Response of Common Bean to *Rhizobium* Inoculation and Fertilizers.

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Abstract

Common bean *(Phaseolus vulgaris)* yields in Western Kenya are low and this has been attributed to low soil fertility. Field trials were conducted in farmers fields in Ukwala Division of Siaya District in Kenya during the long rains of 1998 and 1999 to determine the potential for improving bean yields through *Rhizobium* inoculation, and fertilizer N and P applications. The three factors: *Rhizobium* inoculation at two levels and fertilizers-N and P each at three levels were factorially combined to give 18 treatments. The treatments were laid out in a randomised complete block design with a split-plot structure and three replications. A popular local bean variety *Okuodo* was used as the test crop. During the 1998 long rains season, P significantly (P=O.05) increased the stand count after emergence, pod number per plant and the bean grain yields. Seed number per plant alone was significantly increased by fertilizer-N application. Significant interaction effects (P=O.05) were observed for NXP on the stand count after emergence and for *Rhizobium* inoculation XP on stand count after emergence, stand count at harvest and the bean grain yields. *Rhizobium* inoculation alone did not significantly affect any of the measured variables in both seasons. In 1999, only the bean grain yields were determined and were significantly (P=O.05) increased only by fertilizer P applications.

Introduction

Common bean *(Phaseolus vulgaris)* is an important source of protein and calories in human diets (Laing *et. al*, 1984; Smithson *et. al.*, 1993). Kenya is a leading producer of beans in the Eastern Africa region with over 500,000 ha. of land under the crop (Allen *et. al.*, 1989). Most beans are produced by small holder farmers who rarely inoculate with *Rhizobia* nor apply fertilizers. Bean yields on farmers fields are usually low; ranging from 0.14 to 0.77 t/ha (Kapkiyai *et. al.*, 1998), with the national average standing at 0.50 t/ha (Ssali, 1988). For legumes, nodulation and N_2 -fixation are dependent upon an adequate supply of both macro and micro nutrients (Munns, 1977; Smith, 1982). These nutrients are not only essential for the symbiotic interaction but also for the host plant and its microbial partner. Russo and Perkins-Veazie (1992) have demonstrated that fertillizer N, P and K can increase bean yields even when supplied at rates above those recommended. Symbiotic N_2 -fixation begins only after nodule formation, which is preceded by colonization of the rhizo sphere and infection of legume roots by *Rhizobia* (Hardy *et. al.*, 1971). Nitrogen requirement of legumes can be met by both mineral N assimilation and symbiotic N_2-fixation (George and Singleton, 1992). The plant N requirement may not be met during early vegetative and later productive phases by N_2- fixation. At these critical times, mineral N becomes the most important source of N for grain legumes. Poor nodulation and poor plant vigour have been observed in beans grown in soils low in extractable P (Amijee and Giller, 1998). Fertilizer P increases bean yields and causes optimum nodulation earlier during bean growth (Ssali and Keya, 1986). The bean crop is usually grown in association with maize. Among the benefits of the maize-bean intercrop system, include: enhanced pest tolerance (Ampofo and Massomo, 1998; Ugen and Chris, 1996), weed suppression (Wortman, 1993) and increased productivity (Wortman *et. al.*, 1996). One of the major constraints to bean production in western Kenya is low soil fertility (Rachilo and Michieka, 1991). In six out often years, the high potential parts of Western Kenya receive 1,300 to 1,700 mm precipitation per year. The precipitation is bimodal and allows for the growing of two maize crops per year (Jaetzold and Schmidt, 1983). Due to excessive leaching, the soils in this region are usually acid and low in N. Phosphorus is also frequently deficient in most soils (Karachi, 1979). The Grain Legume Project working in Central Kenya recommended the use of Diammonium Phosphate fertilizer on beans to supply 36 kg N/ha and 40 kg P_2O_5/ha (GLP, 1983). Ssali and Keya (1986) demonstrated that fertilization of beans promoted good early growth and that the beans fixed substantial amounts of dinitrogen.

This study aimed at enhancing bean production among the small holder farmers in Western Kenya through the use of *Rhizobium* inoculation and moderate applications of fertilizers N and P.

Materials and Methods

Field experiments were conducted on a farmer's field in Ukwala Division of Siaya District during the long rains of 1998 and 1999. For site characterisation, composite top (0-20 cm) soil samples were taken from the trial site and subjected to physical and chemical analyses at the time of planting in 1998. The soils were classified as orthic *Acrisols* according to the FAO/UNESCO legend (1988). The soils were acidic, low in total N, organic C, available P and exchangeable bases (**Table 1**).

A popular local bean variety *Okuodo* was used as the test crop. The plot size was 4.0 m by 1.5 m. Each plot had four rows. The inter and intra row spacings were 0.5 m and 0.2 m respectively. Two seeds were placed in each of the ten hills per row. The outer two rows in each plot were guard rows while the inner two rows were used for data collection. The three factors: *Rhizobium* (with and without inoculation), N at three rates (0, 10 and 30 kg N/ha) and P also at three rates [(0, 20 and 40 kg P_2O_5/ha) in 1998 and at (0, 30 and 60 kg P_2O_5/ha) in 1999] were factorially combined to give 18 treatments. The treatments were laid out in a randomised complete block design with a split-plot

Table 1. Characteristics of soils from the experimental fields

Soil property	Soil Test Value
pH water (1:2.5)	5.00
Organic Carbon (%)	0.67
Total Nitrogen (%)	0.07
Cation Exchange Capacity (cmol/gk)	8.10
Exchangeable Bases (cmol/kg)	
Ca	1.10
Mg	0.01
Na	0.01
K	0.20
Available P	
Mehlich P (μ P/g soil)	1.30
Texture	
Sand (%)	34.00
Silt (%)	22.00
Clay (%)	44.00
Textural Class	Clay
Soil Classification	orthic *Acrisol.*

Figure 1. Effect of Nitrogen on the number of seeds per plant

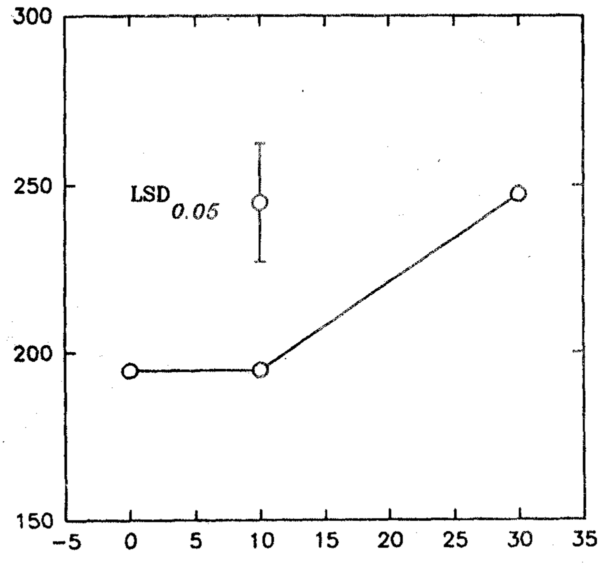


Table 2. The Nitrogen by Phosphorus interaction effect on the stand count of beans after emergence

	Mean Bean Stand Count per Plot		
	P Rate (Kg P_2O_5/ha)		
N Rate (Kg N/ha)	0	20	40
0	61.5bc	62.0bc	58.3bc
10	64.7ab	62.2bc	56.0bc
30	55.2c	70.8a	64.5ab

SED=2.694; LSD=7.864; ∝ =0.05; CV = 10.7%
Means with the same letter/s after them are not significantly different.

structure and three replications. The *Rhizobium* inoculum was prepared and supplied by the MIRCEN project at the Department of Soil Science, University of Nairobi. The sources of N and P were Calcium Ammonium Nitrate (26% N) and Triple Superphosphate (46% P_2O_5) respectively. In each of the planting seasons, the beans were sown at the end of February and harvested at the end of June.

Data collected included; pod and seed numbers per plant for the 1998 season and the bean grain field weight for both the 1998 and 1999 seasons. The data were subjected to analysis of variance using the statistical program MSTAT-C and the means separated by LSD.

Results and Discussion

Rhizobium inoculation did not influence any of the measured variables. Lack of response to *Rhizobium* inoculation has also been observed by Montealegre and Graham (1996) who attributes it to the presence of numerous, ineffective indigeneous *Rhizobia.* According to Mcloughlin and Dunican *(1985)*, competition between *Rhizobia* strains in the soil is a common phenomenon as the introduced inoculum strains compete with indigeneous *Rhizobia* for nodule sites. Montealegre *et. al., (1995)* suggests that cultivars that select strains, rather than nodulate with ineffective indigenous *Rhizobia,* offer one approach to the resolution of lack of response to *Rhizobium* inoculation problem. Moawad *et. al.*, (1998), have found evidence of certain *Rhizobia* strains which only improve N_2-fixation and bean yields in specific cultivars. It is therefore apparent that host variety and strain of *Rhizobium* difference in dinitrogen fixing ability could contribute significantly to the frequently observed unsatisfactory observed responses to inoculation (Graham, 1981).

Whereas some bean cultivars respond to *Rhizobium* inoculation, some only respond to applied N (Duque *et. al*,. 1985). Application of fertilizer-N, significantly ***(P=0.05)*** increased the bean seed number per plant alone (**Figure 1**). This conforms to observations made by Dadson and Acquaah, (1984) who found that in N deficient soils, small starter doses of applied N may stimulate nodule formation and enhance the grain yield of legumes. Phosphorus significantly *(P=0.05)* enhanced the establishment of the beans and increased the stand count after emergence , number of pods per plant, and the bean grain yields for the 1998 and 1999 seasons respectively (**Figure 2**). Phosphorus has been shown to promote the formation of nodes and pods in legumes (Buttery, 1969; Dadson and Acquaah, 1984). The responses due to applied fertilizer-N and P were consistent with the low fertility status of the soils (**Table 1**) on which the field trials were conducted. The low soil N status of the soils was expected to encourage a positive response to *Rhizobium* inoculation particularly in the presence of applied P. This observations contradict observations made by Gobara *et. al.*, (1993). The response to applied P could be attributed to genotypic characteristics. Yan *et. al.*, (1995) and Ssali and Keya, (1986) observed a close correlation between small seeded bean genotypes and P use efficiency. The smaller the seed size the more the efficient the use of P. *Okuodo,* the local bean variety used in this study is small seeded.

There was a significant *(P=0.05)* NxP interaction effect on the stand count after emergence (**Table 2**). This observation suggests that both N and P should be supplied to soils in which they are **deficient in order to ensure good**

Figure 2. Effect of Phosphorus on: a) Bean stand count per plot after emergence; b) Number of pods per plant; c) Bean grain yield in 1998 and; d) Bean grain yield in 1999.

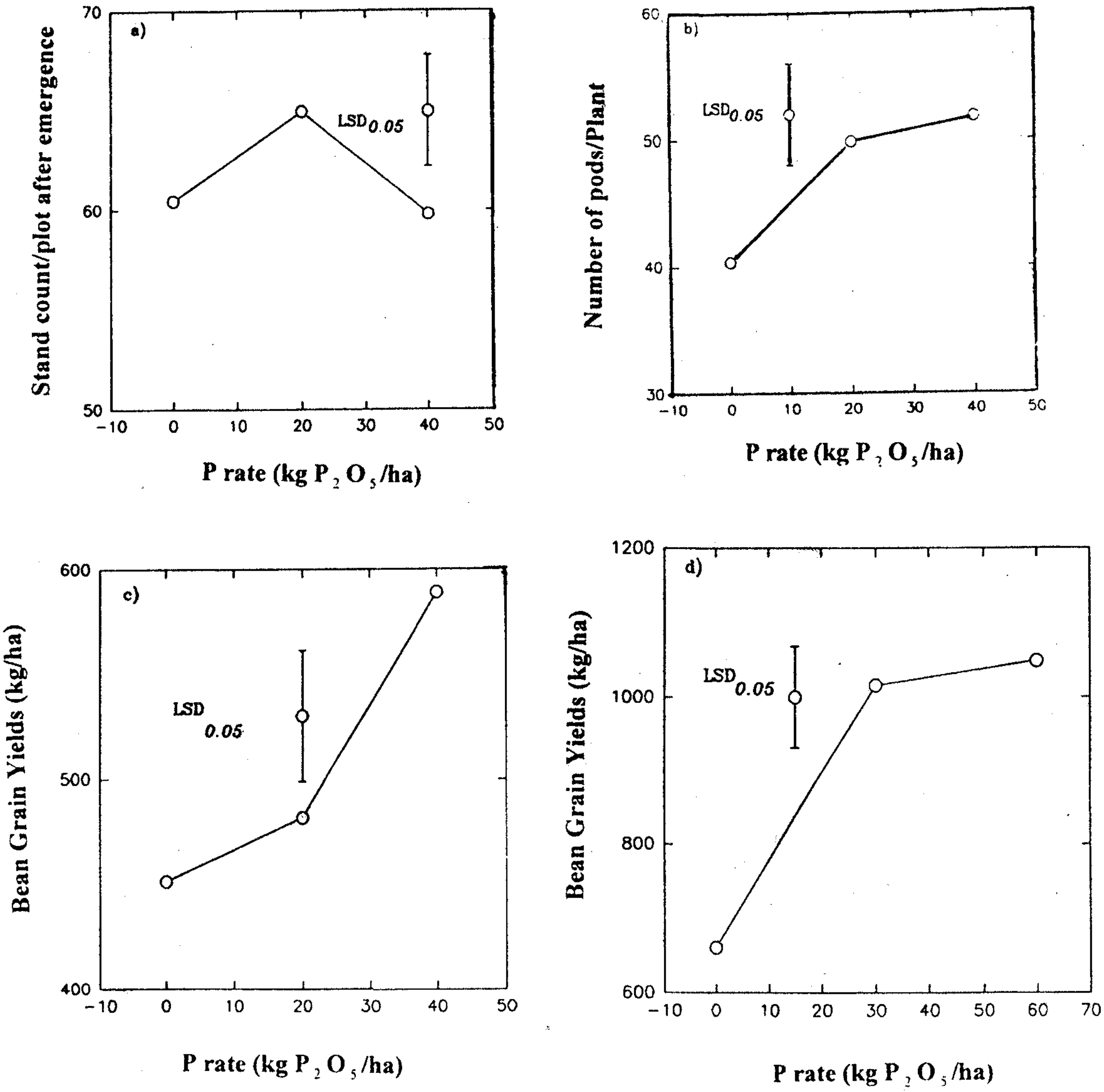


Table 3. The interaction effect of *Rhizobium* inoculation by Phosphorus on the bean stand count after emergence and at harvest.

	Mean Bean Stand Count per Plot at Emergence		
	P Rate (Kg P_2O_5/ha)		
Rhizobium Inoculation	0	20	40
Without	57.1b	64.2a	62.7ab
With	63.8ab	65.8a	56.9b

SED= 2.202; LSD= 6.421; ∝=0.05; CV= 10.7%.
Means with the same letter/s after them are not significantly different.

	Means Bean Stand Count per plot at Harvest		
	P Rate (Kg P_2O_5/ha)		
Rhizobium Inoculation	0	20	40
Without	58.4c	60. 8bc	64.3ab
With	65.0a	63.3ab	60.4bc

SED=1.303; LSD=3.804; ∝=0.05; CV=6.3%
Means with the same letter/s after them are not significantly different.

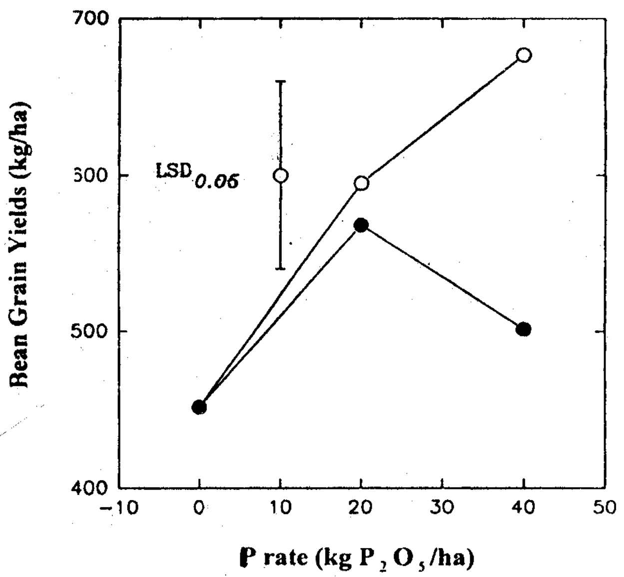
establishment of beans. Significant (P=0.05) interaction effects of *Rhizobium* inoculationXP were found on both the stand counts taken after emergence and at harvest (**Table 3**), and the bean grain yields (**Figure 3**). This interaction probably enhanced N assimilation reinforcing the observed response to N application.

Further investigations are needed to develop appropriate bioeconomic models for the various soil fertility niches. Rhizobia strains and soil types in Western Kenya.

Conclusions

This study has clearly shown that in the low fertility orthic *Acrisols* of Western Kenya, the P applications are key to

Figure 3. Interaction effect of *Rhizobium* inoculation by Phosphorous on bean grain yields. (• without, ○ with) *Rhizobium* inoculation



enhancing bean yields on farmers' fields. However, there is need to determine the conditions under which beans would respond to *Rhizobium* inoculation as this would help in reducing the production cost of beans by the resource poor farmers whose production is limited to subsistence levels.

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