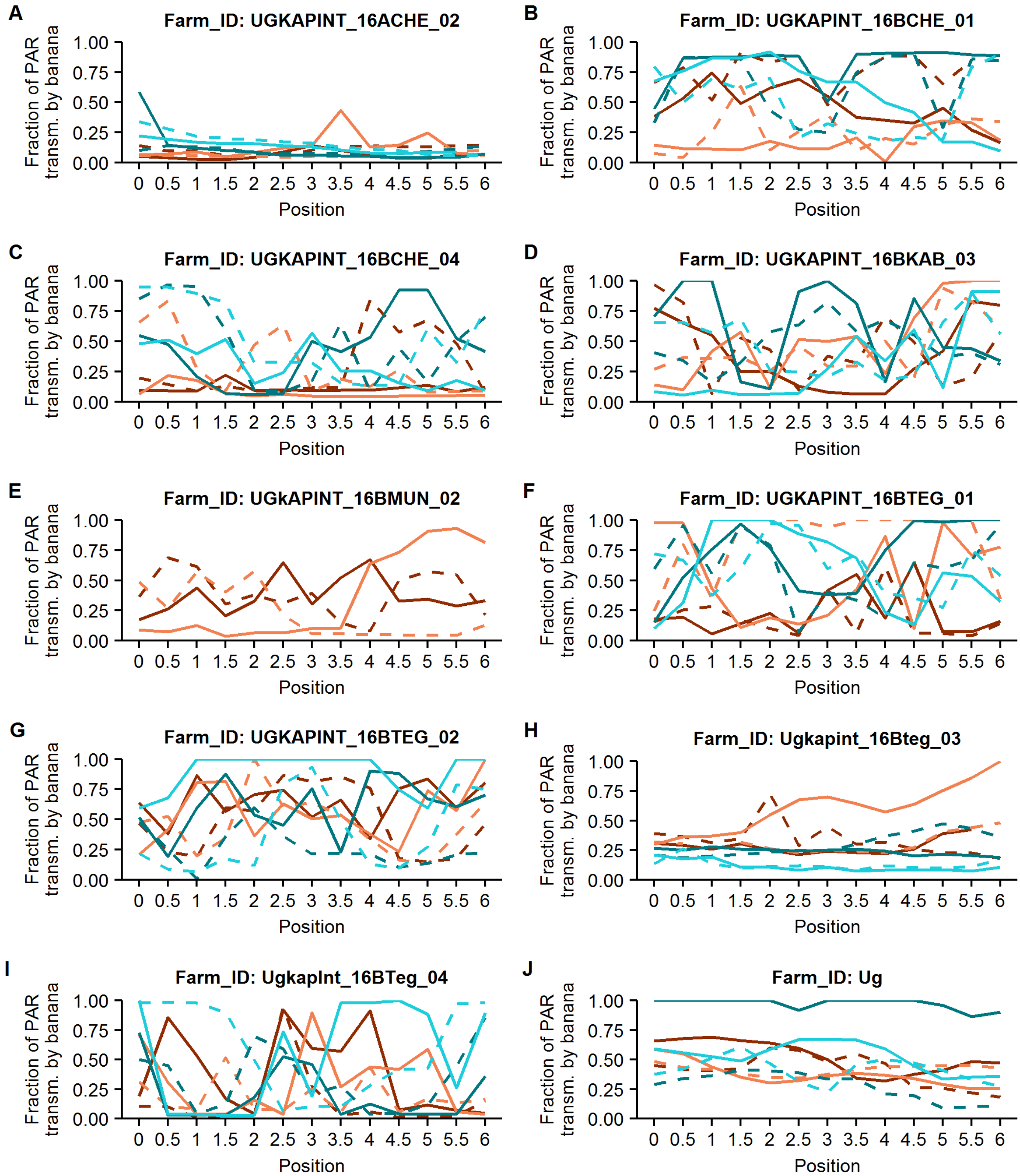


Figure I.2. Fractions of incident PAR transmitted by the banana canopy and available for intercropped beans at thirteen positions on six-meter transects (two per treatment) in **Kanungu** in season **2016B**. P = pruning, NP = no pruning, L = local bean variety Mubano, I = improved bean variety Nabe 12C.



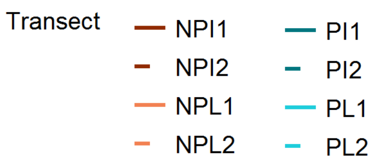


Figure I.3. Fractions of incident PAR transmitted by the banana canopy and available for intercropped beans at thirteen positions on six-meter transects (two per treatment) in **Kapchorwa** in season **2016B**. P = pruning, NP = no pruning, L = local bean variety Atawa, I = improved bean variety Nabe 12C.

Appendix II – PAR availability for beans per weather circumstance

PAR measurements were executed under clear skies if possible, so sometimes the researcher had to wait for clouds to pass. In some cases measurements were taken under uniformly overcast skies. These weather circumstances were noted for all measurements. Figure II.1 shows the fractions of PAR transmitted in different weather circumstances, indicating that these fractions were slightly smaller on overcast days in season 2016B. In season 2016A, no relation was found between fractions of PAR transmitted and the weather circumstances (Figure II.2), which often changed during measurement-taking.

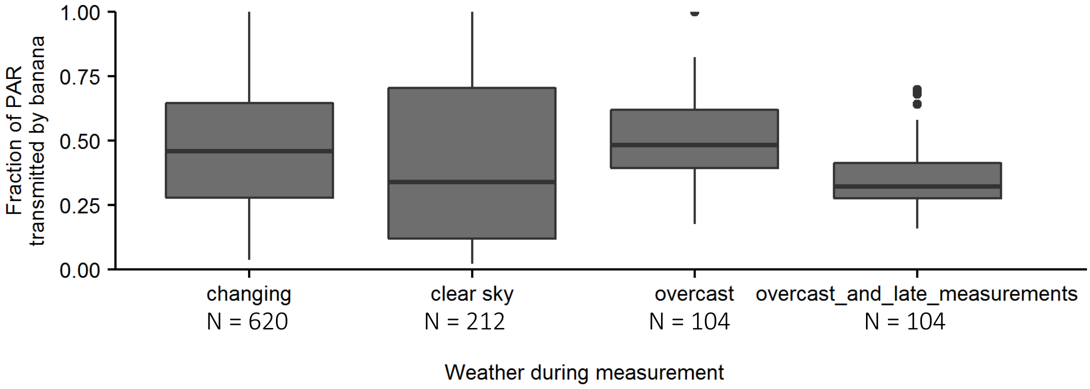


Figure II.1. Fractions of incident PAR transmitted by the banana canopy in various weather circumstances in Kanungu and in Kapchorwa in season 2016A. When there were passing clouds, the measurer would wait until clouds had passed to continue with measurements.

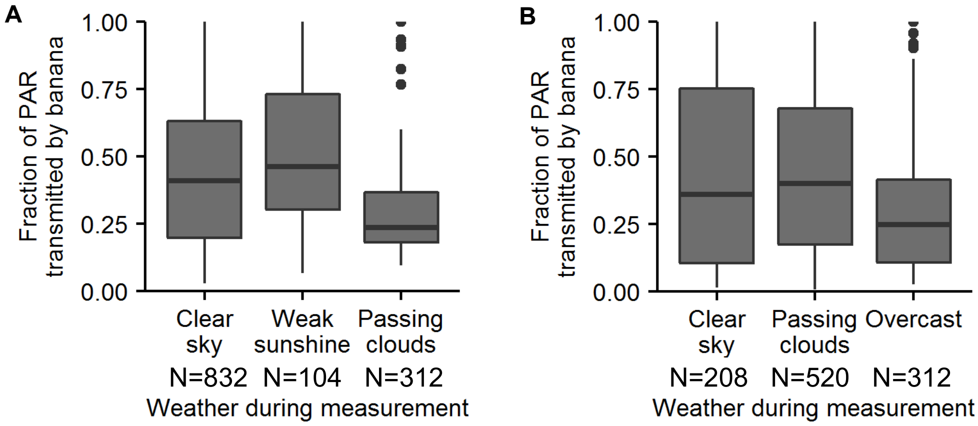


Figure II.2. Fractions of incident PAR transmitted by the banana canopy in various weather circumstances in Kanungu (A) and in Kapchorwa (B) in season 2016B. When there were passing clouds, the measurer would wait until clouds had passed to continue with measurements.

Appendix III – List of project reports

1. N2Africa Steering Committee Terms of Reference
2. Policy on advanced training grants
3. Rhizobia Strain Isolation and Characterisation Protocol
4. Detailed country-by-country access plan for P and other agro-minerals
5. Workshop Report: Training of Master Trainers on Legume and Inoculant Technologies (Kisumu Hotel, Kisumu, Kenya, 24-28 May 2010)
6. Plans for interaction with the Tropical Legumes II project (TLII) and for seed increase on a country-by-country basis
7. Implementation Plan for collaboration between N2Africa and the Soil Health and Market Access Programs of the Alliance for a Green Revolution in Africa (AGRA) plan
8. General approaches and country specific dissemination plans
9. Selected soyabean, common bean, cowpea, and groundnut varieties with proven high BNF potential and sufficient seed availability in target impact zones of N2Africa Project
10. Project launching and workshop report
11. Advancing technical skills in rhizobiology: training report
12. Characterisation of the impact zones and mandate areas in the N2Africa project
13. Production and use of rhizobial inoculants in Africa
18. Adaptive research in N2Africa impact zones: Principles, guidelines and implemented research campaigns
19. Quality assurance (QA) protocols based on African capacities and international existing standards developed
20. Collection and maintenance of elite rhizobial strains
21. MSc and PhD status report
22. Production of seeds for local distribution by farming communities engaged in the project
23. A report documenting the involvement of women in at least 50% of all farmer-related activities
24. Participatory development of indicators for monitoring and evaluating progress with project activities and their impact
25. Suitable multi-purpose forage and tree legumes for intensive smallholder meat and dairy industries in East and Central Africa N2Africa mandate areas
26. A revised manual for rhizobium methods and standard protocols available on the project website
27. Update on Inoculant production by cooperating laboratories
28. Legume seeds acquired for dissemination in the project impact zones
29. Advanced technical skills in rhizobiology: East and Central African, West African and South African Hub
30. Memoranda of Understanding are formalized with key partners along the legume value chains in the impact zones
31. Existing rhizobiology laboratories upgraded
32. N2Africa Baseline report
33. N2Africa Annual Country reports 2011

34. Facilitating large-scale dissemination of Biological Nitrogen Fixation
35. Dissemination tools produced
36. Linking legume farmers to markets
37. The role of AGRA and other partners in the project defined and co-funding/financing options for scale-up of inoculum (Banks, AGRA, industry) identified
38. Progress towards achieving the vision of success of N2Africa
39. Quantifying the impact of the N2Africa project on Biological Nitrogen Fixation
40. Training agro-dealers in accessing, managing and distributing information on inoculant use
41. Opportunities for N2Africa in Ethiopia
42. N2Africa project progress report month 30
43. Review & Planning meeting Zimbabwe
44. Howard G. Buffett Foundation – N2Africa June 2012 Interim Report
45. Number of extension events organized per season per country
46. N2Africa narrative reports Month 30
47. Background information on agronomy, farming systems and ongoing projects on grain legumes in Uganda
48. Opportunities for N2Africa in Tanzania
49. Background information on agronomy, farming systems and ongoing projects on grain legumes in Ethiopia
50. Special events on the role of legumes in household nutrition and value-added processing
51. Value chain analyses of grain legumes in N2Africa: Kenya, Rwanda, eastern DRC, Ghana, Nigeria, Mozambique, Malawi, and Zimbabwe
52. Background information on agronomy, farming systems and ongoing projects on grain legumes in Tanzania
53. Nutritional benefits of legume consumption at household level in rural sub-Saharan Africa: Literature study
54. N2Africa project progress report month 42
55. Market analysis of inoculant production and use
56. Soyabean, common bean, cowpea, and groundnut varieties with high Biological Nitrogen Fixation potential identified in N2Africa impact zones
57. A N2Africa universal logo representing inoculant quality assurance
58. M&E workstream report
59. Improving legume inoculants and developing strategic alliances for their advancement
60. Rhizobium collection, testing and the identification of candidate elite strains
61. Evaluation of the progress made towards achieving the Vision of Success in N2Africa
62. Policy recommendation related to inoculant regulation and cross-border trade
63. Satellite sites and activities in the impact zones of the N2Africa project
64. Linking communities to legume processing initiatives
65. Special events on the role of legumes in household nutrition and value-added processing
66. Media events in the N2Africa project

67. Launching N2Africa Phase II – Report Uganda
68. Review of conditioning factors and constraints to legume adoption and their management in Phase II of N2Africa
69. Report on the milestones in the Supplementary N2Africa grant
70. N2Africa Phase II Launching in Tanzania
71. N2Africa Phase II 6 months report
72. Involvement of women in at least 50% of all farmer-related activities
73. N2Africa Final Report of the First Phase: 2009-2013
74. Managing factors that affect the adoption of grain legumes in Uganda in the N2Africa project
75. Managing factors that affect the adoption of grain legumes in Ethiopia in the N2Africa project
76. Managing factors that affect the adoption of grain legumes in Tanzania in the N2Africa project
77. N2Africa Action Areas in Ethiopia, Ghana, Nigeria, Tanzania, and Uganda in 2014
78. N2Africa Annual Report Phase II Year 1
79. N2Africa: taking stock and moving forward. Workshop report
80. N2Africa Kenya Country report 2015
81. N2Africa Annual Report 2015
82. Value Chain Analysis of Grain Legumes in Borno State, Nigeria
83. Baseline report Borno State
84. N2Africa Annual Report 2015 DR Congo
85. N2Africa Annual Report 2015 Rwanda
86. N2Africa Annual Report 2015 Malawi
87. Contract Sprayer in Borno State, Nigeria
88. N2Africa Baseline Report II Ethiopia, Tanzania, Uganda, version 2.1
89. N2Africa rhizobial isolates in Kenya
90. N2Africa Early Impact Survey, Rwanda
91. N2Africa Early Impact Survey, Ghana
92. Tracing seed diffusion from introduced legume seeds through N2Africa demonstration trials and seed-input packages
93. The role of legumes in sustainable intensification – priority areas for research in northern Ghana
94. The role of legumes in sustainable intensification – priority areas for research in western Kenya
95. N2Africa Early Impact Survey, Phase I
96. Legumes in sustainable intensification – case study report PROIntensAfrica
97. N2Africa Annual Report 2016
98. OSSOM Launch and Planning Meeting for the west Kenya Long Rains 2017
99. Tailoring and adaptation in N2Africa demonstration trials
100. N2Africa Project DR Congo Exit Strategy
101. N2Africa Project Kenya Exit Strategy

102. N2Africa Project Malawi Exit Strategy
103. N2Africa Project Mozambique Exit Strategy
104. N2Africa Project Rwanda Exit Strategy
105. N2Africa Project Zimbabwe Exit Strategy
106. N2Africa Annual Report 2017
107. N2Africa review of policies relating to legume intensification in the N2Africa countries
108. Stakeholder Consultations report
109. Dissemination survey Tanzania
110. Climbing bean x highland banana intercropping in the Ugandan highlands

Appendix IV – Partners involved in the N2Africa project

A2N

Bayero University Kano (BUK)

Caritas Rwanda

Diobass

Eglise Presbyterienne Rwanda

Ethiopian Institute of Agricultural Research

Jay Fortunes

Kwame Nkrumah University of science and Technology

University of Nairobi MIRCEN

Resource Projects-Kenya

Sasakawa Global; 2000

Université Catholique de Bukavu

University of Zimbabwe

Urbanet