# Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 3 (4): 439-448, 2004
ISSN 1682-3974


# Yield and Yield Components of Faba Bean Genotypes Under Rainfed and Irrigation Conditions

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**Abstract:** In this study, thirteen faba bean genotypes were investigated for yield and yield components under rainfed (Maru) and irrigation (JUST) conditions. The results showed that irrigation resulted in a substantial yield increase, more than double that produced under rainfed conditions. The highest seed yield was obtained from genotypes Reina Blanca, L82007-11-3-1, FLIP83-24FB and 80S4387 under both rainfed and irrigation conditions. Higher pods per plant, taller plants, greater hundred seed weight, biological yield, nodule number and nodule dry weight per plant were obtained under irrigation than under rainfed conditions.

**Key words:** Faba bean, rainfed, irrigation

## INTRODUCTION

Faba bean is considered an important food legume crop in Jordan and other Mediterranean countries. Faba bean is a valuable food legume rich in proteins and carbohydrate[1] As a legume; it might produce its own nitrogen supply and might improve N status in the soil for the following crops in the rotation[2]. This crop might have a major role as a break for cereal systems[3]. Most of the faba beans planted in Jordan are grown in the winter under rainfed and irrigated conditions. Annual production of dry faba bean in Jordan is low and varies from year to year and from location to location. Total production of dry faba bean (under rainfed conditions) averaged 700 tons in 1995 cultivated on 800 ha[4]. Average yield of faba bean harvested dry was 825 kg $ha^{-1}$ during the period 1990-1995. The low yield potential of the existing genotypes, together with instability of yield from year to year due to environmental conditions, remain as major constraints for increasing faba bean production in Jordan and other Mediterranean countries. Therefore, efforts should be directed to varietal improvement through identifying high yielding genotypes of faba beans and well adapted to farming conditions of Jordan. Despite the potential of yield represented by good growth in favorable seasons, yield instability is generally considered a major problem in faba bean production particularly when compared with cereals[5-9]. Long-term experiments done by Dyke and Prew[10] have shown that the variability of field bean yield has been about twice that of wheat or barley. Because faba beans are usually shallow rooting[11,12], drought is a major factor that limits yields of faba bean[13]. Faba bean crop is generally regarded as very susceptible to drought[14,15]. Periodical water deficit in soil is considered to be one of the most important factors of yield instability of faba bean[16, 17]. A major feature of faba bean crops is the unreliability of yield and the yields fluctuation widely from season to season as well as from farm to farm[5-9]. The yield response to each mm of applied irrigation water ranged from 0 to 9 kg $ha^{-1}$ and did not appear to be related to the developmental phases of the crop when irrigation was applied. The number of pods per plant as a yield component is most affected by irrigation whereas the number of seeds per pod is being affected to a lesser extent. The final number of pods per plant was found closely correlated with the rate of supply of assimilates during pod filling. Irrigation increases assimilate flux by increasing leaf area, growth rate and total dry matter during pod growth. Relatively little is known about the physiological mechanisms of the effect of drought on field beans during generative development, leading to the reduction of seeds yield[18]. It is assumed that soil drought occurring especially during flowering and pods development causes considerable decrease of yield of faba bean seeds[16]. Singh *et al.*[19] reported that faba bean plant sensitive to moisture shortage at flowering and pod development stages of growth. Moreover, severe drought was found to affect seed yield by decreasing the mean weight per seed of faba bean[6]. Other investigators also found that single or double periods of drought had no significant influence on the number of pods and seeds, but decreased their weight[18]. It was found that drought decrease yield mainly by decreasing radiation received and growth efficiency[20] leaf initiation, expansion and biomass production were found significantly reduced by

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soil water deficits[21]. In contrast, prolonged periods of high soil water content produce excessive vegetative development which also reduces faba bean yield[22,23]. Loss and Siddique[24] demonstrated that faba bean (cv. Fiord) can produce impressive seed yield in a range of dryland Mediterranean-type environments. Field experiments by Thomson *et al.*[25] comparing a range of seed legumes under dry farming conditions in South Western Australia indicated that faba bean (cv. Fiord) yielded well in the water-limited environments. Haddad and Thalji[26] in an experiments conducted at two locations in Jordan (Maru and Mushagar) found that faba bean could be planted successfully under rainfed areas in Jordan where high rainfall (above 350 mm) is expected with a good distribution during the growing season. Across nine environmental conditions, significant variety x environment interactions was detected for seed yield of eight faba bean varieties[27]. Seed yield of hundred and one accessions of Cyprus local faba bean cultivars were varied under irrigated and rainfed conditions[28]. Seed yield varied considerably among these accessions and it was higher under irrigation than under rainfed conditions. Sprent *et al.*[8] suggested that water supply may be an important factor controlling yield than either solar radiation or plant competition, especially during the period after pod setting when plant water requirements is high. Using a computer model to analyse the water relations of the frequently irrigated and unirrigated faba bean crops, Reid[29] found that the root and shoot adaptations were quite successful at reducing drought stress in the unirrigated crop and without them the crop would probably have died prematurely.

Moreover, Day and Legg[11] in their review concluded that there was no specific water-sensitive stage in conventional, indeterminate forms of faba bean. found similar results for semi-determinate (Minica) and a determinate (Ticol) faba bean cultivars grown under different irrigation levels. In addition, seed yield was proportional to dry matter production, the proportionality was not affected by irrigation treatment[30]. Green *et al.*[31] explained the increases in yield associated with the removal of moisture stress at particular phases in the growth of the faba bean plant by increases in total biomass production with the improved environmental situation rather than from an alteration in dry mater partitioning. The objectives of this study were to compare yield and yield components of thirteen faba bean genotypes and identify the relationships of these characters with yield under rainfed and irrigation conditions.

## MATERIALS AND METHODS

Field experiments were conducted under rainfed and irrigation conditions during 1997/98 growing season at two locations in northern Jordan to evaluate thirteen faba bean genotypes for their yield and quality characters. Twelve-faba bean genotypes provided by the International Center for Agricultural Research in the Dry Areas and one local genotype obtained from local market were used in this study. Names, origin and pedigree of faba bean genotypes are listed in Table 1.

**Site description:**

**Maru Agricultural Experiment Station (Maru):** The study area has latitude 34°40′ N and longitude 32°36′ E with an altitude of 590 m above sea level[32]. The average annual rainfall is 407 mm for the period of 1993-97 and the total rainfall during the 1997/98 growing season was 505 mm (Fig. 1). The soil texture is silty clay with pH around 7.9. Total nitrogen and extractable phosphorus in soil were 1.2% and 18 ppm, respectively[33].

**Jordan University of Science and Technology Experimental Station (JUST):** It is located 32°30′ north latitude and 35°59′ east longitude with altitude of 590 m[22]. The average annual rainfall is 227 mm for the period of 1993-97 and the total rainfall and irrigation during the 1997/98 growing season was 292 and 415 mm, respectively (Fig. 2). The soil texture is fine-loamy with a pH around 8.0. Total nitrogen and extractable phosphorus in soil were 1% and 4.5 ppm, respectively[32].

**Cultural practices:** Seeds of the studied genotypes were planted under irrigation at the experimental station of Jordan University of Science and Technology (JUST) and rainfed conditions at Maru Agricultural Experiment Station (Maru). Planting was carried out by hand on November 30th, 1997 at both locations. Irrigation was applied by a trickle irrigation system. It consisted of lateral tubes (16 mm diameter) at 0.40 m apart, each irrigating a pair of crop rows. Each lateral tube had trickle emitters spaced at 0.50 m. Monthly irrigation amounts during the growing season are shown in (Fig. 2). At the two locations, the thirteen genotypes were grown in a Randomised Complete Block Design with three replications. Plots were 2.5 m long and 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 plants $m^{-2}$. Guard strips of 1.5 m between the plots and 2 m between replications were left

Table 1: Names, pedigree and origin of the faba bean genotypes.

| Genotypes | Pedigree | Country of origin |
|---|---|---|
| Aquadulce | ILB 1266 | Spain |
| 80S4387 | X77TA31 E88159 X G88160 | ICARDA© (Syria) |
| 79S4 | ILB 1814 | Syria |
| FLIP87-70FB | S 82148 E50088 X G79S79180 | ICARDA (Syria) |
| 663-4 | BPL 663 | Tunisia |
| FLIP87-26FB | S82148 E50088 X G79S79180 | ICARDA (Syria) |
| FLIP87-140FB | ⑦ MS 86001 | ICARDA (Syria) |
| Reina Blanca | ILB 1270 | United Kingdom |
| L82007-11-3-1 | EILB1817 X G76TA56246 | ICARDA (Syria) |
| FLIP87-147 | S82112 EReina blanca X G7YTA85 | ICARDA (Syria) |
| S82408-1-2-3 | EILB 1814 X GBPL 82 | ICARDA (Syria) |
| FLIP83-24FB | Selection 81S36522 | ICARDA (Syria) |
| Local Check | | Jordan |

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⑦ MS= male sterile

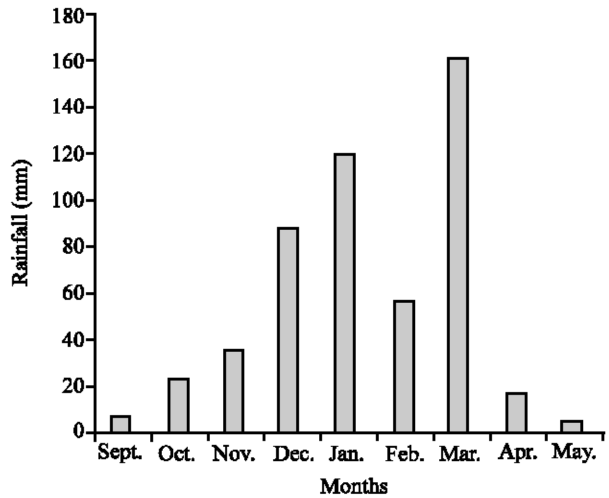


Fig. 1: Monthly rainfall during 1997/1998 growing season at Maru. (Data was obtained from Maru Agricultural Experiment Station).

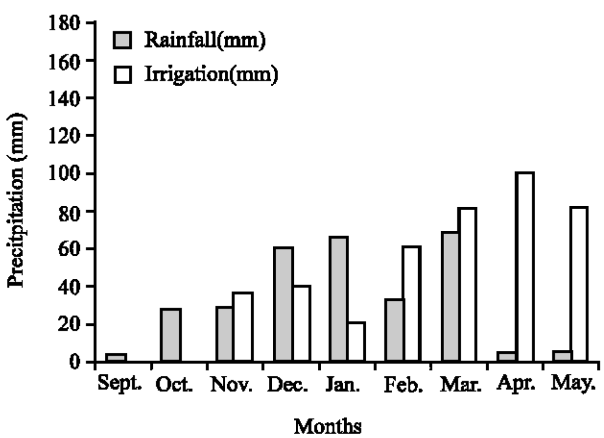


Fig. 2: Monthly rainfall and irrigation during 1997/1998 growing season at JUST. (Data for rainfall was obtained from Ramtha Regional Agricultural Services Center).

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.

**Measured variables:** Seed yield (kg $ha^{-1}$), biological yield (kg $ha^{-1}$), hundred seed weight (g), pods number $plant^{-1}$, plant height (cm), pod length (cm), seeds number $pod^{-1}$, nodules number $plant^{-1}$, nodules dry weight $plant^{-1}$ (g), time to flowering (days) and time to maturity (days).

**Statistical analysis:** Data from each location was analysed separately. Combined analysis of variance over locations was also performed. MSTATC PRGRAM (Michigan State University) was used to carry out statistical analysis. Treatment means were compared using Duncan's Multiple Range Test. Probability of significance was used to indicate significance among treatments and interactions according to Steel and Torrie[34]. The correlation coefficients of average seed yields for all genotypes versus other agronomic characters were also calculated.

## RESULTS AND DISCUSSION

Analysis of variance was conducted to predict the presence of significance between locations, genotypes and location x genotype interactions for all studied characters. The correlation coefficients of average seed yields for all genotypes versus other agronomic characters were also calculated.

**Yield, yield components and agronomic characters:** Analysis of variance showed highly significant environmental (location) effects for all studied traits except for seeds number per pod, which revealed no significant effect of location or genotypes (Table 2). Genotypes varied significantly over locations except for seeds number per pod and time to maturity. Genotype x

Table 2: Probability of significance for yield, yield components and agronomic characters measured in thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season.

| Traits | Location | Genotype | Location x Genotype |
|---|---|---|---|
| Dry seed yield (kg ha$^{-1}$) | ** | ** | ** |
| Biological yield (kg ha$^{-1}$) | ** | ** | NS |
| 100 seed weight (g) | ** | ** | NS |
| Pod number plant$^{-1}$ | ** | ** | NS |
| Plant height (cm) | ** | * | NS |
| Pod length (cm) | ** | ** | NS |
| Seed number pod$^{-1}$ | NS | NS | NS |
| Nodules number plant$^{-1}$ | ** | ** | ** |
| Nodules dry weight plant$^{-1}$ (g) | ** | ** | NS |
| Time to flowering (days) | ** | ** | ** |
| Time to maturity (days) | ** | NS | NS |

**, * are significant at $P \leq 0.01$ and $P \leq 0.05$, respectively.
NS = Non significant.

Table 3: Seed yield (kg ha$^{-1}$) of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season.

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 3927c | (12) | 1947abc | (10) |
| 80S4387 | 4924a | (4) | 2079ab | (7) |
| 79S4 | 4858ab | (6) | 1985abc | (9) |
| FLIP87-70FB | 4116bc | (9) | 1768bc | (11) |
| 663-4 | 3968c | (11) | 2280ab | (4) |
| FLIP87-26FB | 4762ab | (7) | 2059ab | (8) |
| FLIP87-140FB | 4861ab | (5) | 1353c | (13) |
| Reina Blanca | 5009a | (2) | 2320ab | (3) |
| L82007-11-3-1 | 5077a | (1) | 2222ab | (5) |
| FLIP87-147FB | 4360abc | (8) | 2364ab | (2) |
| S82408-1-2-3 | 3756c | (13) | 2489a | (1) |
| FLIP83-24FB | 5009a | (3) | 2149ab | (6) |
| Local Check | 3981c | (10) | 1728bc | (12) |
| Mean | 4508 | | 2057 | |

Means within each column followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 4: Biological yield (kg ha$^{-1}$) of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season.

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 7204b | (12) | 6542ab | (8) |
| 80S4387 | 9698a | (1) | 7660a | (2) |
| 79S4 | 8596ab | (9) | 6568ab | (7) |
| FLIP87-70FB | 8196ab | (10) | 6366ab | (10) |
| 663-4 | 8000ab | (11) | 7932a | (1) |
| FLIP87-26FB | 9149a | (5) | 6520ab | (9) |
| FLIP87-140FB | 9234a | (3) | 5678b | (12) |
| Reina Blanca | 9010a | (6) | 6724ab | (6) |
| L82007-11-3-1 | 9579a | (2) | 6334ab | (11) |
| FLIP87-147FB | 8672ab | (7) | 7011ab | (4) |
| S82408-1-2-3 | 8650ab | (8) | 7593a | (3) |
| FLIP83-24FB | 9183a | (4) | 6875ab | (5) |
| Local Check | 7185b | (13) | 5521b | (13) |
| Mean | 8643 | | 6717 | |

Means within each column followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 5: Hundred seed weight (g) of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 96.4bc | (9) | 78.5cd | (11) |
| 80S4387 | 99.3abc | (8) | 75.3cd | (12) |
| 79S4 | 105.8abc | (6) | 92.5ab | (5) |
| FLIP87-70FB | 94.9bc | (10) | 80.4cd | (9) |
| 663-4 | 91.8bc | (11) | 80.5cd | (8) |
| FLIP87-26FB | 109.5ab | (4) | 100.3a | (1) |
| FLIP87-140FB | 104.5abc | (7) | 79.9cd | (10) |
| Reina Blanca | 110.9ab | (3) | 92.7ab | (4) |
| L82007-11-3-1 | 121.2a | (1) | 82.9bc | (7) |
| FLIP87-147FB | 106.0abc | (5) | 91.9ab | (6) |
| S82408-1-2-3 | 90.8bc | (12) | 94.7a | (3) |
| FLIP83-24FB | 111.9ab | (2) | 96.3a | (2) |
| Local Check | 85.5c | (13) | 70.9d | (13) |
| Mean | 102.2 | | 85.9 | |

Means within each column followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 6: Pods number plant$^{-1}$ of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 11.87ab | (3) | 5.07bc | (9) |
| 80S4387 | 8.93bc | (11) | 5.20bc | (8) |
| 79S4 | 10.27abc | (6) | 5.53bc | (6) |
| FLIP87-70FB | 7.40c | (13) | 5.07bc | (10) |
| 663-4 | 12.40a | (2) | 6.33ab | (2) |
| FLIP87-26FB | 10.20abc | (8) | 5.87abc | (3) |
| FLIP87-140FB | 9.40abc | (10) | 4.53bc | (12) |
| Reina Blanca | 10.43abc | (5) | 5.47bc | (7) |
| L82007-11-3-1 | 9.87abc | (9) | 5.07bc | (11) |
| FLIP87-147FB | 7.53c | (12) | 4.40c | (13) |
| S82408-1-2-3 | 10.47abc | (4) | 5.80abc | (5) |
| FLIP83-24FB | 10.20abc | (7) | 5.87abc | (4) |
| Local Check | 12.57a | (1) | 7.50a | (1) |
| Mean | 10.12 | | 5.52 | |

Means within each column followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 7: Plant height (cm) of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 97.3b | (11) | 92.3a | (7) |
| 80S4387 | 98.9b | (10) | 92.7a | (6) |
| 79S4 | 100.4ab | (9) | 92.9a | (4) |
| FLIP87-70FB | 104.8ab | (6) | 94.7a | (2) |
| 663-4 | 101.7ab | (8) | 87.2a | (10) |
| FLIP87-26FB | 115.0a | (2) | 95.2a | (1) |
| FLIP87-140FB | 115.2a | (1) | 91.3a | (8) |
| Reina Blanca | 105.3ab | (5) | 85.5a | (12) |
| L82007-11-3-1 | 96.3b | (13) | 85.9a | (11) |
| FLIP87-147FB | 107.9ab | (4) | 92.8a | (5) |
| S82408-1-2-3 | 103.3ab | (7) | 89.6a | (9) |
| FLIP83-24FB | 108.3ab | (3) | 94.5a | (3) |
| Local Check | 96.4b | (12) | 83.3a | (13) |
| Mean | 103.9 | | 90.6 | |

Means within each column followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 8: Pod length (cm) of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 10.51abc | (9) | 9.30ab | (6) |
| 80S4387 | 11.82ab | (2) | 8.85ab | (11) |
| 79S4 | 11.09abc | (5) | 8.93ab | (10) |
| FLIP87-70FB | 9.94 cd | (12) | 9.02ab | (9) |
| 663-4 | 9.98 cd | (11) | 8.14bc | (12) |
| FLIP87-26FB | 10.98abc | (6) | 9.83a | (5) |
| FLIP87-140FB | 11.13abc | (4) | 9.88a | (4) |
| Reina Blanca | 11.59abc | (3 | 10.10a | (2) |
| L82007-11-3-1 | 12.11a | (1) | 9.97a | (3 |
| FLIP87-147FB | 10.94abc | (7) | 9.27ab | (7) |
| S82408-1-2-3 | 10.45bc | (10) | 10.28a | (1) |
| FLIP83-24FB | 10.85abc | (8) | 9.15 ab | (8) |
| Local Check | 8.51 d | (13) | 7.47 c | (13) |
| Mean | 10.76 | | 9.25 | |

Means within each column followed by the same letter(s) are not significantly different at P ≤ 0.05 according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location

Table 9: Seed number pod$^{-1}$ of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 2.73a | (7) | 2.56a | (7) |
| 80S4387 | 2.81a | (3) | 2.39a | (12) |
| 79S4 | 2.74a | (6) | 2.45a | (10) |
| FLIP87-70FB | 2.63a | (8) | 2.40a | (11) |
| 663-4 | 2.45a | (12) | 2.38a | (13) |
| FLIP87-26FB | 2.83a | (2) | 2.56a | (6) |
| FLIP87-140FB | 2.81a | (4) | 2.71a | (4) |
| Reina Blanca | 2.59a | (9) | 2.76a | (2) |
| L82007-11-3-1 | 2.53a | (10) | 2.74a | (3) |
| FLIP87-147FB | 3.00a | (1) | 2.83a | (1) |
| S82408-1-2-3 | 2.75a | (5) | 2.66a | (5) |
| FLIP83-24FB | 2.52a | (11) | 2.48a | (8) |
| Local Check | 2.44a | (13) | 2.47a | (9) |
| Mean | 2.68 | | 2.57 | |

Means within each column followed by the same letter(s) are not significantly different at P ≤ 0.05 according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 10: Nodules number plant$^{-1}$ of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 109.0cd | (6) | 66.4ef | (10) |
| 80S4387 | 80.7d | (11) | 63.3f | (11) |
| 79S4 | 76.4d | (13) | 116.7bc | (3) |
| FLIP87-70FB | 133.8bc | (5) | 62. f | (12) |
| 663-4 | 154.9b | (2) | 152.4a | (1) |
| FLIP87-26FB | 147.1b | (3) | 132.3ab | (2) |
| FLIP87-140FB | 96.0d | (10) | 94.1cd | (8) |
| Reina Blanca | 141.8b | (4) | 113.0bc | (5) |
| L82007-11-3-1 | 107.5cd | (8) | 61.6f | (13) |
| FLIP87-147FB | 96.3d | (9) | 113.0bc | (4) |
| S82408-1-2-3 | 107.9cd | (7) | 110.8bc | (6) |
| FLIP83-24FB | 188.4a | (1) | 108.3c | (7) |
| Local Check | 78.3d | (12) | 85.9de | (9) |
| Mean | 116.8 | | 98.5 | |

Means within each column followed by the same letter(s) are not significantly different at P ≤ 0.05 according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 11: Nodules dry weight plant$^{-1}$ (g) of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 0.81abc | (9) | 0.38e | (13) |
| 80S4387 | 0.77bc | (10) | 0.41de | (10) |
| 79S4 | 0.77bc | (11) | 0.59ab | (2) |
| FLIP87-70FB | 0.94abc | (6) | 0.46b-e | (8) |
| 663-4 | 1.07a | (1) | 0.66a | (1) |
| FLIP87-26FB | 0.94abc | (5) | 0.58abc | (4) |
| FLIP87-140FB | 0.84abc | (8) | 0.40de | (11) |
| Reina Blanca | 0.97abc | (3) | 0.55abc | (5) |
| L82007-11-3-1 | 0.70c | (13) | 0.39e | (12) |
| FLIP87-147FB | 0.93abc | (7) | 0.45cde | (9) |
| S82408-1-2-3 | 0.96abc | (4) | 0.53a-d | (6) |
| FLIP83-24FB | 0.99ab | (2) | 0.59ab | (3) |
| Local Check | 0.71c | (12) | 0.47b-e | (7) |
| Mean | 0.88 | | 0.50 | |

Means within each column followed by the same letter(s) are not significantly different at P ≤ 0.05 according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 12: Time to flowering (days) of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 105.3ab | (5) | 101.0ab | (2) |
| 80S4387 | 105.0ab | (6) | 97.7bcd | (8) |
| 79S4 | 105.0ab | (7) | 96.0cd | (10) |
| FLIP87-70FB | 105.7a | (1) | 95.7cd | (11) |
| 663-4 | 104.7ab | (8) | 97.7bcd | (7) |
| FLIP87-26FB | 104.7ab | (9) | 99.0abc | (6) |
| FLIP87-140FB | 100.7c | (13) | 97.3bcd | (9) |
| Reina Blanca | 103.7abc | (10) | 101.0ab | (3) |
| L82007-11-3-1 | 101.7bc | (12) | 102.3a | (1) |
| FLIP87-147FB | 105.7a | (3) | 101.0ab | (4) |
| S82408-1-2-3 | 105.3ab | (4) | 100.3ab | (5) |
| FLIP83-24FB | 105.7a | (2) | 94.3d | (12) |
| Local Check | 102.0abc | (11) | 94.3d | (13) |
| Mean | 104.2 | | 98.3 | |

Means within each column followed by the same letter(s) are not significantly different at P ≤ 0.05 according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 13: Time to maturity (days) of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during 1997/98 growing season

| Genotypes | JUST | | Maru | |
|---|---|---|---|---|
| Aquadulce | 186.3a | (1) | 170.7abc | (5) |
| 80S4387 | 185.3ab | (3) | 168.3abc | (10) |
| 79S4 | 185.7ab | (2) | 167.7abc | (11) |
| FLIP87-70FB | 184.7ab | (6) | 168.3abc | (8) |
| 663-4 | 184.7ab | (7) | 168.7abc | (7) |
| FLIP87-26FB | 183.3ab | (10) | 170.3abc | (6) |
| FLIP87-140FB | 180.0b | (13) | 168.3abc | (9) |
| Reina Blanca | 183.3ab | (9) | 171.3abc | (4) |
| L82007-11-3-1 | 180.3ab | (12) | 173.0a | (1) |
| FLIP87-147FB | 185.0ab | (4) | 171.7abc | (3) |
| S82408-1-2-3 | 184.7ab | (8) | 172.0ab | (2) |
| FLIP83-24FB | 185.0ab | (5) | 165.3c | (13) |
| Local Check | 181.0ab | (11) | 165.7bc | (12) |
| Mean | 183.8 | | 169.3 | |

Means within each column followed by the same letter(s) are not significantly different at P ≤ 0.05 according to DMRT.
Numbers between parenthesis refer to ranking of genotypes at each location.

Table 14: Correlation coefficients for eleven agronomic characters of thirteen faba bean genotypes grown under irrigation (JUST) and rainfed (Maru) conditions during the 1997/1998 growing season

| | BYLD | HSWT | PNPP | PLHT | PL | SNPP | NNPP | NWPP | FLRT | MATT |
|---|---|---|---|---|---|---|---|---|---|---|
| SYLD | 0.709** | 0.807** | -0.278 | 0.116 | 0.704** | 0.242 | 0.237 | 0.109 | 0.278 | 0.194 |
| BYLD | | 0.487 | -0.385 | 0.251 | 0.633 | 0.214 | 0.276 | 0.311 | 0.405 | 0.397 |
| HSWT | | | -0.363 | 0.473 | 0.738** | 0.449 | 0.431 | 0.265 | 0.359 | 0.277 |
| PNPP | | | | -0.522 | -0.561 | -0.615* | 0.238 | 0.181 | -0.311 | -0.318 |
| PLHT | | | | | 0.330 | 0.427 | 0.406 | 0.371 | 0.021 | 0.028 |
| PL | | | | | | 0.617* | 0.009 | -0.088 | 0.531 | 0.458 |
| SNPP | | | | | | | -0.177 | -0.202 | 0.532 | 0.449 |
| NNPP | | | | | | | | 0.934** | 0.089 | 0.063 |
| NWPP | | | | | | | | | 0.122 | 0.166 |
| FLRT | | | | | | | | | | 0.968** |

**,* signficant at $P \leq 0.01$ and $P \leq 0.05$, respectively.

SYLD: seed yield; BYLD: biological yield; HSWT:100-seed weight; PNPP: pods number $plant^{-1}$; PLHT: plant height; PL: pod length; SNPP: seeds number $pod^{-1}$; NNPP: nodules number $plant^{-1}$; NWPP: nodules dry weight $plant^{-1}$; FLRT: time to flowering; MAAT: time to maturity

environment interactions was not significant for all traits except for seed yield, nodules number/plant and time to flowering. The significant genotype x location effects was important in that they indicated relative performance of genotypes was dependent upon the conditions of the growing season.

**Seed yield (kg $ha^{-1}$):** Statistical analysis showed a significant interaction for seed yield between the genotypes and locations (Table 2). This is in agreement with Ibrahim and Ruckenbauer[27] who found a significant variety x environment interactions for seed yield of eight faba bean varieties across nine environmental conditions. Genotypic differences for seed yield were highly significant under both rainfed and irrigated conditions (Table 3). Under irrigation conditions, L82007-11-3-1 gave significantly the highest seed yield (5077 kg $ha^{-1}$), but it was not significantly different from Rina Blanca, FLIP83-24FB and 80S43587, their yields were 5009, 5009 and 4924 kg $ha^{-1}$, respectively. However, S82408-1-2-3 gave the lowest seed yield 3756 kg $ha^{-1}$ under irrigation conditions. Under rainfed conditions, S82408-1-2-3 gave the highest seed yield (2489 kg $ha^{-1}$), but it was not significantly different from FLIP87-147FB, which yielded 2364 kg $ha^{-1}$. However, FLIP87-140FB, gave the lowest seed yield 1353 kg $ha^{-1}$ under rainfed conditions. Overall genotypes, the average seed yield of irrigated planting at JUST was higher than that of rainfed planting at Maru by 2-folds (Table 3). This could be attributed to more favourable moisture conditions. These results are in agreement with Della[28] who found that irrigated planting gave higher seed yield than rainfed planting. Sprent *et al.*[8] suggested that water supply may be a more important factor in controlling yield, especially with period following pod setting when the plant water requirements becomes high.

**Biological yield (kg $ha^{-1}$):** Genotypic differences in biological yield (kg $ha^{-1}$) were highly significant under both rainfed and irrigated conditions (Table 4). Under irrigation conditions, 80S43587 gave the highest biological yield (9365 kg $ha^{-1}$) compared to the other genotypes, while Aquadulce gave the lowest biological yield (7204 kg $ha^{-1}$). Under rainfed conditions, 663-4 gave the highest biological yield (7932 kg $ha^{-1}$), whereas the Local Check gave the lowest biological yield (5521 kg $ha^{-1}$). Overall genotypes, the average biological yield under irrigation conditions (8643 kg $ha^{-1}$) was higher than that under rainfed conditions (6717 kg $ha^{-1}$). This could be attributed to more favorable moisture conditions that extended the crop duration. These results are in agreement with those reported by Thomson and Taylor[15] who found that irrigated faba bean plots had greater biomass than rainfed ones. Biological yield of the genotypes at both locations closely reflected growing season's water supply, supporting the concept that in low-rainfall environments, crop growth is primarily limited by the supply of water. Variable water supply could affect total biomass through effects of water availability on canopy size and duration[35].

**Hundred seed weight (g):** Hundred seed weight was highly and significantly variable among the genotypes under rainfed and irrigation conditions (Table 5). Under irrigation, L82007-11-3-1 had significantly the highest hundred seed weight (121.2 g), while the lowest hundred seed weight was recorded for Local Check (85.5 g). Under rainfed conditions, FLIP87-26FB who ranked the second among genotypes under irrigation conditions, had significantly the highest hundred seed weight (100.6 g), but it was not significantly different from FLIP83-24FB and S82408-1-2-3 (96.3 and 94.7 g, respectively). The lowest hundred seed weight was recorded for Local Check

(70.9 g). The average 100-seed weight for all genotypes was higher under irrigation conditions than that under rainfed conditions. These results agree with those reported by Pilbeam *et al.*[30] who found that faba bean gave higher hundred seed weight when grown under irrigation than under rainfed conditions.

**Pods number plant$^{-1}$:** Genotypic differences for number of pods per plant were highly variable under both rainfed and irrigated conditions (Table 6). The Local Check gave significantly the highest and FLIP87-147FB gave the lowest number of pods per plant among the tested genotypes when grown under both irrigation and rainfed conditions. Overall genotypes the average number of pods per plant under irrigation conditions (10.1 pod plant$^{-1}$) was higher than that under rainfed conditions (5.5 pod plant$^{-1}$) by about 1.8-folds. These results agree with those reported by Pilbeam *et al.*[30] who found that the increase in yield under irrigation conditions was associated with more pods per plant. All genotypes gave a significantly greater number of pods per plant at JUST than Maru location. This is might be due to more favorable soil moisture at JUST during the flower formation and pod setting as compared with Maru. These two stages were reported to be sensitive to shortage in soil moisture content[16].

**Plant height (cm):** Statistical analysis showed highly significant genotypic differences in plant height between genotypes grown under irrigated and rainfed conditions (Table 7). Under irrigation conditions, FLIP87-140FB plants were the tallest (115.2 cm), but they were not significantly different from those of FLIP87-26FB (115 cm). L82007-11-3-1 had significantly the shortest plants (96.3 cm), but these were not significantly different from Local Check and Aquadulce plants (96.4 and 97.3 cm, respectively). However, under rainfed conditions no significant differences between genotypes for plant height were noted. Over all genotypes, the average plant height (103.9 cm) under irrigation conditions was significantly higher than that under rainfed conditions (90.6 cm). The increase in plant height due to increase in soil water content was also reported by[12]. Under irrigation conditions, plants took a longer time until they reach the flowering stage (Table 12) that may resulted in significantly taller plants than under rainfed conditions.

**Pod length (cm):** High variations among genotypes for length of pod under both irrigation and rainfed conditions were observed (Table 8). Under irrigation conditions, L82007-11-3-1 gave significantly the highest pods length (12.11 cm), while Local Check gave significantly the lowest pod length (8.51 cm). Under rainfed conditions, S82408-1-2-3 gave significantly the highest pod Length (10.28 cm), while Local Check gave significantly the lowest pod length (7.47 cm) among the tested genotypes.

**Seeds number pod$^{-1}$:** No genotypic differences for seeds number per pod were noted under either rainfed or irrigation conditions (Table 9). Several researchers reported that seeds number per pod for faba bean is a stable parameter[9,36].

**Nodules number plant$^{-1}$:** Genotypic differences for number of nodules per plant were highly significant under both rainfed and irrigated conditions (Table 10). Under irrigation conditions, FLIP83-24FB gave significantly the highest number of nodules per plant (188.4 nodule), while, 79S4 gave significantly the lowest number of nodules per plant (76.4 nodule), but it was not significantly different from the Local Check and 80S4387 (78.3 and 80.7 nodule, respectively). Under rainfed conditions, 663-4 and FLIP87-24FB gave significantly the highest number of nodules per plant (152.4 and 132.3 nodule, respectively). Mean while, L82007-11-3-1 gave significantly the lowest number of nodules per plant (61.6 nodule), which was not significantly different from FLIP87-70FB and 80S4387 (62.9 and 63.3 nodule, respectively). These results were in agreement with Islam[37] who found that the genotypes varied considerably in their nodule production. The average nodules number per plant for all genotypes was higher under irrigation than that under rainfed conditions. The increase in nodules number due to increase in soil water content was also reported by other researchers[37,38].

**Nodules dry weight plant$^{-1}$ (g):** Genotypic differences for nodules dry weight per plant were highly variable under both rainfed and irrigated conditions (Table 11). Under irrigation conditions, 663-4 gave significantly the highest nodules dry weight per plant (1.07 g), while L82007-11-3-1 gave significantly the lowest nodules dry weight per plant (0.70 g). Under rainfed conditions, 663-4 gave significantly the highest nodules dry weight per plant (0.66 g), while the lowest dry weight was recorded for Aquadulce (0.38 g), but it was not significantly different from L82007-11-3-1 (0.39 g). The average nodules dry weight per plant under irrigation condition for all genotypes was higher than that under rainfed conditions.

The increase in nodules number and dry weight per plant due to increase in soil water content was also reported by Hadadd and Thalji[26].

**Time to flowering (days):** The results showed that there were a highly significant differences in time to flowering between genotypes at both locations (Table 12). Under irrigation conditions, FLIP87-70FB had the longest period to flowering (105.7 days), but it was significantly different only from L82007-11-3-1 and FLIP87-140FB (101.7 and 100.7, respectively). Under rainfed conditions, L82007-11-3-1 had significantly the longest period to flowering (102.3 days). However, the Local Check and FLIP83-24FB had significantly the lowest number of days to flowering (94.3 days), but that was not significantly different from genotypes FLIP87-70FB, 79S4, FLIP87-140FB, 663-4 and 80S4387 (95.7, 96.0, 97.3, 97.7 and 97.7, respectively). The average period from planting to flowering for all genotypes was longer under irrigation conditions than that under rainfed conditions. These results were in agreement with Della[28] who found that under irrigation conditions, faba bean genotypes had longer time to flower than that under rainfed conditions. This could be attributed to low soil water content (especially at flowering stage) under rainfed conditions, which reduced the period to flowering. Statistical analysis showed a significant interaction for time to flowering between the genotypes and locations, suggesting that genotypes differed in their sensitivity to environmental conditions (location).

**Time to maturity (days):** Genotypic differences for time to maturity were not significant under either rainfed or irrigation conditions (Table 13). The average period needed to maturity for all genotypes was longer under irrigation conditions than that under rainfed condition. These results were in agreement with Ibrahim and Ruckenbauer[27] who found that the genotypes varied significantly between different environmental conditions in time to maturity.

**Correlations between the studied agronomic characters:** Simple correlation coefficients between the studied characters were computed and presented in Table 14. Positive significant correlations were found between seed yield and biological yield, hundred seed weight and pod length (r = +0.709**, +0.807** and +0.704**, respectively). Similar observations were recorded about positive relationship between seed yield and hundred seed weight, biological yield and pods per plant[39]. Robertson and El-Sherbeeny[40] found that no significant relationship between pods per plant and seed yield; while biological yield, hundred seed weight and pod length were positively correlated with seed yield. Pod length, hundred seed weight and seeds number per pod were positively correlated with each other. These results suggest that for a high seed yield, fewer pods with large seeds might be compensate for the low pods number per plant. The positive relationship between seed yield and hundred seed weight might indicate the importance of seed size in determining the final yield of faba beans.

Even though the correlations between plant height, seeds per pod, nodule number, nodule dry weight per plant, time to flowering and time to maturity were positively correlated with seed yield, but these correlations were not significant. Haddad and Thalji[26] found a positive significant correlations between seed yield and plant height, nodule number and nodule dry weight per plant.

From the results of the present study, the following conclusions can be drawn:

- The genotypes Reina Blanca, L82007-11-3-1, FLIP83-24FB and 80S43587 are promising genotypes for seed yield under both irrigation and rainfed conditions. In comparison with the Local Check, these genotypes had higher seed yield.
- All genotypes produced higher numbers of pod per plant and hundred seed weight under irrigation than under rainfed conditions.
- The lower seed yield under rainfed conditions might be attributed to fewer pods per plant, lower biological yield and lower hundred seed weight.
- Variation among genotypes in seed yield was highly correlated with biological yield, 100 seed weight and pod length.
- No significant differences between genotypes and locations for seeds number per pod were noted. Therefore, seeds per pod might be a stable component of yield.
- FLIP83-24FB genotype had significantly the highest seed yield content among tested genotypes under both rainfed and irrigation conditions.
- Since Local Check gave the lowest seed yield among tested genotypes, therefor we need to look for high yielding genotypes and well adapted to Jordanian conditions.

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