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

Eva Thuijsman, Esther Ronner

With contributions from Endalkachew Woldemeskel, Speciose Kantengwa, Edouard Rurangwa, Regis Chikowo, Vongai Chekanai, Freddy Baijukya, Ken Giller

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Email: n2africa.office@wur.nl  
Internet: www.N2Africa.org

Authors of this report and contact details

Name: Eva Thuijsman  
Address: Plant Production Systems, Wageningen University, Droevendaalsesteeg 1, Wageningen, the Netherlands  
E-mail: eva.thuijsman@wur.nl

Name: Esther Ronner  
Address: Plant Production Systems, Wageningen University, Droevendaalsesteeg 1, Wageningen, the Netherlands  
E-mail: esther.ronner@wur.nl

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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).

![Figure 1](image1.png)

<table>
<thead>
<tr>
<th>Treatment or year</th>
<th>Mean grain yield ± SE (t ha$^{-1}$)</th>
<th>Tukey’s HSD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>P + inoculant</td>
<td>2.12 ± 0.12</td>
<td>a</td>
<td>49</td>
</tr>
<tr>
<td>P</td>
<td>1.90 ± 0.96</td>
<td>b</td>
<td>49</td>
</tr>
<tr>
<td>Inoculant</td>
<td>1.80 ± 0.96</td>
<td>b</td>
<td>49</td>
</tr>
<tr>
<td>Control</td>
<td>1.53 ± 0.82</td>
<td>c</td>
<td>49</td>
</tr>
<tr>
<td>2017 (all treatments)</td>
<td>2.24 ± 0.70</td>
<td>a</td>
<td>40</td>
</tr>
<tr>
<td>2016 (all treatments)</td>
<td>1.51 ± 0.73</td>
<td>ab</td>
<td>28</td>
</tr>
<tr>
<td>2015 (all treatments)</td>
<td>1.78 ± 0.69</td>
<td>b</td>
<td>128</td>
</tr>
</tbody>
</table>

**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.

![Figure 2 & Table 2](image)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean grain yield ± SE (t ha⁻¹)</th>
<th>Tukey’s HSD P&lt;0.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPK + inoculant</td>
<td>2.87 ± 0.60</td>
<td>a</td>
</tr>
<tr>
<td>PK + inoculant</td>
<td>2.32 ± 0.44</td>
<td>ab</td>
</tr>
<tr>
<td>NPK</td>
<td>1.97 ± 0.43</td>
<td>bc</td>
</tr>
<tr>
<td>PK</td>
<td>1.46 ± 0.33</td>
<td>bcd</td>
</tr>
<tr>
<td>Inoculant</td>
<td>1.28 ± 0.52</td>
<td>cd</td>
</tr>
<tr>
<td>Control</td>
<td>0.88 ± 0.37</td>
<td>d</td>
</tr>
</tbody>
</table>

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.
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13. Production and use of rhizobial inoculants in Africa
14. Adaptive research in N2Africa impact zones: Principles, guidelines and implemented research campaigns
15. Quality assurance (QA) protocols based on African capacities and international existing standards developed
16. Collection and maintenance of elite rhizobial strains
17. MSc and PhD status report
18. Production of seeds for local distribution by farming communities engaged in the project
19. A report documenting the involvement of women in at least 50% of all farmer-related activities
20. Participatory development of indicators for monitoring and evaluating progress with project activities and their impact
21. Suitable multi-purpose forage and tree legumes for intensive smallholder meat and dairy industries in East and Central Africa N2Africa mandate areas
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