Greenhouse Seed Production of Two Dwarf Green Bean Cultivars in Relation to the Duration of Irrigation

Ebrahim M. Khah¹

University of Thessaly, School of Agricultural Science, Department of Crop Production and Agricultural Environment, Fytoko Street, 38446 Nea Ionia, Magnesia, Volos, Greece

Konstantinos A. Akoumianakis and Harold C. Passam

Agricultural University of Athens, Laboratory of Vegetable Production, 75, Iera Odos, 118 55 Athens, Greece

Additional index words. *Phaseolus vulgaris* L., fertilizer, growth, water saving, environment

Abstract. As good quality irrigation water becomes increasingly scarce in the Mediterranean region, especially in coastal areas where greenhouses are located, methods of economizing water consumption are essential. Therefore, the effect of the duration of irrigation on the quality and yield of seed of two cultivars of dwarf green bean ('Larma' and 'Montano', *Phaseolus vulgaris* L.) was studied during fall and spring in Greece. Seeds were sown on 11 Sept. 2000 (fall crop) and 23 Feb. 2001 (spring crop) in peat compost and when the plants had two expanded leaves (11 and 20 days after sowing, respectively), they were transplanted to the soil of an unheated, plastic-covered greenhouse. The following irrigation treatments were applied: 1) irrigation for the entire duration (control), 2) irrigation until the first pods were dry, 3) irrigation until $\approx 50\%$ of the pods had filled, and 4) irrigation till flowering. Fall cultivation was not suitable for seed production due to low yield and reduced seed quality. By contrast, the spring crop had a higher yield, seed size and good germination. Stopping irrigation of the spring crop at the drying of the first pods achieved an $\approx 20\%$ saving in water without significantly affecting seed yield or quality. Earlier discontinuation of irrigation to achieve greater savings of water caused a reduction in yield, but did not affect seed quality.

In the countries of the Mediterranean basin, greenhouse crops are largely concentrated in coastal regions so as to benefit from the warm climate (Castilla, 1992; Olympios, 2002). In Greece, vegetable seed crops, especially those for the production of basic (foundation) seed, are also grown under cover to avoid pathological infections and contamination from cross-pollination (Saplaouras et al., 2001). As a result of intensive cultivation, the supply of water of a quality suitable for irrigation is limited (Antonopoulos, 1991; Kerkides et al., 1997), and because this problem is exacerbated in areas with large numbers of greenhouses, the introduction of desalinization units for water purification has been proposed (Olympios, 2002).

A lack of soil moisture during the flowering and pod growth of beans causes a reduction in yield, whereas irrigation before the flowering stage increases vegetative growth at the expense of flowering (Salter and Goode, 1967). Irrigation of runner beans, starting from the green flower-bud stage, increased yields of fresh pods by 36% in comparison with nonirrigated controls, but when irrigation was started just 1 week later (at the red flower-bud stage), the increase in yield was only 17% (Blackwall, 1963). In arid or semi-arid regions, irrigation during vegetative growth is especially benefi-

cial (George, 1985). Coyne et al. (1965) recommend three to four irrigations for field beans grown in Nebraska, with a total application of 30 cm water during a cool growing season and 40 cm in a hot season.

In the present paper, the effect of irrigation on the yield and quality of beans grown in a greenhouse for the production of seed was studied over a period of two seasons with the aim of determining at what stage of growth water saving could be achieved.

Materials and Methods

Two bean (*Phaseolus vulgaris* L.) cvs. Larma and Montano (dwarf cultivars grown for their fresh green pods) were cultivated for seed in the fall (sowing 11 Sept. 2000) and spring (sowing 23 Feb. 2001). The method used was as follows: 600 seeds of each cultivar were imbibed on moist filter paper and then sown 2 per bag in a commercial peat-based compost (Agrohum) contained in black plastic bags (5 cm in diameter). The plastic bags were placed in an unheated greenhouse. After germination (6 d after sowing), the plants were reduced to one per bag. Plants were transplanted to the soil of an unheated, plastic-covered greenhouse (without supplemental lighting) on 22 Sept. 2000 and 15 Mar. 2001 (11 and 20 d after sowing, fall and spring crops respectively), with 16 plots $\times$ 12 plants per cultivar being planted in double rows at a spacing of 15 $\times$ 30 cm with four border plants per plot. Trickle

irrigation was applied to all plants until the onset of flowering, but thereafter the plots were arranged in a completely randomized design with four replicates of each treatment receiving the following irrigation schedule: 1) irrigation until harvest (control), 2) irrigation until the first two to three pods had dried, 3) irrigation until $\approx 50\%$ of the pods had filled, and 4) irrigation until the start of flowering.

Plants were irrigated 2 to 3 times a week with 1.5 to 2 L water per plant, while the quantities of water consumed by evapotranspiration were estimated by weighing four 15-L plastic pots each containing two plants planted in soil, prior to and after irrigation. Pods were harvested from 1 Nov. until 5 Dec. 2000 (51 to 85 d from sowing, fall crop) and from 15 to 27 May 2001 (81 to 93 d from sowing, spring crop). The number and weight of pods and seeds were recorded. Seeds were tested for germination according to the ISTA rules (Anonymous, 1985). Results were tested for significance by analysis of variance and comparison of means by the least significant difference test ($p = 0.05$).

Results and Discussion

The vegetative growth of beans in the fall was faster than in the spring due to the higher temperatures during the first month after sowing (Table 1), and this resulted in earlier onset of flowering (35 to 37 d and 55 to 58 d, respectively). However, the progressive reduction in temperature and day length in the fall resulted in a longer period of pod maturation, and the duration of harvest was 34 d, in comparison with just 13 d in the spring. The fall cultivation of beans for seed required less irrigation than in the spring, which also related to the lower mean temperatures during the former (Table 1). On the other hand, the yield of dry pods and seed was less in the fall (Table 2) than in the spring (Table 3).

In both cultivations, discontinuation of irrigation when the first two to three pods had dried did not cause a significant reduction in the weight and number of pods or seeds per plant in comparison with the control (irrigated until harvest). Water shortage, especially during flowering, is known to reduce yield of seed and fruit (Salter and Goode, 1967), but discontinuation of irrigation at a stage when 50% of the pods had filled also caused a significant reduction in yield (Tables 2 and 3). Legumes respond positively to irrigation during pod swelling because the increased hydraulic conductivity will compensate for the reduced root growth at this stage (Salter and Drew, 1965). However, the present results show that irrigation after pod swelling is not necessary, therefore water saving can be achieved during the maturation period.

The lower seed yield of the fall crop resulted principally from a reduction in the number of pods per plant, but in 'Larma' the seeds of the fall crop were smaller in size (determined as the weight of 100 seeds) than those of the spring crop (Tables 2 and 3). Seed size and the number of seeds per pod of 'Montano' in the fall were only affected by irrigation when

Received for publication 30 Jan. 2003. Accepted for publication 7 July 2003.

¹Corresponding author; e-mail ekhah@agr.uth.gr.

Table 1. Evapotranspiration in relation to mean maximum and minimum air temperature during the fall and spring cultivation of bean cvs. Larma and Montano for seed. Irrigation was discontinued from 11 Nov. 2000 (2), 26 Oct. 2000 (3), and 16 Oct. 2000 (4) during the fall crop and from 15 May 2001 (2), 7 May 2001 (3), and 22 Apr. 2001 (4) in the spring crop.

Fall (weeks)	Temp (°C)		Evapotranspiration (kg·m ⁻² ·week ⁻¹)	Spring (weeks)	Temp (°C)		Evapotranspiration (kg·m ⁻² ·week ⁻¹)
	Max	Min			Max	Min	
2 Oct.	32	18	2.0	2 Mar.	22	11	---
3	30	15	4.6	3	32	11	---
4	28	15	5.1	4	35	12	---
1 Nov.	30	13	6.6	1 Apr.	36	12	8.9
2	25	9	6.3	2	32	13	6.9
3	26	13	5.1	3	33	11	4.9
4	22	11	4.4	4	34	15	8.8
1 Dec.	23	14	---	1 May	37	19	8.2
				2	38	19	8.4
				3	36	19	8.8
				4	39	21	7.5

²Not recorded.

Table 2. The effect of the duration of irrigation on the production of dry pods and seed by 'Larma' and 'Montano' during fall.

Treatment	Duration of irrigation (d ²)	Pods/plant (no.)	Seeds/pod (no.)	Seeds/plant (no.)	Wt of seeds/plant (g)	Wt of 100 seeds (g)	Germination (%)
Larma							
1	83	8.3 a ^y	4.1 a	34.2 a	6.3 a	18.3 a	81 a
2	68	8.1 a	4.0 a	32.2 a	6.2 a	19.4 a	71 a
3	44	4.8 b	3.4 b	16.1 b	2.9 b	18.1 a	55 b
4	34	2.4 c	2.1 c	5.2 b	1.0 b	19.2 a	52 b
Montano							
1	83	13.5 a	3.7 a	50.3 a	10.8 a	21.4 a	88 a
2	68	12.5 a	3.9 a	48.8 a	9.9 a	20.3 a	85 a
3	44	7.4 b	3.5 a	25.9 b	5.4 b	20.7 a	72 b
4	34	2.9 c	2.7 b	7.7 c	1.4 c	18.1 b	58 b

²Days from sowing for both cultivars.

^yMeans in the same column and variety followed by the same letter are not significantly different ($p = 0.05$) according to the least significant difference test.

Table 3. The effect of the duration of irrigation on the production of dry pods and seed by 'Larma' and 'Montano' during spring.

Treatment	Duration of irrigation (d ²)	Pods/plant (no.)	Seeds/pod (no.)	Seeds/plant (no.)	Wt of seeds/plant (g)	Wt of 100 seeds (g)	Germination (%)
Larma							
1	92	17.1 a ^y	3.9 a	66.2 a	18.4 a	27.9 a	98 a
2	80	15.8 a	3.9 a	61.5 a	15.8 a	26.1 a	90 a
3	72	10.6 b	2.9 b	30.9 b	7.2 b	24.2 b	95 a
4	57	8.1 b	3.3 b	27.0 b	6.0 b	21.9 b	95 a
Montano							
1	92	21.9 a	4.5 a	99.7 a	19.3 a	19.3 a	100 a
2	80	20.4 a	4.5 a	92.2 a	17.8 a	19.3 a	100 a
3	72	14.4 b	4.3 a	61.3 b	10.7 b	17.4 b	100 a
4	57	12.7 b	4.0 a	50.8 b	9.1 b	18.0 b	85 b

²Days from sowing for both cultivars.

^yMeans in the same column and variety followed by the same letter are not significantly different ($p = 0.05$) according to the least significant difference test.

it was stopped at the start of flowering (stage 4). The number of seeds per pod of 'Larma' declined when irrigation stopped at stages 3 and 4, but seed size was unaffected. In the spring, the seed size of both cultivars was reduced when irrigation ceased at stages 3 and 4, but the number of seeds per pod was affected only in 'Larma'. Seed germination of both cultivars was high (95% to 100%) during the spring crop irrespective of the duration of irrigation (Table 3). However, in the fall crop, the germination of seed was low, especially when irrigation was stopped at stages 3 and 4. Seeds that dry slowly within the pod continue developing and so their rate of maturation differs from that of seeds from pods that have dried quickly (Siddique et al., 1987), and immature seeds require a period of desiccation prior to

germinating in water (Dasgupta et al., 1982; Sanhewe and Ellis, 1996). It is likely that the low seed germination of the fall crop related to the slower rate of pod and seed maturation, as reflected by the longer harvest period. By contrast, pods and seeds of the spring crop dried rapidly and germination was high.

The saving of water achieved by stopping irrigation at stages 2 to 4 was 12%, 60%, and 80%, respectively, for the fall seed crop, and 20%, 40%, and 70% respectively for the spring crop. The fall cultivation of beans for seed cannot be recommended due to low yield and reduced seed quality (i.e., lower germination). By contrast, the spring crop produced almost double the amount of seed in comparison with the fall crop, and seed germination was high. Irrigation of the spring crop may be stopped at

the onset of drying of the pods (but not earlier) without a reduction of yield or seed quality. In this way a 20% saving in water consumption may be achieved. Economy of water use and the search for drought-resistant varieties are vital aspects for the future of agriculture, not only in Greece and other Mediterranean countries, but in other arid and semi-arid areas, e.g., southeastern Kenya (Shisanya, 2002).

Literature Cited

- Anonymous. 1985. International rules for seed testing. Seed Sci. Technol. 13:299–519.
- Antonopoulos, V. 1991. Degradation of streams water quality and irrigation return flow. Agr. Res. (Greece) 15:271–281.
- Blackwell, F.L.C. 1963. Factors affecting the set of runner bean pods. Rpt. for 1962, 49. Natl. Veg.

- Res. Sta., Wellesbourne, U.K.
- Castilla, N. 1992. Vegetable production under simple structures in southern Europe. I. Spain. Food Fert. Technol. Ctr. (Taipei, Taiwan) Ext. Bul. 348:1–8.
- Coyne, D.P., F.N. Anderson, A.F. Hagen, O.W. Howe, and M.L. Schuster. 1965. Field bean production in Nebraska. Booklet SB 486. Univ. Nebraska College of Agriculture and Home Economics.
- Dasgupta, J., J.D. Bewley, and E.C. Yeung. 1982. Desiccation-tolerant and desiccation-intolerant stages during the development and germination of *Phaseolus vulgaris* seeds. J. Expt. Bot. 33:1045–1057.
- George, R.A.T. 1985. Vegetable seed production, Longman U.K.
- Kerkides, P., C. Olympios, M. Psychoyou, and A. Lagoudaki. 1997. The effect of saline irrigation waters on crop growth and yield. In 'Water management, salinity and pollution control towards sustainable irrigation in the Mediterranean region'. Proc. Intl. Conf. MAI, Bari, Italy. IV:1–17.
- Olympios, C.M. 2002. Vegetables in Greece: Present situation and perspectives. Acta Hort. 579:31–36.
- Salter, P.J. and D.H. Drew. 1965. Root growth as a factor in the response of *Pisum sativum* L. to irrigation. Nature 206:1063–1064.
- Salter, P.J. and J.E. Goode. 1967. Crop responses to water at different stages of growth. Commonwealth Agr. Bureaux, Farnham Royal, U.K.
- Sanhewe, A.J. and R.H. Ellis. 1996. Seed development and maturation in *Phaseolus vulgaris*. I. Ability to germinate and to tolerate desiccation. J. Expt. Bot. 47: 949–958.
- Saplaouras, K., H.C. Passam, and I. Karapanos. 2001. Seed production of lettuce under plastic in a warm climate in relation to sowing time and gibberellic acid application. Plant Var. Seeds 14:15–23.
- Shisanya, C.A. 2002. Improvement of drought adapted tepary bean (*Phaseolus acutifolius* A. Gray var. *latifolius*) yield through biological nitrogen fixation in semi-arid SE Kenya. Eur. J. Agron. 16:13–24.
- Siddique, M.A., G. Somerset, and P.B. Goodwin. 1987. Time of harvest, prethreshing treatments and quality in snap bean (*Phaseolus vulgaris*) seed crops. Austral. J. Expt. Agr. 27:179–187.