Responses to inoculation of *Phaseolus* beans on N2Africa trials in Ethiopia, Tanzania, Rwanda and Zimbabwe

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N2Africa

Putting nitrogen fixation to work for smallholder farmers in Africa

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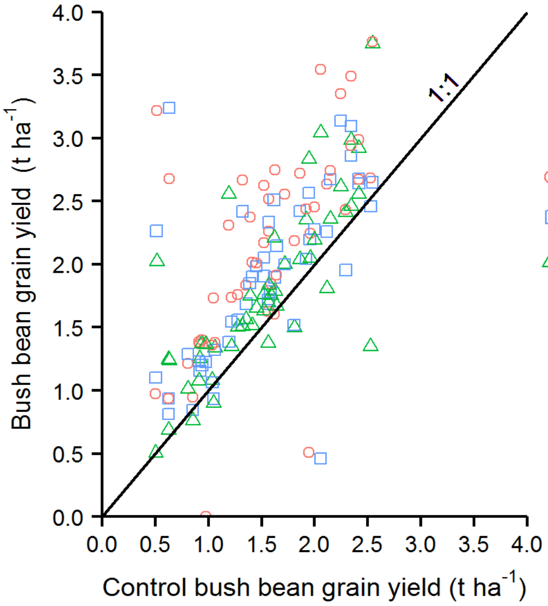
Summary

Studies on responses to inoculation in bush bean (*Phaseolus vulgaris*) were carried out as part of the N2Africa project (www.n2africa.org) in Ethiopia, Tanzania, Rwanda and Zimbabwe.
Inoculant treatments without fertilizer inputs significantly improved yields by 0.27 t ha^{-1} compared to the unamended control in Ethiopia. The combined effect of inoculation and P fertilization was much larger and significant in all four countries. Trials in Tanzania and in Zimbabwe also included the application of N fertilizer, and manure was included on the trials in Rwanda. Largest yields were achieved when inoculant and fertilizer inputs were combined. Inoculation tended to boost responses to fertilizer inputs in Ethiopia, Rwanda and Tanzania. Detailed results per country are given below.

1 Ethiopia

Yield responses of bush bean (cv. Nasir) to inoculation and/or P fertilization were measured on demonstration trials in eight Woredas (districts) in Ethiopia. There were 32 trials in 2015, 7 trials in 2016 and 10 trials in 2017. On each trial there were a control plot and three treatment plots: (1) P + inoculant, (2) sole P, (3) sole inoculant. Figure 1 shows how in the large majority of cases treatment yields were larger than control yields. Yield responses to application of sole inoculant or sole P were similar to each other and on average around 0.3 t ha^{-1} larger than the control yield. Mean yields were largest for the treatment that included inoculation as well as P fertilization: 2.12 t ha^{-1} versus a control yield of 1.53 t ha^{-1}, as shown in table 1. A look at the standard errors shows that the variation in yields was a lot smaller for the P + inoculant treatment than for the other treatments and the control (table 1).

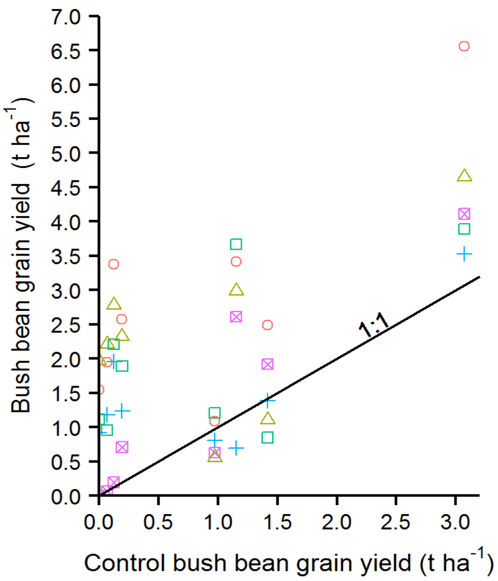


	Treatment or year	Mean grain yield ± SE (t ha^{-1})	Tukey's HSD P<0.1	N
○	P + inoculant	2.12 ± 0.12	a	49
□	P	1.90 ± 0.96	b	49
△	Inoculant	1.80 ± 0.96	b	49
	Control	1.53 ± 0.82	c	49
	2017 (all treatments)	2.24 ± 0.70	a	40
	2016 (all treatments)	1.51 ± 0.73	ab	28
	2015 (all treatments)	1.78 ± 0.69	b	128

Figure 1 & **Table 1**. Bush bean (cv. Nasir) grain yield when treated with inoculant and/or P fertilizer, compared to a control without inputs. The results include 32 trials from 2015, 7 trials from 2016 and 10 trials from 2017. These were installed in Ethiopia (Boricha, Dibate, Gobu Sayo, Halaba, Mandura, Shala, Soddo and Wayu Tuka).

2 Tanzania

Yield responses to inoculation with Legumefix (Legume Technology Ltd, UK) and fertilization were tested on eight demonstration trials in Tanzania for bush bean cultivar Lyamungu 90, in 2017. Results are shown in figure 2 and table 2. Inoculant application alone did not result in a significant yield increase compared to the control treatment without fertilizer and inoculant inputs. However, when inoculants were applied in combination with fertilizers, responses to these fertilizers were boosted by around a tonne per hectare, compared to the treatments with only fertilizers and no inoculation. Compared to the unamended control, the combined treatments with inoculant and fertilizers increased mean bush bean grain yields by up to 2 t ha^{-1}. Application of only NPK led to grain yield increases of a tonne compared to the control. The treatments with sole PK did not result in a significant yield response.



Treatment	Mean grain yield ± SE (t ha^{-1})	Tukey's HSD P<0.1
NPK + inoculant	2.87 ± 0.60	a
PK + inoculant	2.32 ± 0.44	ab
NPK	1.97 ± 0.43	bc
PK	1.46 ± 0.33	bcd
Inoculant	1.28 ± 0.52	cd
Control	0.88 ± 0.37	d

Figure 2 & **Table 2**. Bush bean (cv. Lyamungu 90) grain yield when treated with inoculant (Legumefix) and/or (N)PK fertilizers, compared to a control without inputs, on eight trials in Tanzania (Mvomero, Lushoto and Moshi), in 2017. N = 8 for every treatment.

3 Rwanda

Rurangwa et al. (2017) tested the effects of inoculation and the application of P fertilizer and/or manure on bush bean yields during two seasons in three agro-ecological zones in Rwanda: Bugesera district (1435 masl, 800 mm annual rainfall), Kamonyi district (1661 masl, 1200-1400 mm annual rainfall) and Kayonza district (1601 masl, 1000-1200 mm annual rainfall). There were three replications per agro-ecological zone.

Inoculant alone tended to increase yields in the three sites with an average of 0.6 t ha^{-1} compared to the unamended control, but this effect was not significant. The combined treatment with inoculation and P fertilizer (30 kg ha^{-1}) significantly ($P < 0.001$) improved grain yields and biomass at mid-podding compared to the control, across all tested manure rates (figure 3). Highest yields were achieved when all three inputs were applied together at a manure rate of 10 t ha^{-1}. The responses to sole inoculation or sole P fertilizer (0.4 t ha^{-1}) were not significant.

Inoculation had no significant effect on the percentage of N derived from the atmosphere in the bean plants, which varied between 24% in Bugesera and 53% in Kamonyi. The absolute amount of N fixed was increased in treatments with inoculation combined with P fertilization, compared to the control. Averaged over the three AEZs, inoculation combined with P fertilizer increased the amount of N fixed by 17 kg N ha^{-1} compared to the control and by 64 kg N ha^{-1} when manure was added at 10 t manure ha^{-1}.

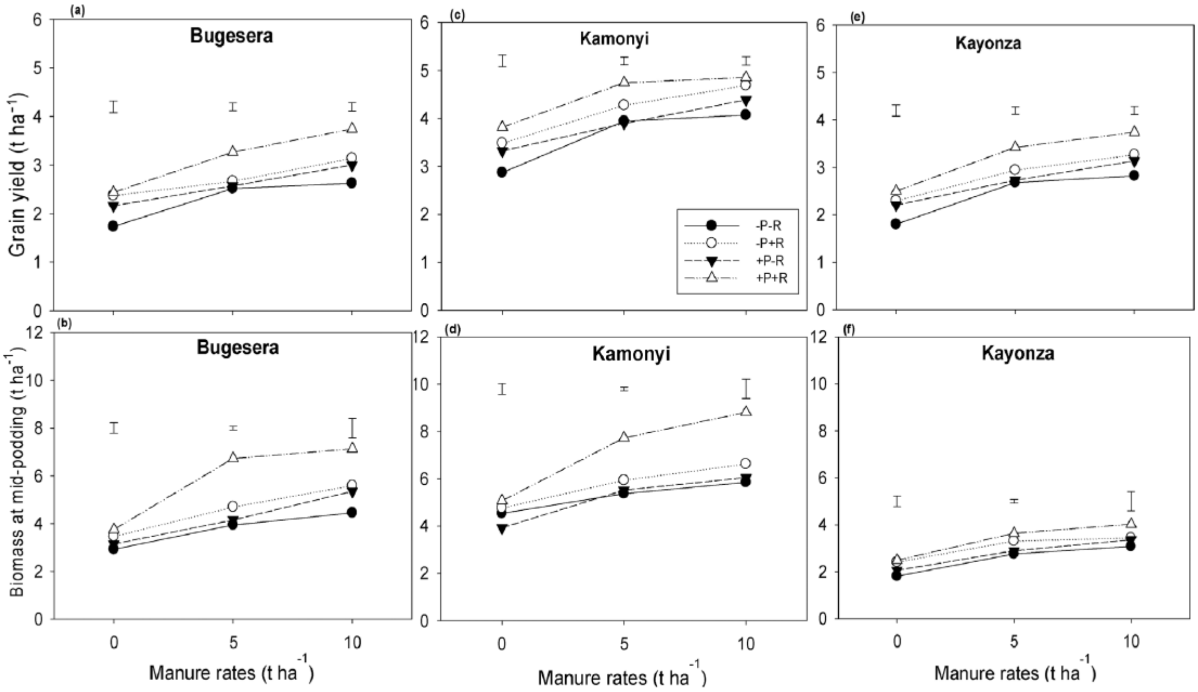


Figure 3. (a, c, e) Grain and (b, d, f) biomass at mid-podding yield response of bush beans (v. RWR 2245) to inoculation, P fertilizer and three rates of manure at (a, b) Bugesera, (c, d) Kamonyi and (e, f) Kayonza, Rwanda, during the short rains in 2014. Error bars represent the standard errors of difference between means; −/+. R: without or with rhizobia (R) inoculation. This figure was taken from Rurangwa et al. (2017).

4 Zimbabwe

The effect of inoculation and the application of N and P on bush bean yield and nodulation was tested in the 2014/2015 and 2015/2016 cropping seasons on largely sandy soils in Zimbabwe. On these trials by Chekana, Chikowo and Vanlauwe (2018, under review), bush beans did not respond to rhizobia inoculation ($P > 0.05$). There were strong responses in the number of pods per plant, the number of seeds per pod and grain yields for either N or P treatments (each at a rate of 40 kg ha^{-1}), as shown in figure 4. The combined application of N and P increased yields on non-degraded soils fivefold. Degraded soils were non-responsive to the application of N, P and/or inoculants: bean yields and podding were barely affected.

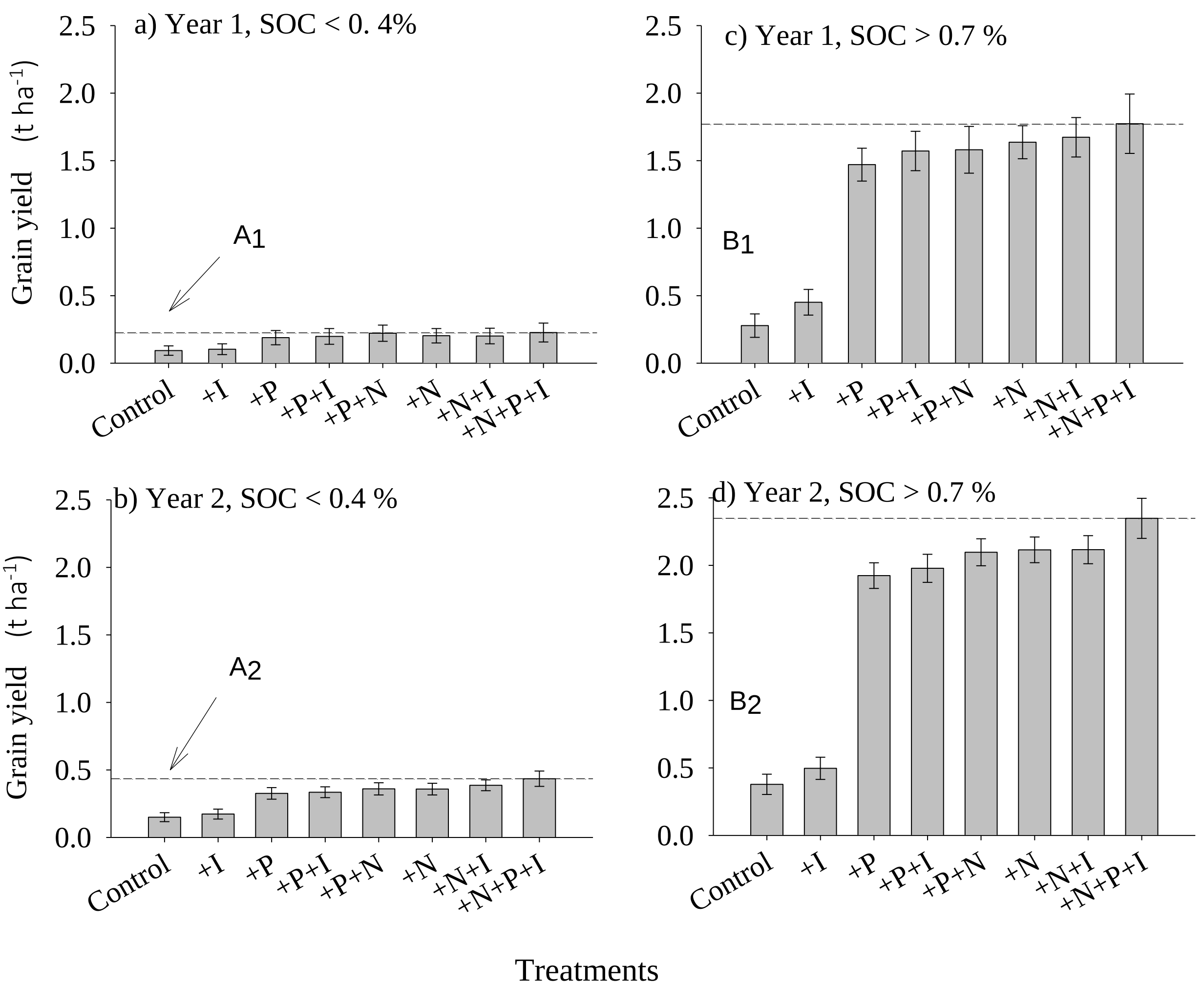


Figure 4. Bush bean (cv. Gloria and NUA 45) grain yield when treated with inoculant, N and/or P fertilizers, compared to a control without inputs, on five trials Zimbabwe in two seasons: 2014/2015 (Year 1) and 2015/2016 (Year 2). Two of the trials had degraded soils (SOC < 0.4%) and three of the trials were non-degraded (SOC > 0.7%). Exploitable yield gaps: A1 = 0.13 t ha^{-1}, A2 = 0.28 t ha^{-1}, B1 = 1.5 t ha^{-1}, B2 = 1.93 t ha^{-1}. This figure was taken from Chekanai et al. (2018, under review).

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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
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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
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11. Advancing technical skills in rhizobiology: training report
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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
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45. Number of extension events organized per season per country
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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
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111. N2Africa Annual Report 2018
112. N2Africa Annual Report 2018 Ethiopia
113. N2Africa Annual Report 2018 Ghana
114. N2Africa Annual Report 2018 Nigeria, Borno State
115. N2Africa Annual Report 2018 Tanzania
116. N2Africa Annual Report 2018 Uganda
117. N2Africa training and extension materials
118. Responses to inoculation of Phaseolus beans

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