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The Importance of Bee-Pollination in Four Genotypes of Faba Bean (*Vicia faba* L.)

IYAD W. MUSALLAM, NIZAR J. HADDAD, ABDEL-RAHMAN M. TAWAHA AND OSAMA S. MIGDADI
National Center for Agricultural Research and Technology Transfer, P.O. Box 639, Baqa'a 19381, Baqa'a, Jordan

ABSTRACT

Faba bean is an important human food crop in the Mediterranean countries. Inadequate pollination is a major constraint to the potential yields of faba bean (*Vicia faba*) crops. Yield and yield components of four faba bean genotypes were compared under two pollination conditions (self-pollination and open pollination) at Maru Agricultural Station in North Jordan. The results showed that honeybees' pollination resulted in an increase in pod set, seeds per pod, and seed yield. But it reduces both plant height and time to maturity. Faba bean has low level of self-pollination and require insect pollination to maximize seed set. The use of bees can increase seed yield by as much as 49%, if the native bee numbers are not high.

Key Words: Faba bean; Honeybees; Pollination

INTRODUCTION

Faba bean is a self-pollinated crop with significant levels of cross-pollination that vary greatly between cultivars (Suso *et al.,* 1996). Selfing in faba bean is associated with inbreeding depression and a reduction in autofertility, while cross-pollination and heterosis are associated with hybrid vigor and improved seed yield (Frusciante & Monti, 1980). The rate of outcrossing ranged from 4-89% depending on the genotype used, environmental factors, row space and the number of pollinating insects, especially honeybees (Rashid & Bernier 1994).

Yield unstability is generally considered as a major problem in faba bean; numbers of both flowers and ovules that are formed always greatly exceeds the resulting number of pods and seeds that are produced (Suso *et al.,* 1996). Rowland and Bond (1983) found in a field trial that about 67% of total examined ovules had not been fertilized. Moreover, Rowland and Bond (1983) found that single-seeded pods were preferentially aborted under water stress conditions. They suggested that in order to increase the number of seeds per pod, frequency of ovule fertilization should be increased.

Pollinators are important for better production in commercial fields (Rebertson & Cardona, 1986). Low number of pollinator has been reported to be one of the causes of producing small and unstable yields of faba beans (Free & Williams, 1976).

Faba bean breeding and seed production has received limited research emphasis in Mediterranean countries. Information is limited on the influence of honey bees on the seed yield, yield components and date to maturity of faba beans. Therefore, efforts should be directed to cultural and varietal improvement through finding high yielding genotypes of faba beans and new seed production technologies. The purpose of this research was to study the direct and indirect effects of pollination with honeybee on yield and yield components of faba bean.

MATERIALS AND METHODS

Three faba bean genotypes obtained from ICARDA and one local cultivar were used for this study. Field experiments were conducted under rainfed conditions (Maru Agricultural Station; 34°40' N, 32°36' E; 600 m evaluation) during the 2000/2001 and 2001/2002 growing seasons.

A randomized complete block design was used with three replications. Plots size was 2.5 x 2.4 m width. Each plot contained 6 rows; spacing between and within rows was 0.4 m and 0.1 m, respectively, resulted in planting density of about 25-plant m^{-2}. Guard strips of 1.5 m between the plots and 2 m between replications were left non-planted. Fertilizer was hand broadcasted prior seeding at a rate of 20 kg ha^{-1} of nitrogen and 40 kg ha^{-1} of P_2O_5. Weeds were removed manually as needed. Each genotype was grown for two years under two different pollination conditions:

(1) Self-pollination SP (bees exclude from cages): these plots were covered shortly before flowering with small Saran cages (3m wide x 2m long x 2m high). The Saran were cages used with 2.0 mm mesh size. Under these conditions, bees and other insects will be excluded from cages.

(2) Bee pollination BP (free-flying bees): in which both self and cross-pollination can take place. Beehives were introduced during the growing season near these plots.

Pollinator activity was recorded every two days within the open pollination treatments. One counting station (1 m^2) was marked at each block in the experiment, and at each scoring date, data was recorded on honey bees visiting the flowers and duration of bee visits. Counts were made at the

period of peak activity (between 11.00 AM and 3.00 PM) for pollen gatherers. Only positive visit (Bond & Poulsen, 1983) to faba bean flowers in a 3-min observation period was recorded (Robertson & Cardona, 1986).

During the growth period, data on time to flowering (the number of days from planting to the day on which at least 50% of the plants in a plot started to flower) and time to maturity (the number of days from planting until 95% of the plants in a plot matured) were recorded.

At flowering, three represented plants were marked to count the numbers of flowers per plant. At maturity stage, the same plant marked at flowering, from each plot before harvest was marked to study the following characters: number of pods per plant, number of seeds per pod, pod length, and plant height. At harvest, biological yield and dry seed yield were estimated on a per plot-basis then converted to kg ha^{-1}. Hundred seed weight was estimated from the seed yield sample.

Statistical analyses. The experimental design was a randomized complete block (RCBD) with three replications. Data for the two years were analyzed. Combined analysis of variance over years was also performed. MSTATC PRGRAM (Michigan State University) was used to carry out statistical analysis. Treatment means were compared using least significant differences Test (LSD) at 0.05 probability level. Probability of significance was used to indicate significance among treatments and interactions according to Steel and Torrie (1980). The correlation coefficients of average seed yields versus other agronomic characters were also calculated.

RESULTS

Yield. Summary of rainfall and temperature during the two growing seasons are given in Table II. Total rainfall during the first growing season was 263.5 mm, which is slightly lower than the long, term average (370 mm yr^{-1}) and in the second growing season it was 459.2 mm. In general, air temperature was higher in 2001 than in 2002. In both years Nodulation was adequate in all plots, and there was no need to artificial inoculation. Plant densities were close to the target ranging from 20-25 plants m^{-2}. The duration from sowing (or in the case of dry seeding, from the first autumn rain) to the first flower ranged from 91 to 102 days in 2001 and 90 to 104 days in 2002, with means of 96.3 and 97.4 days, respectively. The number of days to first flower did not affected by pollination conditions.

In both years, seed yields were greatest under bee pollination conditions. Yield was 2001.7 kg ha^{-1} at the first growing season, and 2611 kg ha^{-1} at the second growing season. Seed yield increase with bee pollination ranging from 2405 to 3022 kg ha^{-1} (Table IV). When compared to the 2002 results, seed yields were much less in the dry 2001 season. Bee pollination resulted in significantly greater seed yields than self-pollination.

Yield components. Total biological yield at maturity varied from 4870.8 to 6645.5 kg ha^{-1} over both years and in general, decreased with bee pollination (Table IV). Harvest index varied from 29 to 54%, with a mean of 49% under bee pollination and 32% under open pollination. Harvest index increased significantly with bee pollination. The mean number of pods per plant tended to increase with bee pollination (Table V). The mean number of seeds per pod was increased under bee pollination conditions, means range from 2.6 under self-pollination condition to 2.9 under bee pollination condition. Mean seed weights varied from 67 to 90 g 100 $seed^{-1}$ in 2001, and were more in the favorable 2002 season (69 to 93 g 100 $seed^{-1}$). Mean seed weights

Table I. Names, pedigree and origin of the faba bean genotypes

Genotype	Pedigree	Country of origin
FLIP87-147FB	S82112 EReina blanca X Γ7YTA85	ICARDA† (Syria)
S82408-1-2-3	EILB 1814 XΓ BPL 82	ICARDA (Syria)
FLIP83-24FB	Selection 81S36522	ICARDA (Syria)
Local Check	----------	Jordan

ICARDA: The International Center for Agricultural Research in the Dry Areas.

Table II. Monthly rainfall (mm), and average air temperature (˚C) during 2000/2001 and 2001/2002 growing seasons at Maru Agricultural Station

Month	Rainfall		Average Temp. (˚C)	
	2000/01	2001/02	2000/01	2001/02
Oct.	27.4	3.0	19.1	20.8
Nov.	0.0	38.4	14.97	14.46
Dec.	86.5	85.3	10.4	10.7
Jan.	46.1	131.6	9.6	7.3
Feb.	78.6	46.0	10.0	11.3
Mar.	12.1	93.7	16.3	13.9
Apr.	0.3	60.7	18.1	15.1
May	12.5	0.5	21.1	19.4
Total	263.5	459.2		

Table III. Probability of significance for yield, yield components and agronomic characters measured in four faba bean genotypes grown under two pollination conditions during 2000/2001 and 2001/2002 growing seasons

Trait	Pollination (P)	Genotype (G)	P x G
Dry seed yield (kg ha^{-1})	**	**	*
Biological yield (kg ha^{-1})	*	**	NS
100 seed weight (g)	NS	**	NS
Pod number $plant^{-1}$	*	**	NS
Plant height (cm)	**	**	NS
Pod length (cm)	NS	**	NS
Seed number pod^{-1}	**	**	NS
Flower number	**	NS	NS
Time to flowering (days)	NS	**	NS
Time to maturity (days)	**	**	NS
Harvest index (%)	**	*	**

**, * are significant at $P \leq 0.01$ and $P \leq 0.05$, respectively; NS = Not significant

Table IV. Seed yield (kg ha^{-1}), biological yield (kg ha^{-1}), flower number per plant, plant height (cm) and harvest index of four faba bean genotypes grown under bee pollination (BP) and self-pollination (SP) conditions during 2000/2001 and 2001/2002 growing seasons

Genotype	Seed yield		Biological yield		Flower number		Plant height		Harvest index	
	BP	SP	BP	SP	BP	SP	BP	SP	BP	SP
	kg ha^{-1}				plant^{-1}		cm		%	
FLIP87-147FB	2879	1928	5869	5969	56.6	67.1	73.8	80.6	49	32
S82408-1-2-3	3022	2000	6375	6582	61.0	67.0	68.3	76.6	47	30
FLIP83-24FB	2758	1835	5658	5749	60.0	67.3	80.3	87.0	49	32
Local Check	2405	1625	4882	4982	57.8	68.3	67.8	75.8	50	33
Mean	2766	1847	5696	5821	58.9	67.5	72.6	80	49	32
LSD (P≤ 0.05)	119.5		202.9		10.9		2.18		0.00	

Table V. Seed number, pods number, hundred seed weight, time to flowering (days) and time to maturity of four faba bean genotypes grown under bee pollination (BP) and self-pollination (SP) conditions during 2000/2001 and 2001/2002 growing seasons

Genotype	Seed number		Pod number		100 seed weight		Time to flowering		Time to maturity	
	BP	SP	BP	SP	BP	SP	BP	SP	BP	SP
	pod^{-1}		plant^{-1}		g		days			
FLIP87-147FB	3.15	2.78	5.53	5.20	85.5	86	102.0	102.0	164.7	168.2
S82408-1-2-3	3.08	2.68	8.10	7.60	88.5	88	99.8	99.8	168.5	171.8
FLIP83-24FB	2.80	2.40	8.46	8.16	90.0	92.2	93.0	93.0	162.7	165.7
Local Check	2.76	2.40	9.25	8.4	69.0	68.7	92.6	92.6	162.8	166.2
Mean	2.9	2.6	9.9	9.8	83.3	83.2	96.9	96.9	164.7	168
LSD (P≤ 0.05)	0.064		0.831		1.59		0.93		1.276	

Table VI. Correlation coefficients for eleven agronomic characters of four faba bean genotypes grown under bee pollination (BP) and self pollination (SP) conditions during 2000/2001 and 2001/2002 growing seasons

	BYLD	HSWT	PNPP	SNPP	PDL	PLHT	FNPP	FLRT	MATT	HI
SYLD†	0.258	0.322	-0.052	0.877**	0.112	-0.527	-0.864**	0.288	-0.293	0.880**
BYLD		0.821	-0.425	0.385	0.127	0.125	0.148	0.719*	0.745*	-0.222
HSWT			-0.378	0.278	0.650	0.480	0.041	0.440	0.318	-0.079
PNPP				-0.437	-0.293	-0.211	-0.034	-0.837**	-0.288	0.171
SNPP					-0.034	-0.580	-0.765	0.666	-0.040	0.700
PDL						0.757*	-0.041	-0.061	-0.367	0.039
PLHT							0.589	-0.161	0.042*	-0.603
FNPP								-0.071	0.595	-0.963**
FLRT									0.584	-0.063
MATT										-0.656

**, * significant at P ≤ 0.01 and P ≤ 0.05, respectively; † SYLD: seed yield; BYLD: biological yield; HSWT:100-seed weight; PNPP: pods number plant^{-1}; PDL: pod length; PLHT: plant height; FNPP: flowers number plant-1; FLRT: time to flowering; MATT: time to maturity; HI: harvest index.

increased significantly with bee pollination (P < 0.05). Simple correlation coefficients between the studied characters were computed and are presented in Table VI. In both years, seed yield was significantly correlated with seed number plant^{-1}, flower number plant^{-1} and the harvest index (P < 0.05, Table VI).

DISCUSSION

Differences among genotypes were statistically significant for all studied traits except for flower number per plant. Differences among pollination conditions were also significant for all traits except for hundred seed weight, pod length and time to flowering. Differences due to genotype x pollination interactions were significant for seed yield indicating the importance of bee pollination on this trait. The average seed yield across genotypes under bee pollination conditions was increased to 49% than those under self-pollination conditions, which was due primarily to more pods per m^2 and number of seeds per pod. Present findings are in agreement with other studies Somerville (2002), who reported that use of honeybees has the potential to increase yields of faba beans by 19-52%. Sometimes other constraints to yield (moisture stress and pest pressure) override the benefits derived from having honeybees on the crop. Flowering occurs from March to late April. Only 8-12% of flowers under self-pollination condition produce pods, where as this percentage increases to 16% under bee pollination condition.

We found that plants with access to bees set more pods on the lower nodes and ripen earlier with significantly more seeds per pod. These results are in agreement with Wafa and Ibrahim (1960) who found that bee pollination accelerated the rate of set of bean pods. Moreover, John

(2000) found that insect pollinated fruit has been found to mature 4-12 days earlier depending on blueberries variety. Hanna and Lawes (1967) showed that the percentage of crossing was higher on the lower nodes (51% below, 33% at upper ones). Bee pollination may also have a benefit on the succeeding generation; numerous scientists have found that in a crop of faba beans the inbred plants will not set seed unless visited by insects, whereas the hybrids are able to set seed by self-fertilization.

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