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Interactive Effects of Cultivars, Foliar Application of Mirconutrients and *Rhizobium* Inoculation on Snap Bean (*Phaseolus vulgaris* L.) Performance

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Abstract: A field experiment was conducted for two successive seasons (1995/96 and 1996/97) to examine the effects of inoculation, micronutrient foliar fertilization and cultivar on growth and yield of snap bean (*Phaseolus vulgaris* L.), in spilt-spilt plot design. The main plot was used for the inoculation, the subplots were allotted for micronutrients and the cultivars were placed in the sub-subplots. The results revealed that micronutrient fertilizers consistently gave a considerable increase in the number of pods and consequently higher yield. The cultivar Narina, generally, had heavier seeds, higher number of seeds per pod and taller plants compared to the cultivar Maestero. *Rhizobium* inoculation had no significant effect on the parameters measured. This necessitates the estimation of the number of native rhizobia for the crop of interest for accurate assessment of the need for inoculation. A significant interaction was found between cultivars and fertilizers only in leaf nitrogen content.

INTRODUCTION

Snap bean (*Phaseolus vulgaris* L.) is grown successfully during winter in central Sudan for export to European markets. Its low yield and poor quality in Sudan could be attributed to excessively high temperature, diseases, salinity and poor cultural practices (Habish and Ishag 1974; Mahdi 1993).

The response of different plant species to fertilization with macro- and micronutrients was investigated by several workers. Application of micronutrient fertilizers resulted in a considerable increase in all growth attributes of snap bean (Zaiter *et al*. 1992; Gobara *et al*. 1993). The bean relies on its symbiotic association with root-nodule bacteria for nitrogen supply. Differences in N_2-fixation efficiencies of rhizobia and the role of the host plant in the symbiosis are well documented (Rodriguez *et al*. 1994). Information on the response of snap bean to foliar spray with micronutrients in Sudan is scarce, although the snap bean is a major cash crop in the northern Sudan. This study was, therefore, conducted to examine the response of snap bean cultivars to foliar application of micronutrients and *Rhizobium* inoculation.

MATERIALS AND METHODS

A field experiment was conducted for two successive seasons (1995/96 and 1996/97) at the Faculty of Agriculture Demonstration Farm, Shambat, Sudan [latitude 15°36´N, longitude 32°32´E]. The soil is montmorillonitic clay with a pH ranging from 8.0 to 8.5, EC of 1.96 dSm^{-1}, and N and P contents of 0.02 and 0.03 mg kg-1 soil, respectively. The characteristics of the soil were determined using the procedures recommended by Page *et al*. (1982) and Klute (1986). The climate of the experimental area is semi-arid with relatively cool winter and hot summer. The experiment was set in a split-split plot design, with four replications. *Rhizobium* Inoculation (uninoculated or inoculated) was assigned to the main plots; the micronutrient fertilizer (no fertilizer, Zinc-nitro or Superfert) to the subplots and snap bean cultivars (Narina and Maestero) to the sub-subplots. Seeds were directly sown in the field at the rate of two seeds per hole on both sides of the ridge at spacing of 15 cm, in the second half of November. Zinc-nitro consisted of 13.7% (w), 1.37% Fe, 4% Zn, 2500 ppm Mn, 130 ppm Cu, 130 ppm B, 60 ppm Mo and 60 ppm Co, while Superfert consisted of 24% nitrogen, 24% P_2O_5, 18% K_2O, 1500 ppm MgO, 1000 ppm Fe, 300 ppm Zn, 100 ppm Cu and 250 ppm Mn. Foliar spray (2 ml/l of either fertilizer) started 15 days after planting and the plants were sprayed four times before harvest (once a week) by thoroughly covering the foliage to runoff.

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Rhizobium strain TAL 1797, (Niftal, Project, University of Hawaii, USA) was applied two weeks after sowing by placing two grams of *Rhizobium* inoculum (carrier-based) below each seedling. Yield data were collected from 10 randomly labelled plants in the northern side of the middle two ridges. The outer two ridges in each plot were used for destructive sampling.

At the 5^{th}, 6^{th} and 7^{th} weeks from sowing, the number of nodules per plant was determined counted by destructive sampling. Plant height was measured at the end of the 5th week. The number of fresh pods per plant was counted, and thousand seed weight was determined from mature pods. The quality of the harvested seeds was evaluated by germination test, according to the rules and methods of the International Seed Testing Association (ISTA 1985).

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RESULTS AND DISCUSSION

Growth attributes and nodulation

Application of foliar fertilizers showed a consistent effect on plant height of both cultivars in both seasons (Table 1). Application of Zn-nitro produced significantly ($P \leq 0.01$) taller plants than the control. No significant difference was obtained between Zn-nitro and Superfert on plant height. These results coincide with the findings of Saren and Locarsico (1975). The cultivar Narina had significantly ($P \leq 0.01$) taller plants than Maestero, and this could be due to genetical differences between the two cultivars. The treatments had no interactive effects on plant height.

Cultivars, fertilizers and inoculation treatment resulted in a non-significant effect on the number of nodules per plant (data not shown). Habish and Ishag (1974) found that nodule numbers of haricot bean at Shambat are markedly low in comparison to northern sites in Sudan due to the warmer winter temperature at Shambat. Generally, the lack of response to inoculation could be due to the presence of relatively high numbers of indigenous snap bean rhizobia in the soil, which implies that competition for nodulation between inoculant and indigenous rhizobia is probably an important factor in the response to inoculation. Therefore, introduced rhizobia must be able to compete against a large native rhizobial population in order to occupy snap bean (Lupwayi and Mkandawire 1992) and groundnut nodules (Hadad and Loynachan 1985) These results reflect the importance of assessing numbers of the indigenous rhizobial population directly with the crop of interest to obtain an accurate assessment of the need to inoculate.

Yield and yield components

Application of Zn-nitro or Superfert significantly increased the number of mature pods per plant in both seasons (Table 2). These results agree with the findings of Saren and Locarsico (1975), who claimed that foliar fertilizers resulted in a significantly higher number of pods/plant. No significant difference was obtained between the two micronutrients treatments, and also no significant differences were found between the cultivars and the inoculation treatments in both seasons.

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Application of Zn-nitro resulted in a high germination percentage in the first season, while application of Zn-nitro or Superfert resulted in a high germination percentage in the second season (Table 3). This is not uncommon as shown by Midan *et al*. (1986), who found that application of $MnSO_4$ increased germination percentage of onion seeds (Table 3).

The effect of Zn-nitro and Superfert on seedling shoot and root length, and fresh and dry weights of snap bean plants were significant ($P \leq 0.05$) in the first season (Table 4), while in the second season only Superfert resulted in a significant effect in seedling shoot and root lengths and seedling fresh and dry weights. This increase was presumably due to increased nutrient acquisition by plants fed with fertilizer. No significant interaction on plant vigour was found. Application of Zn-nitro or Superfert resulted in a significant ($P \leq 0.01$) increase in 1000-seed weight in both seasons (Table 5). These results are in line with the findings of Zaiter *et al*. (1992), who concluded that trace elements increased 1000-seed weight. This is expected since the soil under the crop was alkaline, and this restricts the uptake of these nutrients. Cultivar Narina produced significantly heavier seeds than Maestero, which may be due to difference in the genetic make up of the cultivars.

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Table 1. Effects of inoculation, micronutrient fertilizer and cultivar on plant height (cm) of *Phaseolus vulgaris* L. in the first and the second season

Cultivar	**Fertilizer**				**Fertilizer**			
	Control	Zn-nitro	Superfert	mean	Control	Zn-nitro	Superfert	mean
	First season				**Second season**			
	Uninoculated				**Uninoculated**			
Narina	44.40	45.20	46.25	45.28	40.65	44.20	44.95	43.20
Maestero	35.20	41.50	35.95	37.55	34.20	36.25	36.40	35.61
Mean	39.80	43.35	41.10	41.41	37.42	40.22	40.67	39.43
	Inoculated				**Inoculated**			
Narina	43.20	48.20	48.35	46.58	39.90	45.00	43.12	42.63
Maestero	37.20	38.30	37.85	37.78	34.00	34.40	41.52	36.64
Mean	40.20	43.25	43.10	42.18	36.95	39.70	42.32	39.63
Mean (fertilizer)	40.00	43.30	42.10		37.19	39.96	41.49	
Mean (cultivar)								
Narina				45.94				42.94
Maestero				37.66				36.12

$LSD_{0.05}$ for:		
inoculation	= 7.66	= 3.70
Fertilizer	= 3.30	= 2.55
Cultivar	= 2.64	= 3.00

Table 2. Effects of inoculation, micronutrient fertilizer and cultivar on the number of pods per plant of *Phaseolus vulgaris* L. in the first and the second season

Cultivar	**Fertilizer**				**Fertilizer**			
	Control	Zn-nitro	Superfert	mean	Control	Zn-nitro	Superfert	mean
	First season				**Second season**			
	Uninoculated				**Uninoculated**			
Narina	33.55	44.40	40.70	39.55	28.65	34.90	41.55	35.03
Maestero	32.90	43.00	37.35	37.75	24.35	35.35	38.25	32.65
Mean	33.22	43.70	39.02	38.65	26.50	35.12	39.90	33.84
	Inoculated				**Inoculated**			
Narina	38.05	42.75	44.90	41.90	33.80	44.40	41.25	39.81
Maestero	34.85	42.30	40.30	39.15	33.40	37.30	34.90	35.20
Mean	36.45	42.52	42.60	40.52	33.60	40.85	38.07	37.50
Mean (fertilizer)	34.83	43.11	4081		30.05	37.98	38.98	
Mean (cultivar)								
Narina				40.72				37.42
Maestero				38.45				33.93

$LSD_{0.05}$ for:

inoculation = 19.56 = 7.72

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Fertilizer	= 3.39	= 5.92
Cultivar	= 3.01	= 3.55

Table 3. Effects of inoculation, micronutrient fertilizer and cultivar on seed germination percentage of *Phaseolus vulgaris* L. in the first and the second season

Cultivar	**Fertilizer**				**Fertilizer**			
	Control	Zn-nitro	Superfert	mean	Control	Zn-nitro	Superfert	mean
	First season				**Second season**			
	Uninoculated				**Uninoculated**			
Narina	74.96	95.00	76.88	82.28	79.00	82.00	85.00	82.00
Maestero	79.28	88.00	73.28	80.18	78.00	87.00	83.00	82.66
Mean	77.12	91.50	75.08	81.23	78.50	84.50	84.00	82.33
	Inoculated				**Inoculated**			
Narina	84.00	89.00	75.69	82.89	79.00	89.00	86.50	84.83
Maestero	72.28	84.00	84.00	80.10	81.00	89.00	91.00	87.00
Mean	78.12	86.50	79.84	81.49	80.00	89.00	88.75	85.91
Mean (fertilizer)	77.63	89.00	77.46		79.25	86.75	86.37	
Mean (cultivar)								
Narina				82.58				83.41
Maestero				80.14				84.83

$LSD_{0.05}$ for:		
inoculation	= 24.18	= 6.14

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Fertilizer	= 8.96	= 3.29
Cultivar	= 7.61	= 2.17

Table 4. Main effect of cultivar, fertilizers and inoculation on seedling vigour of *Phaseolus vulgaris* L. in the first and the second season

Treatment	Shoot length (cm)	Root length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)	Shoot length (cm)	Root length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)
	First Season				**Second Season**			
Inoculation								
Uninoculated	6.66	5.91	18.53	2.68	6.17	7.86	7.19	0.95
Inoculated	6.82	5.82	19.53	2.87	6.26	7.47	6.47	0.97
$LSD_{0.05}$	0.50	1.39	6.28	0.58	0.54	2.22	2.16	0.26
Significance level	ns	ns	ns	ns	ns	ns	ns	ns
Fertilizer								
Control	6.34	5.24	17.75	2.34	5.83	6.39	6.23	0.85
Zn-nitro	7.34	6.47	21.20	3.00	6.42	6.68	7.65	1.13
Superfert	6.54	5.90	18.14	2.94	6.37	7.86	6.64	0.90
$LDS_{0.05}$	0.68	0.64	2.68	0.60	0.41	1.32	1.42	0.23
Significance level	*	*	*	*	*	*	*	*
Cultivar								
Narina	6.71	5.93	19.85	2.84	6.36	7.78	7.79	1.09
Maestero	6.77	5.81	18.20	2.70	6.07	7.50	5.90	0.83

$LSD_{0.05}$	0.51	0.74	1.90	0.42		0.40	0.98	1.04	0.16
Significance level	ns	ns	ns	ns		ns	ns	*	*

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Table 5. Effects of inoculation, micronutrient fertilizer and cultivars on 1000 seed weight (g) of *Phaseolus vulgaris* L. in the first and the second season

Cultivar	Fertilizer				Fertilizer			
	Control	Zn-nitro	Superfert	mean	Control	Zn-nitro	Superfert	mean
	First season				**Second season**			
	Uninoculated				**Uninoculated**			
Narina	184.37	216.87	204.82	202.02	197.15	219.30	199.82	205.42
Maestero	152.07	170.02	151.97	158.02	131.25	146.80	145.22	141.09
Mean	168.22	193.44	178.39	180.02	164.20	183.05	172.52	173.25
	Inoculated				**Inoculated**			
Narina	198.15	210.90	198.45	202.50	179.30	214.12	208.25	200.55
Maestero	141.22	165.57	183.15	163.31	142.07	160.82	166.47	156.45
Mean	169.68	188.23	190.80	182.90	160.68	187.47	187.36	178.50
Mean (fertilizer)	168.95	190.83	184.59		162.44	185.26	179.94	
Mean (cultivar)								
Narina				202.26				202.98
Maestero				160.66				148.77

$LSD_{0.05}$ for:		
inoculation	= 16.30	= 15.90
Fertilizer	= 14.00	= 14.85
Cultivar	= 15.63	= 10.62

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