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Effect of Plant Density and Certain Pesticides on Growth, Yield and Rhizobial Nodulation of Faba Bean (*Vicia faba* L.)

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Abstract. The effect of three plant densities (50, 75 and 100 plants/m^2) and five pesticides (bavastin WP 50%, rhizolex WP 50%, primor WP 50%, dimethoate EC 40% and nabu EC 20%) on plant growth, nodulation and acetylene-reduction activity was studied for two seasons. Seed yield/plant and the number of pods/plant decreased as plant density increased. However, the increase in plant density increased total yield per plot in both seasons. The increase in seed yield/plant was largely associated with a decrease in 100-seed weight of the lower density. Number of nodules/plant and the dry weight of nodules for the 50 plants/m^2 treatment was higher than those of other treatments in both years. The yield was decreased by the use of the fungicides bavastin and rhizolex. Seed weight, number of pods/plant and seeds/pod were increased as a result of the nabu treatment. However, the treatments with rhizolex, bavastin and dimethoate caused a reduction in 100 seed weight, as compared to the control. The number of seeds per pod was not affected by primor and dimethoate, while it decreased with bavastin and rhizolex. The number of nodules and dry weight of nodules, shoots and roots were reduced as a result of pesticide treatments. Acetylene - reduction activity was decreased when bavastin, rhizolex and nabu were applied in first year and increased with the use of the insecticides primor and dimethoate in the second season. The level of acetylene reduction activity in nodules obtained from plants treated with nabu was lower than those of all other treatments in both seasons.

Introduction

The production of faba bean (*Vicia faba* L.) in Saudi Arabia is very small as compared to other legume crops. Yields were generally influenced by such cultural practices as pest control and plant density. Faba beans are poor competitors during the early stages of growth and rely heavily on insects for pollination. Furthermore, one of the major benefits of growing a legume crops is the symbiotic fixation of nitrogen. Thus, it is of paramount importance to consider any possible effects pesticide application and population density could have on nodulation and symbiotic nitrogen fixation.

A number of studies indicated the lack of significant effects of plant density on yield and yield components. Increasing the productivity of faba bean crop can be achieved by using high yielding cultivars and by adoption of improved cultural practices. Several investigators studied the effect of plant density on growth and yield of faba bean [1-4]. They reported that the increase in plant density resulted in high seed yield of faba bean. Salem and El-Massri [4] found that the response of seed yield/ha was linear to the increased plant density from 10 to 40 plants per m^2. On the other hand, Hakam and Ibrahim [5] reported that seeding rates between 95 and 240 kg/ha had no clear effect on the seed yield. However, decreased densities lead to high tillering, high number of pods and high seed yield/plant. Increasing faba bean plant density resulted in fewer seeds/plant and lower yield of seeds [6]. Fontes and Ohlrogge [7] declared that the yield gained from increasing the number of plants was smaller than the losses attributed to plant lodging. Several pesticides are commonly used to control the pests affecting the various parts of faba bean plants. Unfortunately, the use of these chemicals may be incompatible with the need for proper inoculation with *Rhizobium leguminosarum* to ensure adequate nodulation and nitrogen fixation. Dunigan *et al.*, [8] tesed certain herbicides on five different soil types and found reductions in the dry weight of soybean nodules. Production guidelines for faba bean [9] indicated that captan and thiram are compatible with *R. leguminosarum* inoculation but others [10 and 11] suggested that some seed treated with rhizobia can be harmed by pesticides.

The present work was aimed to study the effect of plant density and pesticide treatments on the growth, yield, yield components and nodulation of faba bean.

Materials and Methods

Field experiments were conducted for two successive winter seasons of 1990 and 1991 in King Faisal University Research Station, Al-Hassa, Saudi Arabia where the soil is a sandy loam and faba bean cultivar was Has. No.1. The treatments of the first experiment included three plant densities: 50, 75 and 100 plants/m^2. The second experiment consisted of five pesticide treatments and a control. The tested pesticides were two fungicides: bavastin (carbendazim WP 50%) and rhizolex (tolclofos methyl WP 50%); two insecticides: primor (pirimicarb WP 50%) and rogor (dimethoate EC 40%) and one herbicide: nabu (sethoxydim EC 20%). The pesticide treatments were applied as foliar application at the rate of 1g/l for both fungicides, 1.5 ml/l for each insecticide and 5g/l for the herbicide. Six and three plots were used for each treatment of the first and the second experiment, respectively. Each plot consisted of five rows 30 cm apart and 3m long. The seeds were inoculated with *Rhizobium leguminosarum,* then planted in late October 1990 and 1991 and irrigated on weekly basis. Phosphorus at 80 kg/ha and nitrogen at 120 kg/ha were broadcasted and incorporated prior to planting. The experimental design was a completely randomized blocks. At anthesis, five plants were randomly taken from each plot. The roots were excised and the loose

Table 1. Effect of plant density on seed yield, seed weight, number of pods per plant and number of seeds per pod of faba bean plants during 1990 and 1991

plant density per m^2	1990				1991			
	seed yield g/plant	100 seed weight (g)	pod numbers/ plant	seed numbers/ pod	seed yield g/plant	100 seed weight (g)	pod numbers/ plant	seed numbers/ pod
50 plants	54.19^a	36.68^b	36.42^a	3.5^a	69.45^a	45.64^b	40.98^a	4.0^a
75 plants	49.39^b	37.35^b	30.30^b	3.4^b	61.06^b	44.54^b	33.33^b	3.4^b
100 plants	44.62^c	40.51^a	23.20^c	3.3^c	55.17^c	47.71^a	26.34^c	3.3^c
LSD (P=0.05)	2.08	1.31	1.24	0.10	3.67	1.90	2.10	0.09

Data within each column followed by the same letter are not significantly different (P=0.05).

Table 2. Effect of plant density on dry weight of shoot, root and nodules/plants, nodules numbers and acetylene reaction activity in faba bean plants during 1990 and 1991

plant density per m^2	1990					1991				
	dry weight g/plant			nodule number per plant	acetylene reduction activity	Dry weight g/plant			nodule number per plant	acetylene reduction activity
	shoot	root	nodule			shoot	root	nodule		
50 plants	26.88^a	6.27^a	1.81^a	224^a	426.5^a	27.94^a	8.74^a	2.04^a	290^a	613.8^a
75 plants	21.55^b	3.89^b	1.57^b	195^b	383.7^b	22.40^b	7.37^b	1.88^b	252^b	562.2^b
100 plants	16.92^c	2.79^c	1.43^c	179^c	366.5^c	19.24^c	5.58^c	1.67^c	223^c	504.9^c
LSD (P=0.05)	0.54	0.11	0.03	5.51	15.28	0.28	0.19	0.03	6.12	30.42

Data within each column followed by the same letter are not significantly different (P=0.05).

soil was crumbled over sieves to retrieve any detached nodules. The shoots were separated from the roots at the soil-air interface and the roots were then placed into gas-tight containers sealed with a screw-cap lid. After injection of acetylene (10%, Vol/Vol), the samples were incubated at ambient temperature for 60 min. A subsample (10 ml) was then taken using a sterile vacutainer and the samples were transferred to the laboratory. The acetylene reduction assay was performed as described by Rennie and Rennie [12] to determine the nitrogenase activity.

At maturity, the plants were harvested for determination of the number of pods/ plot, seeds/ pod, nodules/ plant and the dry weight of shoot, root, and nodules. The nodules were carefully picked off the roots and counted. Dry weight was measured after plant parts were dried at 80°C for 48 hr. Yield determinations were made by harvesting an area of $1m^2$ of the central rows of each subplot. The samples were then threshed, cleaned and weighed to obtain 100-seed weight and final yield.

The data were analyzed statistically using the analysis of variance. The least significant difference (LSD) was used to determine differences between individual means.

Results and Discussion

Data of the effect of plant densities on yield and growth parameters are presented in Tables 1 and 2. The results indicated that growth, yield and nodulation of faba bean were affected by plant density. The determined growth parameters per plant were steadily decreased by increasing the plant density. The seed yield per plant was significantly decreased as plant density increased (Table 1). However, The increase in plant density increased total seed yield per plot in both seasons. Populations sown at a higher density complete their canopy sooner and so made more use of the available incident radiation than those sown at lower densities, thus producing higher total yield per unit area (Table 2). Similar response was obtained by Kondra [13], and Pandey [3]. On the other hand, El-Saeed [1], Seitzer and Evans [2] and Salem and El-Massri [4] reported that the increase in plant density resulted in high seed yield of faba bean. Salem and El-Massri [4] added that the response of seed yield/ ha was linear to increments plant density from 10 to 40 plants per m^2.

Seed yield is the product of several components: plant density, number of pods/ plant, seeds/ pod and 100-seed weight. The reduction in yield/ plant in higher densities could be attributed to changes in the canopy structure, due to changes in density, and hence in the light interception by the crop. Poulain *et al.*, [14] reported that variations in density change the extent of light interception by the crop canopy and hence lead to differences in photosynthesis. The densely populated crops receive low light intensity in the lower strata of the canopy resulting in less photosynthetic efficiency rate. The significant increase in seed yield/ plant was largely associated with a decrease in 100-seed weight of the lower density (Table 1). The density of 50 or 75 plants/m^2 resulted in significantly lower 100-seed weight than those of 100 plants/m^2. At this low density, plants have a large number of sinks because of the large number of pods and seeds/plant. Consequently seeds could not receive all the photosynthetic assimilates produced by the crop canopy.

The number of pods/ plant shown in Table 1 was greatly reduced as plant density increased. Since there was a strong effect on pods/ plant as plant density increased,

yields remain relatively constant across plant densities. In response to increasing density, number of pods/ plant decreased [15-17], while the number of seeds/ pod remained constant [18, 2 and 19]. The results indicated that faba bean plats are capable of compensating for low plant densities by producing more branches and more pods per plant.

Total plant nitrogen fixation (acetylene reduction) during growth was affected by the relative success of nodulation and the longivity of symbiotically-active nodule populations. These factors were influenced by plant density due to inter and intra-plant competition for water and mineral nutrition. Plant density had statistically significant effects on faba bean nodulation and total acetylene reduction activity (Table 2). Number of nodules/ plant and the dry weight of nodules for the 50 plants/m^2 treatment was significantly higher than the other treatments in both years. The low density tended to increase taproot nodulation and acetylene reduction parameters. A comparison between the 75 and 100 plants/m^2 treatments indicated a tendency for the 75 plants/m^2 treatment to have higher nodulation and acetylene reduction values during both years.

Results of the effect of pesticides on the growth, yield and rhizobial nodulation are presented in Tables 3 and 4. The obtained data showed that the seed yield was significantly decreased by the use of the two fungicide (bavastin and rhizolex) treatments in both years as compared to the control, insecticides (primor and dimethoate) and the herbicide (nabu) treatments. However, the treatments with rizolex, bavastin and dimethoate caused a reduction in 100 seed weight, as compared to the control. No significant differences were observed in seed weight between nabu or primor treatment and the control. The results elucidate that the number of pods/ plant and seed number/ pod were significantly increased with nabu treatment over the control. In contrast, the other tested pesticide treatments decreased the pod numbers when compared to the control. However, a similar tendency to reduce the number of pods per plant was observed for both insecticides and fungicide in the second year as well. The number of seeds per pod was not significantly affected by primor and dimethoate, while decreased with both fungicide treatments (Table 3).

All the tested pesticide significantly reduced dry weight of shoot that ranged from 8.08-19.60% and 6.59-17.16% and root 8.18-16.56% and 8.53-16.06% in both seasons of 1990 and 1991, respectively (Table 4). The tested pesticides applied to faba bean tended to slightly decrease, the number and dry weight of nodules in the two seasons. The number of nodules were decreased by 9.26, 8.53, 11.11, 7.41 and 10.19% as compared to the control in the first year (1990) with primor, dimethoate, bavastin, rhizolex and nabu treatments, respectively. In the second year (1991) the percent of reduction in nodule number was 7.22, 9.03, 9.75, 9.59, and 12.27% with the above mentioned pesticide, respectively.

Table 3. Effect of certain pesticides on several growth parameters numbers seed yield, of faba bean plants during 1990 and 1991 groing seasons

Pesticides	1990				1991			
	seed yield g/plant	100 seed weight (g)	pod numbers/ plant	seed numbers/ pod	seed yield g/plant	100 seed weight (g)	pod numbers/ plant	seed numbers/ pod
Primor	50.34^{a}	37.99^{bc}	29.14^{c}	3.4^{b}	64.79^{a}	45.40^{bc}	33.13^{c}	3.5^{b}
Dimethoate	50.91^{a}	36.79^{c}	28.02^{cd}	3.3^{bc}	61.42^{ab}	45.83^{b}	32.52^{cd}	3.5^{b}
Bavastin	46.11^{b}	37.22^{c}	26.69^{d}	3.2^{c}	57.35^{b}	42.74^{c}	31.16^{d}	3.4^{b}
Rhizolex	47.06^{b}	37.10^{c}	28.71^{cd}	3.1^{c}	60.58^{ab}	44.29^{bc}	32.68^{cd}	3.4^{b}
Nabu	51.64^{a}	40.78^{a}	34.72^{a}	4.0^{a}	64.60^{a}	51.46^{a}	38.93^{a}	4.1^{a}
Control	50.53^{a}	39.20^{ab}	32.67^{b}	3.4^{b}	62.80^{a}	46.07^{b}	35.00^{b}	3.5^{b}
LSD (P=0.05)	2.84	1.86	1.76	0.13	5.20	2.69	1.89	1.3

Data within each column followed by the same letter are not significantly different (P=0.05).

Table 4. Effect of certain pesticides on dry weight of shoot, root and nodules/plant, nodules numbers and acetylene reaction activity in faba bean plants during 1990 and 1991 growing seasons

Pesti-cides	1990					1991				
	dry weight g/plant			nodule number per plant	acetylene reduction activity	Dry weight g/plant			nodule number per plant	acetylene reduction activity
	shoot	root	nodule			shoot	root	nodule		
Primor	21.09^{cd}	4.38^{b}	1.61^{a}	196^{b}	413.5^{a}	22.65^{c}	7.29^{b}	1.86^{b}	257^{b}	734.4^{a}
Dimethoate	20.36^{cd}	4.26^{bc}	1.45^{b}	198^{b}	400.9^{a}	21.86^{d}	6.96^{cd}	1.81^{c}	252^{bc}	650.5^{b}
Bavastin	20.10^{d}	3.98^{c}	1.58^{ab}	192^{b}	377.3^{b}	21.76^{d}	7.08^{bc}	1.78^{c}	250^{bc}	493.9^{cd}
Rhizolex	21.19^{c}	4.27^{bc}	1.58^{ab}	200^{b}	388.8^{b}	22.08^{d}	7.18^{bc}	1.81^{c}	251^{bc}	509.1^{c}
Nabu	22.98^{b}	4.08^{c}	1.58^{ab}	194^{b}	349.9^{c}	24.54^{b}	6.69^{d}	1.81^{c}	243^{c}	453.9^{d}
Control	25.00^{a}	4.77^{a}	1.68^{a}	216^{a}	408.0^{a}	26.27^{a}	7.97^{a}	2.1^{a}	277^{a}	518.3^{c}
LSD (P=0.05)	0.54	0.11	0.03	5.51	15.28	0.28	0.19	0.03	6.12	30.42

Data within each column followed by the same letter are not significantly different (P=0.05).

Acetylene - reducing activity was decreased when bavastin, rhizolex and nabu were applied in first seasons. However, in the second seasons (1991), the use of the insecticides primor and dimethoate resulted in a significant increase in acetylene reduction activity ranging between 42.08 to 25.51, respectively. In both two seasons,

the level of acetylene reduction activity for plants treated with nabu was significantly lower than those of all other treatments and control. Apparently, primor and dimethoate did not interfere with the nodule activity but only with nodule formation and growth. It appears that faba bean plants assimilated more soil and/or fertilizer nitrogen to compensate for lower nitrogen fixation rates, similar results were observed in soybean by Rennie *et al.*, [20] and Rennie and Dubetz [11]. This tends to explains why the effects of pesticides on nitrogen fixation were not reflected in seed yields. The harmful effects of pesticides on nitrogase activity must be considered physiologically and cannot be attributed to better pest control. These findings support the conclusion of other authors [21, pp 689-720] that the effect of pesticides is not on inhibition of nodulation or nitrogenase activity per se, but is deleterious to root growth and plant development.

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تأثير الكثافة النباتية وبعض مبيدات الآفات على نمو ومحصول وتكوين العقد البكتيرية في نباتات الفول *(Vicia faba L.)*

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(قدم للنشر في ١٤١٢/١١/٩هـ؛ وقُبل للنشر في ١٤١٤/٧/٢٩هـ)

ملخص البحث. تمت دراسة تأثير ثلاثة مستويات من الكثافة العددية لنباتات الفول البلدي هي: ٥٠، ٧٥ و١٠٠ نبات/م^2 وخمسة مبيدات هي: بافستين، ورايزولكس، وبريمور، ودايميثويت، ونابو على تكوين العقد البكتيرية ونمو ومحصول نباتات الفول *V. faba* وذلك في موسمين متتاليين تحت الظروف الحقلية في محطة البحوث الزراعية والبيطرية جامعة الملك فيصل بالأحساء ـ المملكة العربية السعودية وذلك لمدة عامين متتاليين ١٩٩٠ و١٩٩١م. وأظهرت النتائج أن كمية المحصول وعدد القرون للنبات تنخفض كلما زادت كثافة وأعداد النباتات المنزرعة. بينما وجد أن كمية المحصول الكلية تزداد بزيادة عدد النباتات المنزرعة وكانت النتائج متماثلة في الموسمين. كما أوضحت النتائج أن انخفاض كثافة النباتات المنزرعة (٥٠ نبات/م^2 يؤدي إلى زيادة عدد البذور للنبات والتي كانت مرتبطة بانخفاض وزن البذرة). وقد بينت النتائج زيادة عدد العقد البكتيرية والوزن الجاف للعقد عند زراعة ٥٠ نبات/م^2 وذلك بمقارنتها بالمعاملات الأخرى.

كما أظهرت النتائج أن استخدام المبيدات الفطرية بافستين ورايزولكس قد أدى إلى انخفاض المحصول. وقد انخفض عدد العقد البكتيرية والوزن الجاف للعقد نتيجة لاستخدام كل من المبيدات المختبرة. كما أوضحت النتائج المعاملة بالمبيد العشبي نابو أدت إلى زيادة وزن البذور وعدد القرون وعدد البذور في القرن. بينما لم تؤثر المعاملة بكل من البريمور والدايميثويت على عدد البذور ولكنها كانت منخفضة الوزن بمقارنتها بالنباتات غير المعاملة.

كما أدت المعاملة بالمبيدين بافستين ورايزولكس إلى انخفاض نشاط البكتيريا في اختزال الأسيتيلين في الموسم الأول بينما قد زاد النشاط نتيجة استخدام المبيدات الحشرية في الموسم الثاني بينما انخفض النشاط بشدة عند استخدام المبيد العشبي نابو بالمقارنة بالمعاملات الأخرى أو النباتات غير المعاملة وذلك في الموسمين.