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YIELD AND WATER USE EFFICIENCY OF FABA BEAN SOWN AT TWO ROW SPACINGS AND SEED DENSITIES

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SUMMARY

The performance of promising genotypes of faba bean developed for areas with limited rainfall was compared with the local landrace, ILB 1814, at Tel Hadya in Syria during 1984–1988 using different row spacings and sowing densities. In the last two years of the trials the performance of the improved genotypes and ILB 1814 was compared with and without supplemental irrigation. Yields of ILB 1814 were better than the highest yielding genotypes in some years and similar to them in others. In seasons with limited rainfall the best yields were obtained by using a narrow row spacing and dense sowing, and yields were significantly improved by irrigation. Grain yield was correlated with biomass and the number of pods per unit area. The percentage of radiation intercepted was highest in ILB 1814, particularly when sown with a narrow row spacing and at a high plant density. Soil water extraction, evapotranspiration and water use efficiency were improved by sowing at a narrow row spacing and high plant density.

Rendimiento y de uso de agua del poroto 'Faba'

RESUMEN

Se comparó la actividad de genotipos prometedores de poroto 'Faba' desarrollados para zonas con precipitaciones limitadas, con la de la variedad local, ILB 1814, en Tel Hadya, Siria, durante 1984–1988, utilizando diferentes separaciones entre hileras y densidades de siembra. Durante los dos últimos años del estudio se comparó la actividad de los genotipos mejorados y el ILB 1814, con y sin irrigación complementaria. Los rendimientos del ILB 1814 fueron superiores a los de los genotipos de mayor rendimiento en algunos de los años, y similares en otros. En las temporadas con precipitaciones limitadas, los mejores rendimientos fueron obtenidos utilizando espacios angostos entre las hileras, y una alta densidad de siembra; y los rendimientos mejoraron significativamente con la irrigación. El rendimiento de grano estuvo correlacionado con la biomasa y la cantidad de vainas por unidad de superficie. El porcentaje de radiación interceptada fue superior en la variedad ILB 1814, en particular cuando se lo sembró con espacio angosto y alta densidad. La extracción de agua del suelo, la evapotranspiración, y la eficiencia de uso de agua mejoraron con el uso de espacios angostos entre hileras y alta densidad de siembra.

INTRODUCTION

In West Asia and North Africa (WANA), rain falls in the winter months and faba bean (*Vicia faba* L.) is grown as a rainfed crop in areas receiving more than

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400 mm of rainfall (Saxena, 1985). In the drier areas of WANA, however, the crop is given supplementary irrigation or is grown entirely as an irrigated crop, in such places as the Nile Valley (Saxena, 1985). At the International Center for Agricultural Research in the Dry Areas (ICARDA), faba bean genotypes have been developed for the drier areas of the WANA region, that is those with a mean annual rainfall of less than 400 mm (ICARDA, 1984). In these drier areas, the grain yield and water use efficiency of barley (Cooper *et al.*, 1987b) and lentil (Silim *et al.*, 1993) have been improved by improving early ground cover.

The experiments described here were designed to investigate whether or not faba bean genotypes developed at ICARDA for the low rainfall areas of WANA were superior to the local landrace and whether or not a narrow row spacing and dense sowing would improve grain yield, as in lentil.

MATERIALS AND METHODS

The study was conducted at the ICARDA's main research station at Tel Hadya, North Syria over four growing seasons; 1984/85, 1985/86, 1986/87 and 1987/88. The soil at the study site is a Calcic Luvisol, highly calcareous and more than two metres deep.

The long-term mean annual rainfall for Tel Hadya is 331 mm. In 1984/85, total precipitation was 373 mm but its distribution was poor, most of the rain falling between November and February. Rainfall between March and May was only 38% of the long-term mean for that period. The total precipitation in the 1985/86 season was 316 mm, but was evenly distributed. In 1986/87, total precipitation was 359 mm, and an additional 80 mm of water was applied to all the plots immediately after the beans were sown to ensure complete emergence; an extra 150 mm of water was applied in an irrigated treatment. In 1987/88, the total rainfall received was 504 mm, the wettest season since 1940/41, and an additional 145 mm of water was applied in an irrigated treatment.

There was a prolonged period of frosts in late February and early March in the 1984/85 season, which caused damage to the faba bean crop. Temperatures in 1985/86 were similar to the long-term average and in 1986/87 were very favourable for crop growth, mild at the beginning of the crop season and cooler than the long-term average during April and May. In 1987/88 temperatures were similar to the long-term average.

The experimental design in 1984/85 and 1985/86 was a randomized block replicated three times, with treatments factorially arranged. Eight faba bean genotypes were compared: seven developed for areas with limited rainfall (80S 43856, 80S 44358, 80S 44367, 80S 44815, 80S 45057, 80S 64214 and 80L 90121) and the local landrace (ILB 1814) as a control. Two row spacings were used: wide, 0.45 m (the recommended row spacing) and narrow, 0.225 m. The seeds were sown at two densities: low, 22 plants m^{-2} and high, 44 plants m^{-2}. The experimental design in 1986/87 was a split plot, replicated four times. The main plots were used to compare two levels of moisture supply (rainfall alone, and rainfall plus irrigation). The sub-plots were factorially arranged and contained the highest yielding genotypes from the 1984/85 and 1985/86 seasons (80S 43856, 80L 90121) and ILB 1814 at two seeding densities: 22 plants m^{-2} (at the wide row spacing) and 44 plants m^{-2} (at the narrow row spacing). In 1987/88, the treatments were similar to those in 1986/87; the genotypes used were 80S 43856 and ILB 1814 from the previous seasons and two promising determinate lines, FLIP 84-239F and FLIP 84-241F.

A basal application of 22 kg P ha^{-1} was incorporated into the soil. Sowing took place during the first week of November each year. Immediately after sowing, pre-emergence herbicides were applied: terbutryne (Igran) at a rate of 2.5 kg active ingredient (a.i.) ha^{-1} and pronamide (Kerb) at a rate of 0.5 kg a.i. ha^{-1}. Weeds were controlled mechanically later in the season. Fungicides were used to control chocolate spot (*Botrytis fabae*).

Soil moisture content was monitored at 7–10 day intervals at 0.15 m depth intervals to a depth of 1.8 m using a neutron probe (Wallingford Model 225). The moisture content of the top 0.15 m of the soil profile was determined gravimetrically. In 1984/85 and 1985/86, 2.0 m access tubes were installed between the rows of all the genotypes in the treatment combination of 0.45 m row spacing and 22 seeds m^{-2} and in all the treatment combinations of the genotype used as the control, ILB 1814. In 1986/87 access tubes were installed among all three genotypes in all treatments.

Incident and transmitted solar radiation were measured weekly during the 1987/88 season, using tube solarimeters (Delta-T Devices). Two tubes were placed at ground level across the rows below the leaf canopy in each of the plots to measure transmitted solar radiation and one solarimeter was mounted above the canopy to measure incoming solar radiation.

At maturity, the borders of each plot were discarded and 7.2 m^{2} areas harvested for the determination of grain yield. Yield components were determined at final harvest from separate 0.725 m^{2} sub-sample areas.

RESULTS

In both 1984/85 and 1985/86, ILB 1814 produced the best yields and 80S 44367 the worst (Table 1). Dense sowing and narrow rows resulted in better yields than less dense sowing and wider rows. ILB 1814 had the least number of pods m^{-2} and seeds per pod, but this was compensated for by its large 100-seed weight. The number of pods m^{-2} was greater at the narrow row spacing and high plant density, but neither of these treatments significantly affected the number of seeds per pod and 100-seed weight.

Irrigation increased grain yield and biomass in both 1986/87 and 1987/88 (Table 2). There were no significant differences between varieties or treatments in 1986/87, but in 1987/88, ILB 1814 and 80S 43856 produced the best yields while ILB 1814 and FLIP 84-241F showed the greatest response to irrigation.

Table 1. *Effect of genotype, row spacing (m) and plant density* m^{-2} *on grain yield* ($t\ ha^{-1}$) *and some yield components of faba beans, 1984/85 and 1985/86*

	Grain yield		Yield components (1984/85)		
Genotype	1984/85	1985/86	Pods m^{-2}	Seeds pod^{-1}	100-seed wt (g)
ILB 1814	2.57	1.54	106	1.9	124
80S 43856	2.12	1.30	126	2.1	82
80S 44358	1.83	1.37	151	2.3	67
80S 44367	1.40	1.15	152	2.1	53
80S 44815	1.86	1.22	140	2.0	68
80S 45057	1.73	1.35	130	2.1	72
80S 64214	1.78	1.38	145	2.0	66
80L 90121	1.82	1.46	163	2.0	69
SE	0.090	0.085	11	0.13	5.6

	1984/85		1985/86	
	Row spacing		Row spacing	
	0.45	0.225	0.45	0.225
	Grain yield			
Plant density				
22	1.26	1.87	0.83	0.50
44	1.73	2.71	1.24	1.80
SE	0.064		0.053	
	Pods m^{-2}			
Plant density				
22	117	115		
44	133	192		
SE	7.5			

Grain yield and total biomass were closely correlated in all years (Table 3). Grain yield was also correlated with the number of pods m^{-2} in three years out of the four but with 100-seed weight in only one year.

There were significant differences among genotypes in the radiation intercepted. These differences appeared early and persisted throughout the season (Fig. 1). The interception of radiation was greatest in the treatment that combined a narrow row spacing with high seed density.

Soil moisture profiles for genotype ILB 1814 at maximum recharge and at crop maturity were similar in all four years; the results for 1984/85 (Fig. 2) show that the roots of this genotype extracted most moisture from the top 0.45 m of soil. Sowing at a narrow row spacing, especially when combined with high plant density, resulted in moisture extraction at a greater depth. Changes in the maximum depth of water extraction gave an indication of the maximum effective

Table 2. *Effect of moisture supply and genotype on grain yield (t ha^{-1}) and biomass (t ha^{-1}) of faba beans, 1986/87 and 1987/88*

	Grain yield		Biomass	
	Unirrigated	Irrigated	Unirrigated	Irrigated
		1986/87		
ILB 1814	3.94	4.91	8.62	10.82
80S 43856	4.34	5.08	8.43	9.87
80L 90121	4.01	5.11	7.83	9.80
SE	0.113		0.245	
		1987/88		
ILB 1814	2.94	3.88	5.90	7.68
80S 43856	3.12	3.59	5.99	6.48
FLIP 84-239F	2.17	2.73	4.08	5.13
FLIP 84-241F	1.98	2.90	3.81	5.21
SE	0.173		0.373	

rooting depth of the beans (Fig. 3). As would be expected, roots extended further down the soil profile as the season progressed, but the effective rooting depth was greatest at the narrow row spacing.

The cumulative evapotranspiration (ET) of the crop was computed for all seven improved genotypes sown at a wide row spacing and a low density and for ILB 1814 in all treatment combinations (Table 4). There was little genotypic variation in ET but ET was greatest in ILB 1814 in both years in the treatment combining a narrow row spacing with a high seed density.

The water use efficiency (WUE) ranged from 3.49 to 6.28 in 1984/85 and from 3.08 to 4.18 in 1985/86 and was greatest in ILB 1814 in the combination of narrow row spacing and high seed density (Table 4).

DISCUSSION

Grain yield of faba bean in this study was most strongly correlated with biomass, as also found by Hedley and Ambrose (1981) for peas, Saxena *et al.* (1990) for

Table 3. *Correlation between grain yield and some yield components of faba beans, 1984/85 to 1987/88*

	1984/85	1985/86	1986/87	1987/88
Biomass	0.91***	0.97***	0.82***	0.94***
Pods m^{-2}	0.44***	−0.03	0.44**	0.36**
Seeds pod^{-1}	−0.08	−0.10	0.07	0.09
100-seed weight	0.21*	−0.01	0.28	0.53***
Harvest index	−0.38***	0.05	0.22	−0.06

*, ** and *** denote significance at $P < 0.05$, 0.01 and 0.001, respectively.

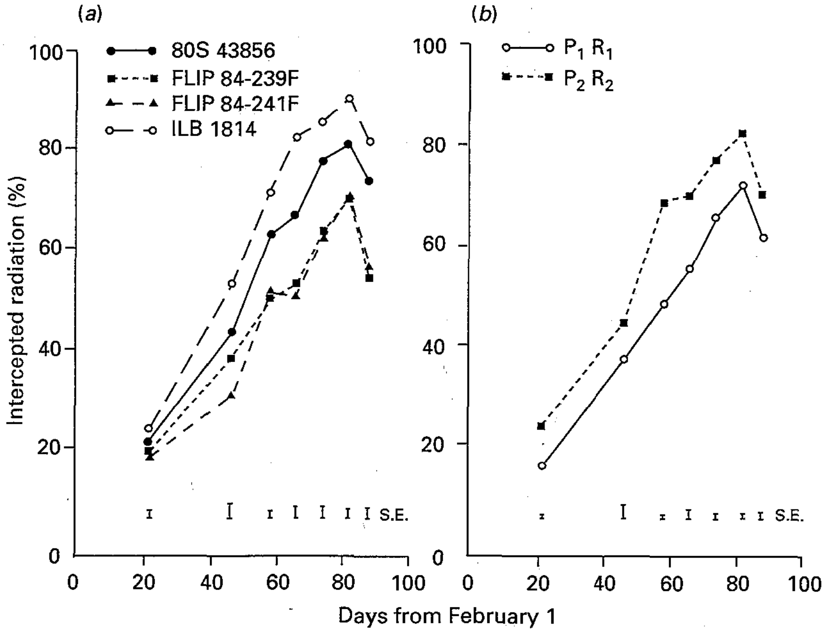

Fig. 1. Percentage of radiation intercepted by faba bean at different growth stages at Tel Hadya, Syria, 1987/88; (a) means for the genotypes 80S 43856, FLIP 84-239F, FLIP 84-241F and ILB 1814; (b) means for the treatment combination of 22 plants m^{-2} with a 0.45 m row spacing (P1R1), and 44 plants m^{-2} with a 0.225 m row spacing (P2R2).

chickpea, Silim and Saxena (1992a) for faba bean and Silim *et al.* (1993) for lentil, showing that the production of a large biomass is one of the main prerequisites for high grain yield.

The well adapted Syrian landrace ILB 1814 gave grain yields at least as high as those of the highest yielding genotypes bred for low rainfall environments. In the WANA region, where faba bean is grown as a rainfed crop (where the mean annual rainfall is greater than 400 mm), there are wide year-to-year fluctuations in the amount, frequency and duration of rainfall (Kassam, 1981; Smith and Harris, 1981) and the local landraces may therefore be expected to have developed good adaptation to low rainfall. Silim and Saxena (1992b) reported that differences in light use efficiency amongst faba bean genotypes of varying growth habit were mainly due to variation in the amount of radiation intercepted, as also found in the present investigation, where ILB 1814 intercepted the most radiation and produced the largest amount of biomass.

In areas of Syria where the rainfall is limited, water loss from the soil surface is substantial: 35% of the seasonal evapotranspiration for wheat and 55% of that for barley (Cooper *et al.*, 1987a). Recommended management practices for reducing this loss include sowing at a narrow row spacing and a high seed density (Saxena, 1981; Cooper *et al.*, 1987b; Richards, 1987; Silim *et al.*, 1990). Our results support these recommendations and show that when moisture supply is limited, substantial increases in grain yield can be obtained by sowing at a narrow row spacing

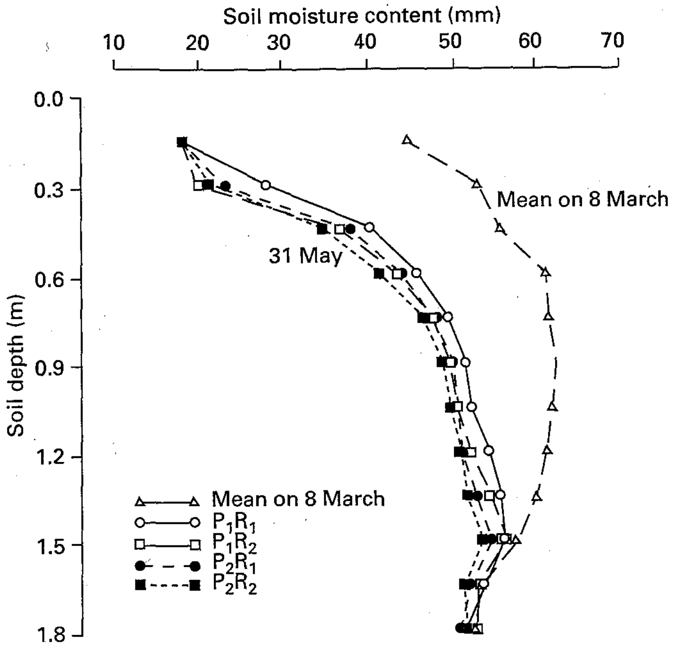

Fig. 2. Distribution of moisture in the soil profile at maximum recharge (8 March, mean value of all row spacing and population combinations of faba bean genotype ILB 1814) and at crop maturity (31 May, same genotype), sown at 22 (P1) and 44 (P2) plants m^{-2}, and 0.45 m (R1) and 0.225 (R2) row spacings, 1984/85.

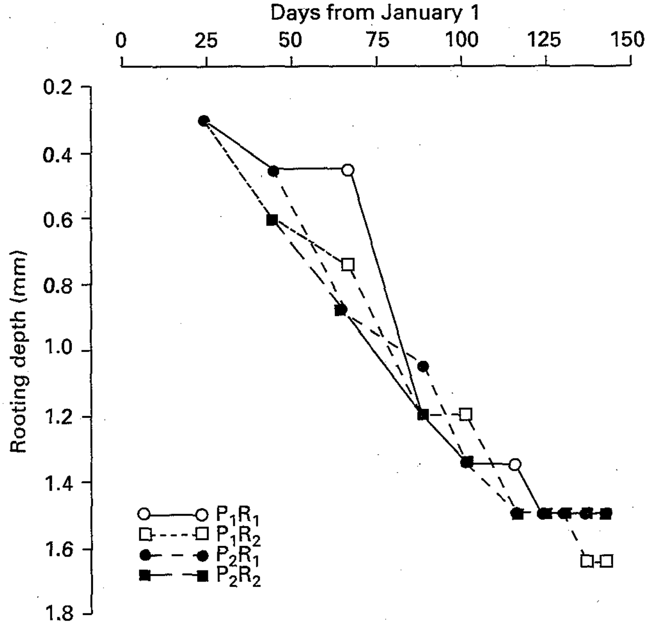

Fig. 3. Effective rooting depth (as indicated by the maximum depth of water extraction) at different growth stages of faba bean genotype ILB 1814, sown at 22 (P1) and 44 (P2) plants m^{-2}, and at 0.45 m (R1) and 0.225 (R2) row spacings, 1984/85.

Table 4. *Grain yield (t ha^{-1}), evapotranspiration (ET, mm) and water use efficiency (WUE, kg ha^{-1} mm^{-1} ET) of ILB 1814 grown at 22 (P1) and 44 (P2) plants m^{-2} and 0.45 m (R1) and 0.225 (R2) row spacings and seven other genotypes grown at 22 plants m^{-2} and 0.45 m spacing (P1R1), in 1984/85 and 1985/86*

		1984/85			1985/86		
	Treatment	Grain yield	ET	WUE	Grain yield	ET	WUE
ILB 1814	P1R1	1.77	281	6.3	0.92	239	3.8
ILB 1814	P1R2	2.69	293	9.2	1.82	244	7.5
ILB 1814	P2R1	2.50	298	8.4	1.45	242	6.0
ILB 1814	P2R2	3.33	303	11.2	1.96	253	7.7
80S 43856	P1R1	1.04	262	4.0	0.89	227	3.9
80S 44358	P1R1	1.46	280	5.2	0.81	221	3.7
80S 44367	P1R1	1.23	262	4.7	0.68	220	3.1
80S 44815	P1R1	1.33	269	4.9	0.68	228	3.1
80S 45057	P1R1	1.24	269	4.6	0.70	229	3.2
80S 64214	P1R1	0.84	239	3.5	0.97	233	4.2
80L 90121	P1R1	1.20	271	4.4	0.91	241	3.8

and high seed density. These practices encourage early canopy closure and an increase in the total amount of light energy intercepted and enable the crop to use water that would have otherwise evaporated from the bare soil. Early depletion of moisture from the upper soil surface layers probably encouraged deeper rooting and more efficient water extraction, leading to increased evapotranspiration. However, under favourable thermal regimes (as in 1986/87) and with adequate moisture (as in the irrigated treatment), there may be no grain yield advantages from sowing at a narrow row spacing or high density. Under favourable thermal and moisture regimes Hodgson and Blackman (1956) and Murinda and Saxena (1985) reported considerable plasticity in faba bean, with yields remaining unaffected by a wide range of row spacing and seed density combinations. In locations with adequate moisture supply and a long growing season, a wide row spacing and low seed density are therefore recommended.

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