

## **Response of introduced soybean varieties to inoculation with rhizobium in Sud Kivu province, Democratic Republic of Congo**

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### **Abstract**

Soybeans are a major source of protein; they contribute to combat-ing malnutrition especially among children. They play very important roles in NRM because they contribute to biological nitrogen fixation through the inoculation with rhizobium. After finding that the response of soybean to inoculation with rhizobium was more evident on soybean than on beans and that the response varied from soybean varieties used, this work reports on the response of introduced soybean germoplasm in many locations in the mandate N2Africa areas in Sud Kivu province, DR Congo to the inoculation with rhizobium, adding P and K so as to not be limitant factors. Trials were carried out first on split split plot design in Mudaka, administrative area of Kabare and then on split plot design in Murhesa, Mushinga, Mudaka local areas, in Kabare and Walungu administrative areas; a total of 10 varieties were tested, among them 8 introduced varieties, compared to 2 local check. Results showed that the response of varieties to inoculation varied with varieties and with locations. P application revealed significant effect even where the soil was considered as fertile. These trials have allowed understanding where to apply inoculation in the perspective of soybean variety dissemination in the mandate areas of N2Africa project. The analysis of additive main effect and multiplicative interaction (AMMI) based on inoculation and potassium factors showed genotype variability on performance of tested varieties; this allow to know where to disseminate which variety.

Key words: inoculation, N2Africa mandate area, soybean varieties, variability and yield

### **Résumé**

Le soja est une source majeure de protéines, contribuant à la lutte contre la malnutrition, surtout des enfants. Il joue un rôle important dans la gestion des ressources naturelles par sa capacité de fixer biologiquement l'azote à travers la nodulation avec le rhizobium. Compte tenu d'une étude antérieure qui a montré que la réponse du soja à l'inoculation était plus évidente sur le soja que sur le haricot et que cette réponse variait avec les variétés utilisées, ce travail donne la synthèse des travaux d'introduction des variétés de soja dans diverses localités des zones mandataires du projet N2Africa en province du Sud Kivu, en République Démocratique du Congo et leur réponse à l'inoculation au rhizobium, en ajoutant le potassium

et le phosphore pour qu'ils ne soient pas des facteurs limitants de la nodulation. Les essais ont d'abord été conduits sur un dispositif en parcelles subdivisées (split split plot) à Mudaka, en territoire de Kabare, ensuite en parcelles divisées (split plot) à Murhesa, Mushinga, Mudaka, en territoires de Kabare et Walungu ; un total de 10 variétés ont été testées, parmi lesquelles 8 importées et 2 locales. Les résultats ont montré que la réponse des variétés à l'inoculation variait avec les variétés et les localités. L'application de phosphore a montré des effets positifs, même dans les sols dits fertiles. Ces essais ont permis de connaître les localités où appliquer l'inoculation, dans la perspective de la dissémination des variétés de soja dans les zones mandataires du projet N2Africa. L'analyse de l'effet additif du facteur principal et de l'interaction multiplicative basée sur les facteurs inoculation et potassium a montré une variabilité dans les performances des génotypes testés.

Mots clés: inoculation, zones mandataires de N2Africa, variétés de soja, variabilité, rendement

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## Background

Soybeans are the second most important grain legumes after common beans in Sud Kivu province. But their full potential is still untapped. Soybeans have very important roles in Natural Resource Management (NRM) because they contribute to biological nitrogen fixation and they respond to inoculation with rhizobium. In Brazil, rates of nitrogen fixation with soybeans under field conditions can exceed 300 kg of N ha<sup>-1</sup> each year, providing up to 94 % of total plant N and an estimated saving to the economy of up to US\$ 6.6 billion per year (Hungria *et al.*, quoted by Giller, 2010). Multi-purpose varieties can provide great quantity of biomass which has additional benefits in soil fertility.

Because soybeans are a major source of protein, they contribute to combat-ing malnutrition, especially among children. Soybeans are much used by women, especially pregnant women. In South Kivu soybeans opportunities are in processing plants including Murhesa factory, Centre Olame; also informal processors in urban centers, especially Bukavu, producing poultry feed and blended flour, flour for flavorings, soybean coffee, roasted nuts and tofu for human consumption (Rusike, 2011).

With the N2Africa project aim at putting nitrogen biological fixation to work for smallholder African farmers, N2Africa project activities in Sud Kivu province of the Democratic Republic of Congo (DRC) are now more oriented in soybean production. This has led to test many introduced soybean germoplasm in many locations for response to inoculation with rhizobium, adding P and K so as to be no limitant factors. This is in the view of soybean varieties dissemination in N2Africa mandate areas.

## Literature summary

In a previous study, Walangululu *et al.* (2013), found that on contrasting soil fertility (degraded soil and fertile soil), the response of soybean to inoculation with rhizobium in Walungu and Kabare administrative areas was more evident on soybean than on beans and this response varied from soybean varieties used.

Phosphorus is an essential element required for legume growth and nitrogen fixation (Giller, 2001). As many African soils are old and highly-weathered (Vandamme, 2008), P fertilizers are required virtually everywhere for all crops. This is the case on majority of soils in Sud Kivu province where kaolisols and ferralsols are dominant. Legumes tend to have a stronger requirement for P than cereals due to their less-branched, less fibrous root systems. From Ojiem study in 2006 (Giller, 2010), soybean yielded 1.2 tons per ha on high fertile soil in Kenya with no P applied, versus 2.8 tons with an addition of 30 kg per ha of P; on a low fertility soil, the yield was 0.8 tons in case of no P supply, versus 1.2 tons with 30 kg per ha of P.

This work reports on trials conducted by Université Catholique de Bukavu, a partner of N2Africa project, on the response of 8 introduced varieties, to inoculation with rhizobium, compared to 2 checks in many locations of N2Africa action sites: Mudaka and Mulamba local areas (in Walungu administrative area) in 2011 and 2012 with and without P; Murhesa and Mushinga local areas (in Kabare administrative area) without P limitation, in 2011.

### **Study description**

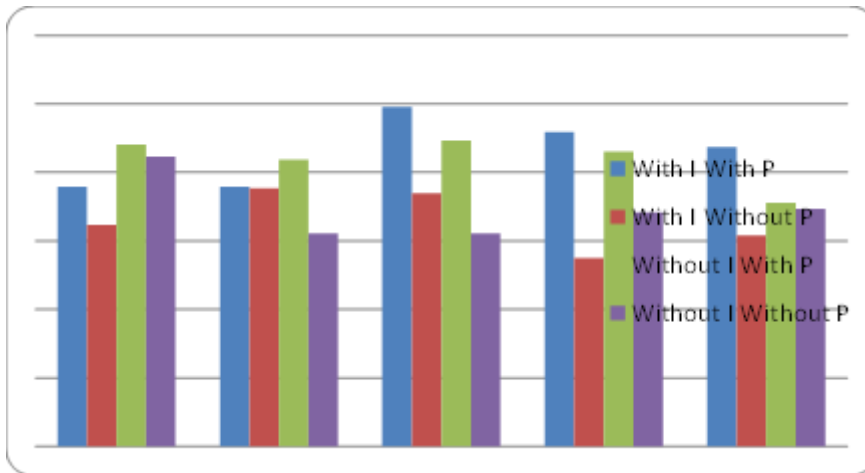
Trials were first carried out from February to June 2011, in farmer fields at Mudaka and Mulamba local areas, on a split split plot design with three replications, to assess the effect of P supplying on inoculated introduced 4 soybean varieties, compared to one local in use in the province. P effect was assessed, following mineral deficiencies noted on soybean in need to inoculate trials, deficiencies whose symptoms could not be clearly attributed to P or K deficiencies. Results of this trial led to another trial from September to February 2012 in Murhesa local area on a split plot design with three replications, applying P as TSP and K, as KCl, limiting factors for BNF, at a rate of 30 kg ha<sup>-1</sup> on all plots at the sowing date. For this second trial, soybean varieties were the same as previously (TGX-64F, TGX-11F, TGX-20F, TGX-28F, SB19) but 4 others were added (SC Saga, SCS823-6-10, SC Squire, Imperial).

Another trial was set up in Mushinga local area in 2011, on a split plot design with three replications, applying P as TSP and K, as KCl, limiting factors for BNF, at a rate of 30 kg ha<sup>-1</sup> on all plots at the sowing date. Varieties used were TGX-11F, TGX-20F, TGX-28F, TGX-64F and SB24.

Parameters observed were percent germination, height at 50 % podding, collar diameter, fresh and dried biomass, number of leaves, nodule score and efficient nodules, pods per plant and grains per pod, weight of 100 grains and yield. Nodulation was assessed in the second trial in Murhesa local area.

### **Research application**

Grain yield results of soybean at Murhesa (split split plot design) are shown in Figure 1. The mean comparison at the phosphorus x varieties interaction level (C.V. >15 %) has shown the phosphorus effect, with or without inoculation, except for varieties TGX 1987-20F which appeared in group B and TGX 1987-11F without P in group A. All varieties which appeared



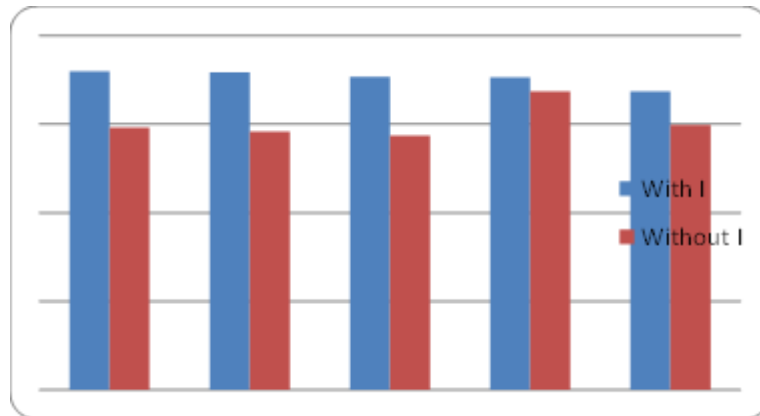
**Figure 1. Yield at Murhesa (kg/ha)**

in A group, with the check SB 24 already adapted in rural areas, recorded good grain yield, varying from 1927 to 2551 kg/ha, showing that they can be considered as adapted as the check. There was no effect of inoculation per se, due to the fact that soil analysis showed appreciable N rate (0.3 %) but low level of P (5,4 ppm); soil pH was acceptable (6,12), soybean, as many legumes, requests an pH rate from 6,0 to 6,5 (Javaheri and Baudouin 2001).

Without P application, grain yield results were also appreciable (from 1423 to 1825 kg/ha), the mean yield increase versus P application was 25,2 % ; concerning varieties, this increase was 44,3 % for TGX 1987-64F, 38,4% for TGX 1987-28F, 21,02 % for SB 24 and 8,8% for TGX 1987-11F. It is well known from the literature that because of low pH, tropical soils are not deficient in P but available P is low due to the firmly link with clay structure, accompanied with Al toxicity.

Grain yield results of soybean at Mushinga are shown in Figure 2. It has to be reminded that for this trial, there was no P limitation; P was applied to all plots, due to the fact that soils in this location are known as less fertile. This is confirmed by the yield of the check SB 24, which did not reached the potential of the variety, 2500 kg/ha. In Walungu administrative area soils are generally acidic with high aluminum saturation (>60%). In these conditions, available phosphorus as well as other nutrients especially cations content are very low and very often deficient (Lunze, 2000). Nevertheless, this low fertility is not evenly perceived everywhere in the studied area as soil fertility is very heterogeneous. The level of fertility is highly variable and heterogeneous with high variability from one farm to another as locally and throughout the world (Pypers *et al.*, 2010).

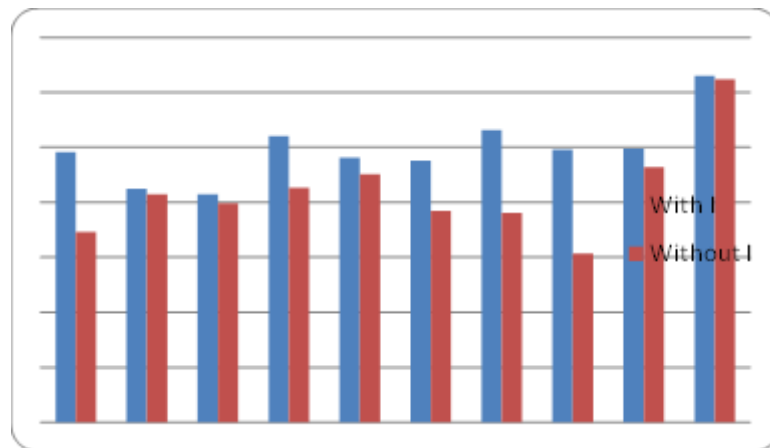
The analysis of variance showed inoculation effect: the mean grain yield reached 1761 kg/ha, versus 1494 kg/ha without inoculation; mean yield increase was 12.6 %, which is low, even in inoculation effect.



**Figure 2. Yield at Mushinga (kg/ha).**

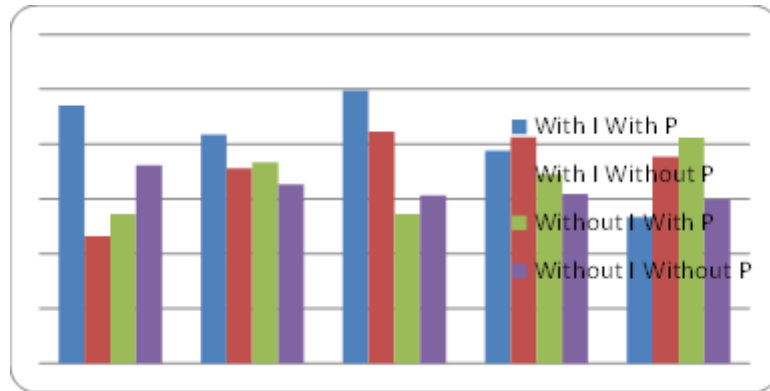
Yield results at Murhesa for additional varieties are shown in Figure 3. In this trial, no P was applied, as it is known that the soil is fertile, as stated previously and this can be confirmed by the yield obtain from SB24 adapted in the region (more than 3000kg/ha).

Analysis of variance showed interaction inoculation x varieties effect; the mean separation showed inoculation effect only on SCS823-6-10 although the number of red nodules was high on all inoculated varieties, except on 11F, 28F and 20F varieties. The absence of inoculation effect highlights what is stated in the literature about the fertile soil.



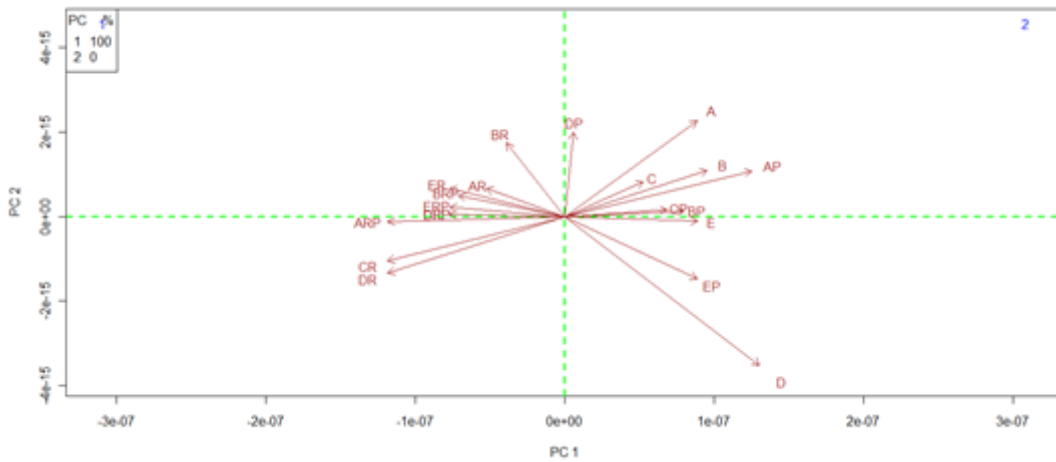
**Figure 3. Grain yield at Murhesa**

Yield results at Mulamba are shown in Figure 4. According to those results, there was no effect between varieties, inoculation or P application. This can be explained by the pH level of Mulamba (4,3) soils in Walungu administrative area where soils are known acidic with high Al toxicity (Vandamme, 2008).



**Figure 4. Grain yield at Mulamba.**

In summary, trials have shown that in less fertile soils inoculation effect is variable according to the pH level; even with P application pH level is still determinant for inoculated plants to benefit from P application in nitrogen fixation, because in acidic soils, legume development is poor. Two questions rose from these trials: due to poor response in many fertilization trials, is the P quantity (30 kg/ha) adequate for soils in the province when the literature recommends 45 kg/ha (Javaheri and Baudouin, 2001)? The P quantity applied is that recommended by N2 Africa project according to what is used by the project in Kenya and what is affordable by



**Figure 5. Analysis of varieties stability in integration of P-fertilizer and Rhizobium inoculation according to the yield through PCA.**

Legende

ARP=SB24/Rh+/P+ AR=SB24/Rh+/P- AP=SB24/Rh-/P+ A=SB24/Rh-/P-  
 BRP= PK06/Rh+/P+ BR= PK06/Rh+/P- BP= PK06/Rh-/P+ B= PK06/Rh-/P-  
 CRP =TGX-11F /Rh+/P+ CR= TGX-11F /Rh+/P- CP= TGX-11F /Rh-/P+  
 C= TGX-11F /Rh-/P- DRP= TGX-28F /Rh+/P+ DR= TGX-28F /Rh+/P-  
 DP= TGX-28F /Rh-/P+ D= TGX-28F /Rh-/P- ERP= SB19/Rh+/P+ ER= SB19/Rh+/P-, EP= SB19/Rh-/P+  
 E= SB19/Rh-/P-

farmers. Does the legume plant benefit from P applied at the sowing day, especially in acidic soils? The analysis of additive main effect and multiplicative interaction (AMMI) based on inoculation and potassium factors is shown in Figure 5.

The analysis of additive main effect and multiplicative interaction (AMMI) based on inoculation and potassium factors (Fig. 5) has shown that the yields of all the varieties varied according to the treatments used (P fertilizer and inoculation). Different treatments gave good stability and yield: three varieties without any external input (SB24, PK06, TGX-11F) and four with additional of P-fertilizer (SB24, PK06, TGX-11F and TGX-28F). Three other treatments gave high yield but low stability (TGX-28F without any input, SB 19 without any input and S19 with P). The treatments with inoculation didn't give high yields, however they are mostly stable with low yields, especially when coupled with P, except for SB24 which had slightly lower and unstable yield. Among all the varieties, TGX-28F and TGX-11F with Rhizobium only are the worse treatments. These results showed different behaviors of all the varieties in the study area. All the exotic varieties were less stable according to the yield in the different zones and this means that each variety should have its specific zone of dissemination and not all of them in the same area. However, SB24, PK06 and SB 19 under utilization in the area were most stable than the exotic ones (TGX-11F and TGX-28F).

### Acknowledgement

Authors would like to thank N2 Africa project who funded the work and all who participated in its implementation.

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