IMPROVEMENT OF GRAIN LEGUME PRODUCTION IN DRYLAND FARMING SYSTEMS OF KENYA THROUGH BIOLOGICAL NITROGEN FIXATION: EXPERIENCE WITH TEPARY BEAN (*PHASEOLUS ACUTIFOLIUS A. GRAY var. LATIFOLIUS)*

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INTRODUCTION

Currently, food production in the arid and semi-arid lands (ASALs) of Kenya has lagged behind population growth and as such there is an urgent need to step-up food production for the expanding population (Bohlool et al., 1992). One of the major steps towards increasing food production in the ASALs is the use of modern technologies in agriculture and selection of suitable crop cultivars. Dow (1989) emphasized the need for research on drought tolerant crop species of short vegetative cycle, e.g. *Pima-Papago* maize (*Zea mays*) varieties (Tohono *O'odham* Z16) and tepary beans (TB) (*Phaseolus acutifolius*), as one of the special issues in development related to drought, desertification and food deficit in Africa. Unfortunately, the use of the above mentioned technologies in the ASALs have not been adequately adapted because of socio-economic constraints (Shisanya, 1999). Most farmers in the ASALs are resource-poor and cannot afford the required inputs, mainly in the form of chemical N fertilizers. Legume-*Rhizobium* has been exploited elsewhere as a substitute for the N fertilizers (Hornetz et al., 2000). This technology uses the *Rhizobium*-legume symbiosis that has become particularly important because it has shown very high rates of N_2 fixation (Zargar and Kahlon, 1995). There is very little research work that has been carried out on the effectiveness of N_2 fixation of indigenous (natural) and inoculated (host-specific) rhizobia strains on drought-adapted legumes, e.g. TB in semi-arid SE-Kenya (Maingi et al., 2001). The main objective of this study was therefore to investigate N_2 fixation in TB through inoculation by different host-specific rhizobia strains under the semi-arid environment of SE-Kenya.

MATERIALS AND METHODS

Tepary Bean Seeds

TB seeds were obtained from smallholder farmers at Kiboko, SE-Kenya. Undamaged seeds of uniform colour and size were selected for the field experiments.

Field Experiments

Field experiments were conducted during the long rains season of 2000. Tepary beans were sown in rows 50 cm apart with spacing of 20 cm giving a plant density of 100,000 plants ha^{-1} in a complete randomised block design. The treatments were as follows: (1) Nitrogen (N), (2) Control, (3) R578, (4) R446, (5) R579, (6) R3254 and (7) RTB. Nodule assessment was carried out using the method described by Vincent (1970). The number of Rhizobia in the soil was determined using the MPN plant infection technique as described by Beck et al. (1993). Plants were sampled at 21, 42 and 70 days after emergence (DAE), corresponding to first nodule formation, flowering and physiological full maturity, respectively. Four plants were randomly sampled from each treatment replicated and various parameters assessed. All data were subjected to ANOVA and means separated using Duncan's multiple range test at $P \leq 0.05$ level (Steel and Torrie, 1981).

RESULTS AND DISCUSSION

There were significant differences ($P \leq 0.05$) in nodule number and the corresponding nodule dry weight between treatment R3254 and the rest of the other treatments at 21DAE (Table 1). Treatment R3254 had the highest number of nodules at this stage of growth. The rest of the treatments had the same number of nodules. However, no significant differences in total plant dry weight between the different treatments, 21 DAE, were observed (Table 1).

Table 1. Effects of rhizobia inoculation on growth and nodulation of TB 21 DAE during the long rains season of 2000.

Treatment	Nodule number (plant^{-1})	Nodule dry weight (mg plant^{-1})	Plant dry weight (g plant^{-1})
(1) TB + N*	10^b	4.9^b	2.8^a
(2) Control	10^b	4.8^b	2.2^a
(3) TB + R3254	16^a	7.8^a	2.7^a
(4) TB + R446	10^b	4.7^b	2.6^a
(5) TB + RTB	10^b	4.8^b	2.5^a
(6) TB + R578	10^b	4.6^b	2.7^a
(7) TB + R 579	10^b	5.0^b	2.4^a

Means (n = 28) followed by the same letter down the column are not statistically different ($P \leq 0.05$) by Duncan's multiple range test. *Nitrogen (N) fertilizer was top-dressed 10 DAE at the rate of 40 kg ha^{-1} of CAN (26 % N) powder.

The pattern observed 21 DAE was similar to that at 42 DAE, except for the pod dry weight and plant dry weight (Table 2). Treatment R3254 had significantly ($P \leq 0.05$) higher pod numbers per plant and hence pods dry weight. There was no significant difference ($P \leq 0.05$) in plant dry weight between the N and R3254 treatments. The other treatments had similar plant dry weights (Table 2). At final harvest, the R3254 treatment had significantly ($P \leq 0.05$) higher pod dry weight, plant dry weight, 100 seed weight, seed weight per plot and grain yield (Table 3). At 42 DAE during the season, there was no significant difference ($P \leq 0.05$) in plant dry weight between the N and R3254 treatments (Tables 4 and 7). The other treatments had similar plant dry weights, which were significantly lower ($P \leq 0.05$) than the N and R3254 treatments. At final harvest, the N fertilized plots had significantly lower grain yield compared to treatment R3254 over the two seasons (Tables 5 and 8). Soil mineral N is often a major limitation to crop growth and productivity. Apparently this was not the case in the present study since increasing supply of mineral N by fertilizer additions had no significant effect on dry matter production or grain yield in both seasons. However, uptake of N may be constrained by low root length density, which is typical of tepary bean (Shisanya, 1998), and/or inadequate soil moisture content by which mineral N can move to the plant root (Pilbeam et al., 1995). Further, the aspect of fast mineralization of N under such semi-arid conditions cannot be ruled out (Hornetz, 1997; Eichinger, 1999). According to Ledgard et al. (1985), Danso et al. (1988), Hardarson et al. (1988) and Launauce (1996), among others, for temperate and cold climates, it seems that very little N is transferred to the plants in the short term period because of mineralization.

Table 2. Effects of rhizobia inoculation on growth and nodulation of TB 42 DAE during the long rains season of 2000

Treatment	Nodule number ($plant^{-1}$)	Nodule dry weight (mg $plant^{-1}$)	Pod number ($plant^{-1}$)	Pod dry weight (g $plant^{-1}$)	Plant dry weight (g $plant^{-1}$)
(1) TB+N*	25^{b}	5.8^{b}	28^{b}	25.3^{b}	12.6^{a}
(2) Control	25^{b}	6.0^{b}	26^{b}	19.7^{b}	9.5^{b}
(3) TB + R3254	43^{a}	15.4a	45^{a}	43.4^{a}	12.8^{a}
(4) TB + R446	26^{b}	5.9^{b}	25^{b}	18.6^{b}	8.5^{b}
(5) TB + RTB	24^{b}	5.7^{b}	26^{b}	23.4^{b}	10.5^{b}
(6) TB + R578	25^{b}	5.8^{b}	27^{b}	25.3^{b}	9.6^{b}
(7) TB + R579	27^{b}	5.9^{b}	29^{b}	18.8^{b}	9.3^{b}

Means (n = 28) followed by the same letter down the column are not statistically different ($P \leq 0.05$) by Duncan's multiple range test. *Nitrogen (N) fertilizer was top-dressed 10 DAE at the rate of 40 kg ha^{-1} of CAN (26 % N) powder.

Table 3. Effects of rhizobia inoculation on growth and grain yield of TB at final harvest 70 DAE during the long rains season of 2000

Treatment	Pod dry weight (g $plant^{-1}$)	Seed weight (g $plot^{-1}$)	Grain yield (kg ha^{-1})
(1) TB+N*	2415.3^{b}	1776.4^{b}	945^{c}
(2) Control	1955.3^{b}	1446.3^{b}	884^{c}
(3) TB + R3254	3418.3^{a}	2827.4^{a}	1419^{a}
(4) TB + R446	1959.3^{b}	1447.3^{b}	796^{c}
(5) TB + RTB	1964.4^{b}	1454.3^{b}	834^{c}
(6) TB + R578	1816.0^{b}	1333.7^{b}	792^{c}
(7) TB + R579	2270.3^{b}	1700.3^{b}	1039^{b}

Means followed by the same letter down the column are not statistically different ($P \leq 0.05$) by Duncan's multiple range test. *Nitrogen (N) fertilizer was top-dressed 10 DAE at the rate of 40 kg ha^{-1} of CAN (26 % N) powder.

CONCLUSION

It is evident from the results of this study that inoculation is necessary if high yields of tepary bean are to be realized in the semi-arid areas of SE-Kenya. Though the indigenous rhizobium specific to tepary bean (RTB) does fix some amount of nitrogen, it is less infective compared to the commercially available strain R3254. This strain offers a better alternative to the resource poor farmers than the more expensive artificial fertilizers for the improvement of tepary bean production in the region.

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