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Effect of Seed Size and Plant Population Density on Yield and Yield Components of Local Faba Bean (*Vicia faba* L. Major)

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ABSTRACT

Field experiments were carried out to evaluate the effects of four seed size (large, medium, small, and very small) and five plant populations (12.5, 25, 50, 100, and 150 plants m^{-2}) on local faba bean yield and yield components. A split plot design with three replications was used, in which plant populations were assigned to main plots and seed size to sub plots. Small seeds significantly increased seed yield during the first growing season (248 mm), whereas seed size did not have any effect in the second growing season (292 mm). Plants originating from very small and small seeds were faster in emergence, earlier in flowering, in podding, in maturity, and gave the highest harvest index values, which positively influenced seed yield. However, large seeds were more sensitive to the adverse seasonal conditions such as drought and low temperature. Highest seed yield was obtained at 12.5 plant m^{-2} in the second growing seasons, but in the first growing season the greatest seed yield was obtained at 25 plants m^{-2}, and further increase in the plant population density did not resulted in more increases in seed yield. Results indicated that the highest yield was obtained from planting small seeds at a density of 25 plants m^{-2}. Small seeds produce substantially good yield over a range of seasonal conditions because it can apparently flower earlier, set pods efficiently, complete its reproductive growth quickly, and fill seeds efficiently.

Key Words: Faba Bean; Seed Size; Plant density

INTRODUCTION

Faba bean is the fourth important pulse crop in the world**.** It occupies the greatest area planted to legume crops in the Arab countries (Amin, 1988). Nutritionally, faba bean seeds contains between 24-32% proteins (Li-Jean *et al.*, 1993). Faba bean constitutes a cheap source of protein for large proportion of the Arab countries (FAO, 1995). Plant population is one of the factors that affect growth and yield. High plant population adversely affects plant growth and development, while suboptimal plant population results in high yield per plant but lower yield per unit area (Singh *et al.*, 1992).

Results that describe yield response to plant population alteration in different cultivation systems are highly variable. The best faba bean yield was obtained at a plant density of 25 plants m^{-2} in Romania (Comarovschi, 1974) and France (Rebillard & Lelievre, 1980); whereas, Christensen (1974) in Denmark, and Bonari and Macchia (1975), and Bianchi (1979) in Italy, obtained the highest yields at 40 and 85 plants m^{-2}, respectively. In Spain, Caballero (1987) found that increasing plant population from 10 to 50 plants m^{-2} increased seed yield from 4.59 to 5.23 tons ha^{-1}. In Egypt, Leilah and El-Deeb (1990) reported that higher seed yields were obtained when 36 or 60 kg nitrogen ha^{-1} was applied to a density of 33 plants m^{-2}. Mc-Ewen *et al.* (1988) showed that seed yield of faba bean was always greater by combining a plant population of 12 plants m^{-2} at early sowing. Whereas 24 plants m^{-2} were needed to obtain comparable yields under exceptionally sever winter conditions that killed many plants. On the other hand, 36 plants m^{-2} were needed to achieve similar yield at the latest sowing dates.

Faba bean escape drought when sown after first autumn rains in Mediterranean environments and produce seed yield of 0.8-4.2 t ha^{-1} depending upon the season's rainfall (Loss *et al.*, 1977b). The influence of seed size on seed yield has been under investigation for a long time ago (Srivastava & Nigam, 1973). The simplest argument for relation between seed yield and seed size suggest that seed size should have a positive, neutral, or negative influence on seed yield. So, if seed size influence yield, it would be advantageous to plant the seeds that give the highest yield (Reddy *et al.*, 1989).

Plant ecologists generally concur that larger seed size leads to larger initial plant vigor. So, greater seed weight results in greater growth and greater yield. Ashley (1984), and Dhillon and Kler (1976), working on peanut, reported that plants derived from larger seeds flower earlier, produce greater number of branches, grew taller, had higher leaf area index, higher dry matter yield, greater number of pods, larger pods, more seeds per pod, heavier seed weight and higher seed yield.

Tomaszewski *et al.* (1978) indicated that faba bean plants developed from large seeds had greater fresh matter and seed yields. In contrast, Salih and Salih (1980), and Salih (1983) revealed that seed size had no significant effect upon seed yield, although the highest yields were obtained from planting medium –sized seeds. As a result, they suggested that grading faba bean seeds would be of little or no economic value to the farmer. Similarly, Agung and McDonald (1998) observed that yields of different faba bean accessions were not consistently related to the seed size. But among the small and medium sized seed accessions, early flowering ones yielded more than late flowering accession; whereas, no relationship was observed between flowering time and yield among large-seeded accessions. On the contrary, Pilbeam *et al.* (1989) indicated that the small size of determinate faba bean and their ability to branch might enable them to more effectively exploit the earlier environment, particularly at wide inter-row spacing. The objective of this research was to study the effect of seed size and plant population density on yield and yield components of local faba bean.

MATERIALS AND METHODS

Study site. Studies were carried out in the agronomy field at Jordan University of Science and Technology campus (JUST) in northern Jordan [32° 34′ N latitude, 36° 01′ E longitude, and 520 m altitude] (Turk & Al-Jamali, 1998) during the two growing seasons of 1996/97, and 1997/98. The location has Mediterranean climate of mild rainy winters and dry hot summers (Loss & Siddique, 1997). The soil type is silty clay loam.

Seeds of the locally planted faba bean cultivar (*Vicia faba* L. Major) which has been obtained from local market were cleaned from residues, broken, defective and foreign materials. A germination test was conducted in order to adjust the plant populations accordingly. Based on weight, seeds were graded individually into four seed size categories; large (>1500 mg seed^{-1}), medium (1001-1500 mg), small (700-1000 mg), and very small (<700 mg).

A split–plot arrangement in a randomized complete block design with three replications was used to conduct all trials. The five plant populations of 12.5, 25, 50, 100, and 150 plants m^{-2} were randomly assigned for main plots that had a size of 22 m^2. The four seed sizes were randomly assigned to 4 m^2 sub plots. Sub plots consisted of eight 2 m rows that were 25 cm spaced a part. One meter Guard strips were maintained unplanted between the sub plots, while 2 m unplanted strips were kept between replications. The experimental field received granular fertilizer DAP (diammonium phosphate 18 % N and 46 % P_2O_5) at a rate of 100 kg ha^{-1} before plowing. Disc plow followed by duck`s foot plow were used to prepare seed bed.

Hand planting was practiced on December 1st, and November 29th, in the 1996/97 and the 1997/98, growing seasons, respectively. The trial lands were irrigated at amounts of 20 mm once at both growing seasons after the first effective rainfall. The total amount and distribution of rainfall for both growing seasons was listed in Table I. Weeds were removed manually whenever needed.

Harvesting was done on May 21, and June 15 in the 1996/97 and the 1997/98 growing seasons, respectively. A one m^2 quadrate was used to harvest the plants of central rows of each sub plot using pruning shears. Cutting height was few centimetres above soil surface.

Table I. Total amount and distribution of rainfall (mm) at Ramtha station from the period 1996-1998

Month	1996/97	1997/98
September	0.0	2.9
October	15.4	26.7
November	27.3	27.5
December	20.3	60.3
January	54.8	64.9
February	69.1	31.9
March	48.8	67.5
April	11.5	4.4
May	0.8	5.6
Total	248.0	291.7

Measured variables. Seed yield (g m^{-2}), biological yield (g m^{-2}), plant height (cm), number of seeds pod^{-1}, 100 seed weight (g), and harvest index.

Statistical analyses. The MSTAT-C program was used for statistical analyzes. Data for each trait were analyzed for a randomized complete block design (RCBD) with split-plot arrangement according to procedure outlined by Steel and Torrie (1980). Comparisons between means were made using least significant differences (LSD) at 0.05 probability level.

RESULTS AND DISCUSSION

Seed yield. Seed yield was influenced by the growing season (Table II, IV). The second growing season of 1997/98 resulted in higher seed yield than the first growing season 1996/97. Average increase in seed yield was about four folds in comparison with the first growing season. A major feature of faba bean crop is the unreliability of the yield, and the way yield fluctuate widely from season to season as well as from farm to farm (Hebblethwaite *et al.*, 1977). This may be attributed to several factors such as: moisture content and temperature stresses.

Inadequate moisture is usually the largest constraint to faba bean crop production (Blum & Pnuel, 1990). During the first growing season, rainfall during winter and spring was within (11 mm) of the long-term average (237 mm), whereas the second season was (55 mm) above the long term-average. The total perceptions were 248, and 292 mm year^{-1} in the first and second growing season, respectively.

The sensitivity of faba bean to water stress (Xia, 1994), is probably due to its shallow root system (Day & Legg, 1983), and to the little osmoregulation (Bond *et al.*, 1994). For these reasons, faba bean is often grown under irrigation in many parts of the world, that supported by ICARDA researchers, who reported that until recently, faba bean was only considered suitable for production in Mediterranean-type environments with high rainfall (ICARDA, 1994).

Table II. Summary of main and interaction effects for yield and yield components of local faba bean

	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)	100 seed weight (g)	Plant height (cm)	Seeds pod^{-1}	Pod length (cm)	Pod width (cm)	Branches plant^{-1}	Flowers plant^{-1}	Pods plant^{-1}
1996/97												
P	*	*	*	*	NS	*	NS	NS	NS	*	*	*
S	*	*	*	*	*	*	NS	*	*	*	*	*
P x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS	NS
1997/98												
P	*	*	*	*	*	*	NS	NS	NS	*	*	*
S	NS	*	*	*	*	*	NS	*	*	*	*	NS
P x S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

P = plant population; S = seed size; P x S = plant population and seed size interaction effect; * significant and NS, not significant according to F-tests at P = 0.05.

Table III. Summary of main and interaction effects for phenological traits of local faba bean

	First flowering	50 % flowering	100 % flowering	First podding	50 % podding	Physiological maturity
1996/97						
P	NS	*	*	*	_	*
S	*	*	*	*	_	*
P x S	NS	NS	NS	*	_	NS
1997/98						
P	NS	*	*	NS	NS	*
S	*	*	*	*	*	*
P x S	*	NS	*	NS	NS	NS

P = plant population; S = seed size; P x S = plant population and seed size interaction effect; * = significant; NS= not significant according to F-tests at P = 0.05; data were not collected at this stage

Another reason behind the low seed yield in the first in comparison to the second growing season is probably the fluctuation in temperature that occurred during April, 1997. Such fluctuations between 2ºC and 35ºC, while faba bean plants were at full bloom and podding stage has been already started, probably caused serious losses in faba bean production, since the indeterminate habit of faba bean inflorescence permits development of pods from late flowers. Accordingly, if low temperatures occurred during this critical stage, losses are difficult to offset. The effect of chilling on faba bean was previously described by many researchers (Liu, *et al.,* 1993; Minguez *et al.,* 1993; Loss & Siddique, 1997). Seed yield was not significantly affected by seed size during the second growing season 1997/98 (Table IV). This could be explained by the lack of significant effect of seed sizes on number of seeds per pod (Table V), and number of pods per plant (Data not shown). Since pod and seed number per unit area had the strongest relationships with seed yield (Loss & Siddique, 1997). These confirm the results of Ishag (1973), and Pilbeam *et al.* (1989). Similar results were obtained by Salih and Salih (1980), Salih (1983) and Agung and McDonald (1998). On the other hand, data presented in Table IV shows that, the small seeds gave significantly the highest seed yield (1388 kg ha^{-1}) compared with the other seed size categories in 1996/97 season. This could be due to the importance of flowering and podding time. The very small and small size categories were faster than the large seeds to reach flowering and podding stages (Data not shown), which minimizes the possibility of smaller seeds being exposed to the adverse conditions of temperature fluctuations during flowering and podding. These results are in agreement with those obtained by Weber *et al.* (1996), who reported that large faba bean seeds may have a long period of seed growth, and consequently, flowering time, and the length of pod filling period may be relatively more important in large seeds than in small ones, particularly in environment where seed growth is curtailed by a terminal water stress, as was the case in the present study. The plant population is determined by various attributes which are largely under grower control (Dantuma & Thompson, 1983). The data recorded during the two growing seasons, indicated that plant population of 25 plants m^{-2} produced greater seed yields (Table IV). These results are in agreement with Comarovschi (1974) in Romania, Rebillard and Lelièver (1980) in France, Graf and Rowland (1987) in Canada, Haddad and Thalji (1988) in Jordan and Agung and McDonald (1998) in Australia all working on faba bean. On the other hand, as plant population increases above 25 plants m^{-2}, seed yield did not increased significantly. This could be attributed to the internal faba bean plant competition, which was considered as an important determinant of the actual seed yield (Rowland *et al.,* 1986; Stringi *et al.,* 1986; Pilbeam *et al.,* 1989).

Based on the fact that marginal response in yield is very small at high populations, the optimum population is highly dependent upon seed cost. Accordingly, from the economical point of view, the 25 plants m^{-2} seems to be the best population, because below this the yield was significantly less, and above 25 plants m^{-2}, the seed yield did not increases significantly. This confirm results of Graf and Rowland (1987), who concluded that when the marginal cost of an increase in plant population, including the additional input costs approaches the marginal return from the increase in yield, further increases in seeding rate are not warranted.

Increasing plant population from 12.5 to 25 plants m^{-2} resulted in a significant increase in seed yield of almost 350 kg ha^{-1} in the first season. This increase was probably due to the increase in plant population, harvest index (Table IV), plant height (Table V), and number of seeds per pod (Table V), and efficient use of available moisture and nutrients.

Biological yield. Crop yield of faba bean is commonly proportional to total biomass production (Pilbeam *et al.,*

Table IV. Effect of seed size and plant population on seed yield, biological yield and Harvest index of local faba bean grown at JUST

Treatments	Seed yield (kg ha^{-1})		Biological Yield kg ha^{-1}		Harvest index (%)	
	1997/98	1997/98	1997/98	1996/97	1997/98	1996/97
Seed size						
Very small	4298	4298	7856	2326	55.3	48.4
Small	4479	4479	8982	2879	50.2	52.1
Medium	4118	4118	8842	3232	47.3	38.3
Large	4513	4513	9528	3675	48.1	25.6
LSD (0.05)	NS	NS	738	524	3	10
Plant population (m-2)						
12.5	4474	4474	7563	1773	59.1	44.0
25	4376	4376	7763	2200	56.7	51.9
50	4927	4927	9840	2886	50.3	43.6
100	4436	4436	9752	3764	45.8	33.3
150	3547	3547	9093	4518	39.1	32.5
LSD (0.05)	770	770	1172	776	3	10
S x P	NS	NS	NS	NS	NS	NS

S x P = seed size and plant population interaction effect; LSD, least significant difference (P = 0.05); NS, not significant

Table V. Effect of seed size and plant population on 100 seed weight, plant height and seed per pod of local faba bean grown at JUST

Treatments	100 seed weight (g)		Plant height (cm)		Seeds per pod	
	1997/98	1996/97	1997/98	1996/97	1997/98	1996/97
Seed size						
Very small	90.5	56.6	67.6	41.4	2.2	1.8
Small	111.0	63.5	75.4	48.1	2.6	1.9
Medium	115.3	71.3	76.8	48.3	2.6	1.9
Large	127.8	80.0	81.9	47.9	2.6	1.7
LSD (0.05)	6	6	4	3.6	NS	NS
Plant population (m-2)						
12.5	118.2	73.2	56.3	38.9	2.6	1.6
25	115.1	69.9	68.1	42.3b	2.6	1.8
50	110.4	69.4	81.0	45.9	2.5	1.9
100	108.1	62.7	84.1	51.7	2.3	1.9
150	103.9	63.9	87.6	53.3	2.5	1.8
LSD (0.05)	4	NS	4	5	NS	NS
S x P	NS	NS	NS	NS	NS	NS

S x P = seed size and plant population interaction effect; LSD, least significant difference (P = 0.05); NS, not significant

1992; Loss *et al.,* 1997a). Biological yield was greater in the second growing season than the first season (Table IV). The average increase in biological yield in the second growing season was about three folds in comparison with first growing season. This reduction in biological yield could be attributed to the deficiency and early bad distribution of water in the first growing season. These results confirm what was reported by Silim and Saxena (1992). Biological yield was significantly affected by seed size. Low biological yield was obtained when very small seeds were planted in both growing seasons. This could be due to low moisture availability. In both seasons, numerically the highest biological yield was obtained when large seeds were planted. This trend, although non significant, is in agreement with results reported by Agung and McDonald (1998), who indicated that plants developed from large seeds had greater biomass than smaller ones.

Concerning the effect of plant population on biological yield, the higher plant populations of 100 and 150 plants m^{-2} produced the greater amounts of biomass. This could be attributed to the increase in the number of plants per unit area, and the associated increase in plant height (Table V). Similar results were reported by Coeiho and Pinto (1989), who observed that at the final harvest of faba bean, the dry matter yield of above-ground parts increased with increasing plant population.

Harvest index. The harvest index reflects the ability of the genotypes to partition its dry matter into seed and straw, and the ability to maintain the right balance between seed and straw yield. During the two growing seasons, the highest harvest indices (Table IV) were obtained from the very small and small seed categories compared with medium and large. This could be attributed to the rapid development of seed yield in smaller seeds, once the reproductive phase started, so that the process of maturation proceeded quickly and led to a harvestable crop while weather conditions are good. Despite of the greater amounts of biomass production obtained by planting large and medium (Table IV), small seeds produced the highest seed yield in the first growing season (Table IV). Less biological yield was produced by small seeds that produced the highest seed yield compared to the larger seed sizes that had higher biological yields during the second season, where seed yield production was not significantly affected by seed size. These results suggest that the ability of partition dry matter is relatively more important than the ability to produce large quantity of dry matter in determining yield. Similarly, Ishag (1973) revealed that faba bean plants grown at a lower level of inputs and had limited vegetative growth, always produced higher seed yield and harvest index. Limited vegetative growth in this experiment was obtained from planting very small and small seeds (Table IV). Dantuma and Thompson (1983) indicated that early maturing plants generally achieve higher values of harvest index. In this study, very small and small seeds matured earlier than the other seed sizes and had higher harvest indices. Similar findings were achieved by White *et al.* (1992b), working on common bean who indicated that large seed size associated with lower harvest index.

Plant populations in both growing seasons had significant effect on harvest indices. Results indicated that as plant population increases, lower harvest index was obtained, in which 12.5 and 25 plants m^{-2} gave the highest values. This could be due to the increase in biological yield as the number of plants per unit area increased with no significant increases in seed yield (Table IV), leads to lower harvest indices. These results are in agreement with results of Dantuma and Thompson (1983), who indicated that high plant density favored early full canopy development and increased light interception, but this advantage may well be outweighed by a reduced harvest index.

Hundred seed weight. The 100 seed weights were greater in the second growing season compared with the first: average weights were 111, and 68 g, respectively

(Table V). This could be attributed to lower rainfall amounts during the first growing season. Similarly, Grzesiak *et al.* (1989) indicated that periods of drought during faba bean development had decreased seed weight.

During both growing seasons, the highest 100 seed weight was obtained by sowing large seeds. The 100 seed weight decreased as seed size decreased. This could be due to the greater biological yield (Table IV) in both seasons, and limited number of pods only in the first growing season (Data not shown) when large seeds were planted. This allowed fewer but stronger sinks for attracting assimilates. These results confirm that reported by Salih (1982). Similarly, Day and Legg (1983) indicated that faba bean is able to compensate for losses in pod numbers by increasing the mean grain mass.

Plant population had no significant effect on 100 seed weight at the first growing season (TableV). The same result was reported by Salih (1985) and Graf and Rowland (1987). On the other hand, plant population had an effect in the second growing season, in which the lower plant populations of 12.5 and 25 plants m^{-2} had heavy 100 seeds. Less competition between plants of lower populations on available resources such as water and light, increase the available assimilates per pod and result in increased seed weights. Similar result was reported by Stringi *et al.* (1988), who found that 100 seed weight of faba bean decreased with increasing plant population.

Plant height. In the second growing season, taller plants were produced compared to the first: average heights were 87.6 and 53.3 cm, respectively (Table V). This could be due to less available water in the first season. Similar results were reported by Husain *et al.* (1990), who revealed that faba bean crop respond to water stress by reducing its rate of height increase.

Seed size had a significant effect on plant height. Large, medium, and small seeds produced the tallest plants at the first growing season, whereas the very small seeds produced the shortest. On the other hand, the tallest plants were obtained from large seeds in the second season. This could be attributed to the greater biological yield obtained from the larger seeds (Table IV). These finding are in agreement with that of Tomaszewski *et al.* (1978), who found that large seeds of faba bean produced the highest dry matter, and tended to be taller than smaller sizes.

The plant populations of 100 and 150 plants m^{-2} gave the tallest faba bean plants in both growing seasons. This is probably due to competition between plants at the higher populations on light, resulting in taller plants. Similar findings were achieved by Dantuma and Thompson (1983). Stringi *et al.* (1986) related the increase in plant height and consequently lodging occurrence to the increase in plant population due to weaker stems.

Number of seeds per pod. The number of seeds per pod was greater in the second season comparing with the first: average numbers were 2.5 and 1.8, respectively (Table V). This could be related to the drought conditions during the first season that agrees with the results reported by El-Nadi (1970).

Results of the two growing seasons indicated that both seed size and plant population did not affect the number of seeds per pod. These results confirm what was reported by Agung and McDonald (1998) who revealed that for any given cultivar of faba bean, the average number of seeds per pod is a relatively stable character.

CONCLUSIONS

Small seed size (700-1000 mg $seed^{-1}$) significantly increased the seed yield during the first growing season 1996/97 compared to other sizes. However, during the second growing season the potentiality of small seed size was not significantly visible. Accordingly, the importance of grading seeds was obvious in this study, so small seed size should be used for planting in order to insure high yields, to reduce seeding rate and to withstand environmental stresses such as low moisture and temperature.

The plant population of 12.5 plants m^{-2} was found to be optimum in the second growing season, whereas 25 plants m^{-2} was considered the proper population where chilling injury and drought were prevailing. Due to unpredictable environmental conditions a planting density of 25 plants m^{-2} should be used. Further increase of population will have no economical return on the produced yield. Irrigation of faba bean is often recommended particularly during moisture-sensitive periods of flowering and pod-filling.

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