

Response of *Vice faba* to Seed Inoculation, Nitrogen and Phosphorus at Two Different Areas in the Sudan

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ABSTRACT. The effect of starter N and P were studied on seed inoculated faba bean at three different locations in the Sudan namely Wad Medani and Turabi in the Gezira (new area) and Abu Hasheem (traditional faba bean growing area) in the Northern Province.

Starter N (20 kg N/ha) dose seemed to inhibit nodulation in the warmer area of Wad Medani while at the relatively cooler area of Abu Hasheem, the depressing starter N effect on nodule formulation was not evident.

Inoculation resulted in increased nodulation and plant dry matter production up to 6-8 weeks from sowing. Increased nodulation, however, was not reflected in shoot N uptake or seed yield.

Phosphorus enhanced nodulation, nitrogen fixation and seed yield. The enhancement was greater when a starter dose of N was applied. It seemed to have increased biological N₂ fixation and/or the N use efficiency by faba beans. It is worth mentioning that P application though resulted in significantly higher seed yields, but it at the same time reduced the 1000 seed weight.

On the other hand, faba bean seed yield did not respond to seed inoculation or even fertilizer N in both areas in the absence of P. This indicated efficient N-fixation by the indigenous rhizobia in both areas.

The importance of faba bean (*Vicia faba*) in the Nile Valley is that millions in the Sudan and Egypt depend on it as a staple food for both breakfast and dinner. The grain, which contains 30% protein, (Mukhtar and Nourai 1984) is the main protein source especially for the poor sectors in both countries.

Faba bean cultivation in Sudan was limited to the comparatively cooler, arid climate zone of the Northern Region known as its traditional area. After the initiation of the international Centre for Agricultural Research in the Dry

Areas/International Fund for Agricultural Development Nile Valley Project (NVP), possible expansion south of Khartoum was contemplated. The area with warm winters and semi-arid climate, was to include the Gezira, Rahad, Turabi and New Halfa (see Fig. 1 for mean temperature of the two areas). Soil in all sites is alkaline heavy clays low in available P (~ 4 ppm) (Table 1).

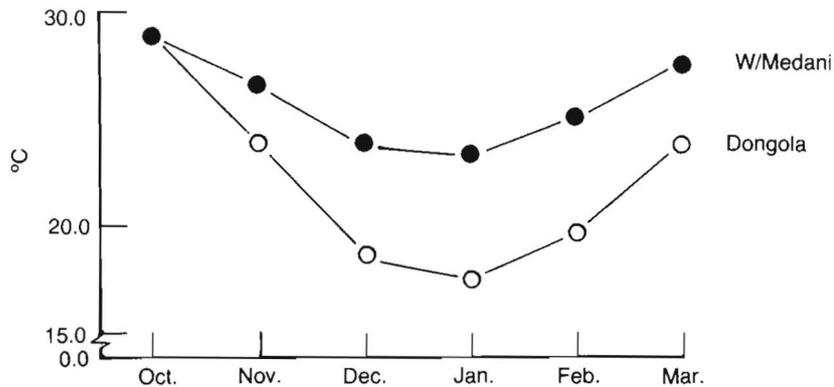


Fig. 1. Mean temperature (30 years) at Dongola (traditional) & Wad Medani (New Areas)

Table 1. Some soil properties at Wad Medani (New Area) and Zeidab (Traditional Area)

	pH	Clay %	C %	N ppm	Total salts %	Available P
Gezira W/Medani	8.5	60	0.40	400	0.06	4.0
Zeidab	8.0	50	0.75	600	low	4.0

In the traditional area, a high population of *Rhizobium leguminosarum* exists and a good deal of nodulation and N_2 -fixation is evident (Musa 1982). This is reflected in the crops negative response to added fertilizer nitrogen except under some adverse situations, e.g. salinity and in pockets of areas where the *Rhizobium* population is low due to lack of previous faba bean cultivation (Mukhtar and Nourai 1984 and Witty *et al.* 1980).

In the new areas nodulation and N_2 -fixation follow the cropping history of the particular plot and the response to fertilizer-N behaves similarly (Musa 1982, Mahdi *et al.* 1983). In general, however, the new areas harbour a scanty number of *R. leguminosarum* (Mukhtar *et al.* 1985-87).

Hitherto, microbial research in the traditional area should perhaps cater for making conditions better for the existing high population of *Rhizobium* rather than introducing new strains. This possibly achieved through following the optimum sowing date, adding aiding (starter) dose of N, phosphorus and trace elements. In the new areas, however, the most efficient strains should be introduced through intensive screening.

The present work was carried out between seasons 1982/83 to 1984/85 in both the traditional and new areas of faba bean in the country, with the aim of improving the performance of the already present indigenous rhizobia in the traditional area through P and starter N dose application. Inoculation was included here since the area studied was virgin to faba bean though within the traditional area. In the new areas, however, the purpose of this work was to introduce the most efficient strains available.

Dependence on N-fixation for the production of the crop being the final goal since nitrogenous fertilizers became very expensive lately and hard currency for their importation even very dear.

Experimental

All sowings were effected between the 31st of October and the 20th of November, the optimum sowing date being the first week of November (Ageeb, personal communication). A randomized complete block design replicated four times was used. Sowing was done using 60 cm ridges by 15 cm between holes and 2-4 seeds/hole. Seed inoculation was the rule for all experiments. This was done by mixing the seed thoroughly with a slurry of the peat-based inoculant in a 6.6% solution of gum arabic. Both nitrogen (urea) and phosphorus (triple super phosphate 'T.S.P.'), were applied as side dressing. Irrigation was effected every 7-10 days.

In all experiments the parameters studied included nodule number and/or dry weight, shoot dry weight, shoot nitrogen content at different time intervals during crop development.

Shoot N-content was measured through Kjeldhal determination of the total N % in the plant material which was then calculated for the plant material produced. At harvest seed yield, total biological yield as well as yield components were estimated.

Experiment 1

Effect of inoculation with a starter dose of fertilizer N on nodulation, N₂-fixation and yield of faba bean - 1982/83.

This experiment was carried out at the Wad Medani location in season 1982/83. It included the following treatments:

T ₁ Uninoculated	T ₂ 120 kg N/ha (3-splits) sowing, 1 month and 2 months.
T ₃ Inoculated SL24 (Aleppo).	T ₄ Inoculated with a local strain
T ₅ Inoculated SL24 + 20 kg N/ha.	T ₆ Inoculated local + 20 kg N/ha.

The strain SL24 was a composite of the Aleppo Strains BB80b, BB54b and SL23 which performed well at this location in the previous season.

Experiment 2

Best available strain + starter N at 2-levels of phosphorus and its effect on nodulation, N₂-fixation and yield of faba bean - 1984/85.

To study P effect on nodulation together with the starter N dose used. The following treatments were carried out at the two locations of Wad Medani (New Area) and Rubatab (Traditional but not grown to faba bean before):

T ₁ Uninoculated	T ₂ As for T ₁ + 50 kg P ₂ O ₅ /ha
T ₃ Inoculated SL24	T ₄ As for T ₃ + 50 kg P ₂ O ₅ /ha
T ₅ Inoc. SL24+10 kg N/ha	T ₆ As for T ₅ + 50 kg P ₂ O ₅ /ha
T ₇ Inoculated + 20 kg N/ha	T ₈ As for T ₇ + 50 kg P ₂ O ₅ /ha
T ₉ 120 kg N/ha (3-splits) at sowing, 1 and 2 months from sowing.	T ₁₀ As for T ₉ + 50 kg P ₂ O ₅ /ha

Experiment 3

This season 1984/85 the same experiment for 1983/84 was repeated at three locations. In addition to the Wad Medani and Rubatab, Turabi inside the Gdzira Scheme was included to avoid possible P and pesticide residual effects at the GRF, where the former are frequently applied.

Results

Experiment 1

All results are displayed in Table 2. At 40 days from sowing, significantly more nodule dry matter was produced by all inoculated treatments over T₂ (120 kg

N/ha), *i.e.* the higher dose of N reduced nodule formation. The inoculated treatments (T₅ and T₈) aided with a starter N dose, however, failed to exceed the control treatment. Inoculation without N produced significantly more nodular dry matter over the control. Even the small (20 kg/ha) N₂ dose has an adverse effect on nodulation. This has been reported with only high N applications (McEwen 1970 and Islam 1981).

Table 2. Effect of inoculation with and without starter N on seed yield, nodule dry weight and shoot N, uptake, Wad Medani, 1982/83

Treatment	Seed yield (t/ha)	Nod dry wt. g/plant 40	Nod dry wt. g/plant 80	Shoot N uptake g/plant 40 days from sowing
T ₁ Control	1.84 a	0.35 cd	1.09 abc	0.38 a
T ₂ 120 kg N/ha	1.76 a	0.12 d	0.31 e	0.46 a
T ₃ Inoculated (SL 24)	1.56 a	0.68 ab	1.51 ab	0.40 a
T ₄ Inoculated (Local)	2.12 a	0.77 d	1.64 a	0.35 a
T ₅ SL 24 + 20 kg N/ha	1.62 a	0.50 abc	0.86 bc	0.37 a
T ₆ Local + 20 kg N/ha	1.52 a	0.61 abc	1.00 abc	0.43 a
	NS	*	*	*NS
S.E. ±	0.18	0.09	0.18	0.04
LSD 5%	0.53	0.28	0.53	0.12

Duncan Multiple Range Test (DMRT): Means in the same column followed by same letter(s) are not significantly different at the 5% level.

At 80 days from sowing, all treatments produced significantly more nodules over the nitrogen treatment. It is worthnoting that at this date the adverse N effect was significant.

Though the plant dry matter was not affected by treatment, the shoot N content was significantly higher than that of the control for T₂ and T₃ at 40 days from sowing (Table 2). This was, however, not detected at the 80-day sampling.

As far as seed yield is concerned, even T₂ (120 kg N/ha) failed to produce any increase in yield over the control.

Experiment 2

At Wad Medani, significantly more nodular dry matter was produced at four weeks by T₃, T₄, T₅ and T₈ than T₁, T₂, T₉ and T₁₀. This was also true for the six week old plants (Table 3).

Table 3. Best available strain \pm N at 2-levels of phosphorus; nodule dry weight (g/plant) Medani/Rubatab - 1983/84

Treatment	Time from sowing					
	4 Weeks		6 Weeks		8 Weeks	
	Wad Medani	Rubatab	Wad Medani	Rubatab	Wad Medani	Rubatab
T ₁ Control	0.12	0.09 c	0.44 b	0.38 c	0.82 a	1.13 bc
T ₂ Control + P ¹	0.12	0.17 c	0.25 b	0.37 c	1.16 a	0.68 cd
T ₃ Inoculated	0.18	0.34 a	1.08 a	0.83 bc	0.72 a	1.58 ab
T ₄ Inoc. + P	0.31	0.35 a	1.04 a	0.81 bc	1.50 a	2.15 a
T ₅ Inoc. + 10 kg N/ha	0.27	0.32 ab	0.73 ab	0.81 bc	1.11 a	1.49 abc
T ₆ Inoc. + 10 kg N + P	0.13	0.39 a	0.58 bc	1.11 ab	0.97 a	1.87 ab
T ₇ Inoc. + 20 kg N/ha	0.23	0.32 ab	0.68 bc	0.76 bc	1.09 a	1.54 abc
T ₈ Inoc. + 20 N + P	0.13	0.27 ab	0.75 ab	0.98 b	1.09 a	1.70 ab
T ₉ 120 kg N/ha	0.07	0.18 bcd	0.18 c	0.23 c	0.63 a	0.63 c
T ₁₀ 120 kg N + P	0.11	0.13 de	0.12 c	0.37 c	0.36 a	0.70 cd
	*	*	*	*	NS	*
S.E. \pm	0.04	0.04	0.15	0.14	0.23	0.30
LSD 5%	0.11	0.13	0.44	0.40	0.66	0.89

P¹ 50 kg P₂O₅/ha

DMRT: Means followed by the same letter(s) on the same column are not significantly different at the 5% level.

At Abu Hasheem (Rubatab), the effect was more pronounced at all sampling times. At four weeks, all inoculated treatments (T₃–T₈) + starter N and/or P gave significantly more nodular dry matter over T₁, T₂, T₉ and T₁₀. At six weeks the same effect continued except that T₇ was not significantly different from T₁ and T₂ (controls). At 8 weeks, in addition to the positive effect of inoculation, a trend of increase in nodule dry matter with added P was evident (Table 3).

Shoot dry matter production was not affected by treatment at Wad Medani. At Rubatab only the 6 week old crop showed a differential response. Thus T₈ produced significantly ($P = 0.05$) more shoot dry matter over all treatments except T₆.

Shoot total N uptake did not show any treatment influence at Wad Medani. At Rubatab, however, T₈ (inoc. + N + P) lead to significantly more shoot N content than all other treatments.

Seed yield at Wad Medani was influenced by treatments, where T₅ significantly ($P = 0.05$) outyielded T₁, T₃ and T₉ (all without P). At the same time T₁₀ (120 kg N/ha + P) outyielded T₁ and T₉ (120 kg N/ha) (Table 4).

Table 4. Best available strain \pm starter dose of N₂ at two levels of P; effect on seed yield, shoot dry matter and shoot total N uptake - 1983/84

Treatment	Seed yield (t/ha)			Shoot total N uptake (g/plant) at 6 weeks from sowing		Shoot dry matter (g/plant) at 6 week
	W/Medani	Rubatab	Mean	W/Medani	Rubatab	Rubatab
T ₁ Control	1.63 bc	1.45 d	1.54 c	0.12 a	0.12 b	14.40 bc
T ₂ Control + P	1.80 abc	2.01 c	1.95 b	0.12 a	0.10 b	10.99 c
T ₃ Inoculated	1.60 bc	1.53 d	1.56 c	0.13 a	0.12 b	13.54 c
T ₄ Inoculated + P	1.75 abc	2.07 bc	1.91 ab	0.15 a	0.13 b	14.37 bc
T ₅ Inoc. + 10 N	2.27 a	1.59 d	1.93 ab	0.15 a	0.12 b	13.90 bc
T ₆ Inoc. + 10 N + P	1.79 abc	2.37 ab	2.08 a	0.13 a	0.16 ab	16.98 ab
T ₇ Inoc. + 20 N	1.77 abc	1.46 d	1.62 bc	0.11 a	0.12 b	12.90 bc
T ₈ Inoc. N + 20 N+P	1.56 abc	2.48 a	2.02 a	0.13 a	0.20 a	22.28 a
T ₉ 120 kg N/ha	1.35 c	1.62 d	1.49 c	0.11 a	0.10 b	10.73 bc
T ₁₀ 120 kg N + P	2.11 ab	2.28 bc	2.20 a	0.15	0.14 b	14.34 bc
	*	*	*	NS		*
S.E. \pm	0.17	0.14	0.163	0.02	0.02	1.92
LSD 5%	0.49	0.41	0.332	0.06	0.05	5.69

DMRT: Means in the same column followed by the same letter(s) are not significantly different at the 5% level.

At Abu Hasheem (Rubatab), all treatments receiving P gave significantly ($P = 0.05$) more seed yield over treatment not receiving P. T₈ in addition was significant ($P = 0.05$) over T₂ and T₄ while T₆ was significant over T₂ only (Table 4).

The mean of the two locations as far as grain yield is concerned showed that for each pair of similar treatments the one receiving P was significant over the other (Table 4). In addition, all treatments gave significantly more seed yield over T₁, T₃ and T₉ (all not receiving P). Thus inoculation with a starter N exceeded inoculation alone when the former was given P. The higher starter dose of 20 kg N/ha was better than the 10 kg N/ha dose. In general, yields of the traditional area of Rubatab were higher than those of the new area of Wad Medani. The adverse effect of starter N on nodulation shown in experiment 1 disappeared in the presence of P. Yield components were studied at the Rubatab location only. Here

T₄ significantly produced more pods per plant than T₃, T₅, T₇ and T₉ (all without added P). The least number of pods were formed where the crop received N without P (Table 5).

Table 5. Best available strain \pm starter N at two levels of P, number of pods/plant, seeds/pod and 1000 seed weight at Rubatab 1983/84

Treatment	Number/pod/plant	Seed/pod	1000 seed weight
T ₁ Control	16.6 abce	2.3 bc	377.9 abc
T ₂ Control + P	20.2 ab	2.8 a	359.4 ce
T ₃ Inoculated	14.5 bce	2.6 abc	385.8 ab
T ₄ Inoculated + P	23.1 a	2.7 ab	357.8 ce
T ₅ Inoc. + 10 kg N/ha	15.7 bce	2.2 c	387.4 a
T ₆ Inoc. + 10 N + P	18.9 abc	2.8 a	372.2 abce
T ₇ Inoc. + 20 kg N/ha	10.9 c	2.5 abc	385.9 ab
T ₈ Inoc. + 20 N + P	19.4 abc	2.7 ab	376.4 abce
T ₉ 120 kg N/ha	13.3 ce	2.5 abc	382.2 ab
T ₁₀ 120 kg N + P	17.1 abce	2.6 abc	366.1 bce
	*	*	*
S.E. \pm	1.95	0.13	5.95
LSD 5%	5.8	0.39	17.66

DMRT: Means in the same column followed by the same letter(s) are not significantly different at the 5% level.

As for number of seeds/pod T₂, T₄, T₆ and T₈ were significant ($P = 0.05$) over T₅ while T₂ and T₆ were also significantly ($P = 0.05$) better than T₁ (Table 5).

The results of the 1000 seed weight showed that lighter seed were produced where P was applied. This decrease in weight was significant. Thus, all inoculated treatment without P gave significantly ($P = 0.05$) higher 1000 seed weight than T₂ and T₈, while T₅ and T₉ gave also significantly ($P = 0.05$) higher seed weight than T₄ and T₁₀ (Table 5).

Experiment 3

The Wad Medani (GRF) suffered from what is believed to be a herbicidal residual effect. A lot of leaf burning and stunted plants were witnessed. The plants recovered after about six weeks, but ended up with lower yields than those of the previous seasons. The leaf miner incidence was high this season at both Turabi and Wad Medani but the lowering of yields could not be solely attributed to that. This is so because it was coupled with a short winter.

Shoot dry matter was studied at Wad Medani and Turabi only. At Medani, in week 6 (T₆ inoc. + 10 kg N/ha + P) produced significantly ($P = 0.05$) more shoot dry matter than treatment T₁, T₃ and T₆ (inoc. + 10 kg N/ha), T₉ and T₁₀. The other treatments showed an insignificant trend in favour of P (Table 6).

At Turabi, at week 4, T₂ (uninoculated + P) gave significantly ($P = 0.05$) more shoot dry matter than T₁ (control). T₈ (inoc. + 20 kg N + P) was also significant over T₇ (same without P).

Nodule dry matter and shoot tissue total N uptake were not influenced by treatment at all three locations. Nonetheless, the latter showed a strong trend in case of applied P at Rubatab and Turabi. Here both seed and straw yields were influenced by P application favourably but not significantly. Increments in seed yields due to P ranged from 6% (control) to 33% (N) at Rubatab, but did not reach the level of significance attained in the previous season. The economic feasibility for P application cannot be ruled out (Table 6).

Table 6. Shoot dry matter (g/plant), grain and straw yields (ton/ha) at the locations shown, 1984/85

Treatment	Shoot dry matter		Straw yield		Grain yield Rubatab
	Wad Medani (6 weeks)	Turabi (4 weeks)	Wad Turabi	Rubatab	
T ₁ Control	1.03 c	1.31 cd	1.65 a	1.77 a	1.80 a
T ₂ Control + P	2.06 abc	1.99 a	1.92 a	2.00 a	2.00 a
T ₃ Inoculated	1.96 bc	1.42 bcd	1.60 a	1.65 a	1.95 a
T ₄ Inoc. + P	2.18 abc	1.73 abc	2.06 a	1.88 a	2.07 a
T ₅ Inoc. + 10 kg N/ha	1.96 bc	1.31 cd	1.80 a	1.60 a	1.88 a
T ₆ Inoc. + 10 N + P	3.58 a	1.62 abcd	1.71 a	1.94 a	2.11 a
T ₇ Inoc. + 20 kg N/ha	2.06 abc	1.19 c	1.18 a	1.76 a	2.94 a
T ₈ Inoc. + 20 N + P	3.10 ab	1.81 ab	1.40 a	1.96 a	2.09 a
T ₉ 120 kg N/ha	1.64 bc	1.73 ab	1.52 a	1.54 a	1.60 a
T ₁₀ 120 kg N + P	2.00 bc	1.56 abcd	1.80 a	1.78 a	2.14 a
S.E. ±	0.45	0.15	0.21	0.16	0.17
LSD 5%	1.31	0.44	0.61	0.464	0.49

DMRT. Means followed by same letter(s) in the same column are not significantly different at 5% level.

Discussions

The reduction of nodulation and nitrogen fixation especially with high doses of inorganic N is well documented in literature (McEwen 1970 and Islam 1981). The fact that even a small starter dose of 20 kg N/ha reduced nodulation (Table 3) in the new area could be attributed to the low N demand by the crop. Since plants here are smaller in size and low yielding compared to the traditional area (Mukhtar and Abu Naib 1986). This is because the new area is said to be a marginal area to faba bean cultivation as far as climatic conditions are concerned (Ageeb and Mohamed 1985).

The disappearance of the starter N adverse effect on nodulation when P was applied was perhaps because the latter enhanced the efficiency of N uptake or even increased the crops demand for N. Increased demand could lead to rapid N uptake thus removing the latter from the zone of the rhizosphere of the plant. This is possible since nodulation in the traditional area, where N demand is higher, was not affected by the 20 kg N/ha.

The fact that added fertilizer N up to 120 kg N/ha did not increase seed yield, is indicative of efficient N₂-fixation or at least that the plant need for N is met from fixation and/or soil N. Since soil could provide only about one third of the crops demand in the new area (Mukhtar and Abu Naib 1986), therefore around 70% of the crop need for N came from fixation.

The decrease in the 1000 seed weight (Table 5) was contrary to the finding of (Salih and Ali 1986) and needs further work.

Decrease in yield due to short winters was reported by (Ageeb and Mohamed 1985) who found that an elevation of 5°C in the mean November temperature reduced faba bean yield by about 40%. Short winter always comes later than the optimum sowing date which is the first week of November. Elevated temperatures also are said to affect seasonal response to different treatments (Willy *et al.* 1980). This was shown in that the highly significant P influence in season 1983/84 was much reduced in the short winter season of 1984/85.

Conclusions

Whenever a high population of *Rhizobium leguminosarum* is present in the soil, faba bean did not respond to inoculation or added fertilizer N. This was true for the traditional faba bean areas except for some small pockets where the crop was not grown before.

Wherever the *Rhizobium* population was low, there was response to seed

inoculation and added fertilizer N. The former gave better results when P was added.

Phosphorus application enhanced nodulation, N-fixation and crop yield either significantly or to a reasonable percentages that need to be evaluated economically.

Since using expensive nitrogenous fertilizers defeats the purpose of growing legumes for cheaper food and protein production and for the maintenance of soil fertility, seed inoculation should be adopted in the new areas or indeed whenever the rhizobium population is low. This would be aided with phosphorus addition.

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أثر الأزوت والفسفور على تجارب الفول المصري للتلقيح (Inoculation) ببيكتريا العقد الجزرية (*Rhizobium leguminosarum*)

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وجد أنه حتى جرعات الأزوت الصغيرة (Satarter dose) (٢٠ كجم للهكتار) أثرت سلباً على تكون العقد الجزرية في منطقة مدني وهي الأكثر دفئاً بينما أختفى ذلك الأثر السلبي في المنطقة التقليدية للفول وهي المنطقة الباردة نسبياً.

أدى التسميد بالفسفور (٥٠ كجم للهكتار) إلى زيادة في الإنتاجية وفي تكون العقد الجزرية وتثبيت الأزوت بواسطة الفول المصري ويعتقد أن وجود الفسفور قد أدى كذلك إلى تنشيط امتصاص أزوت التربة بواسطة المحصول ولذلك يوصي بالتسميد الفسفوري لهذا المحصول، ومن الغريب أن سماد الفسفور ورغم زيادته للإنتاجية إلا أنه نتج عنه حبوب خفيفة الوزن.

وقد أثبت هذا البحث أن بيكتريا الرايزوبيا (*Rhizobia*) المستوطنة تقوم بمد محصول الفول بما يحتاج من الأزوت في المناطق التقليدية بينما يحتاج المحصول للتلقيح في المناطق الجديدة، إلا أن كلا المنطقتين لا يحتاجان للتسميد بالأسمدة الأزوتية.