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Irrigation, Fertilization, and Polyethylene Covers Influence Bud Development in Prickly Pear

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Abstract. **With the aim of inducing early cropping, the effects of irrigation, fertilization, and polyethylene covering on bud emergence were studied in a 1-year-old plantation of prickly pear (*Opuntia ficus-indica* Mill.) established on sandy soil in the western Negev desert of Israel. Interruption of either irrigation and fertilization (N, P, K) or of irrigation in winter reduced the number of floral buds per plant and slightly delayed their emergence when compared to plants receiving continuous irrigation and fertilization. Polyethylene covering placed over the plants from mid-February to the end of March induced early floral bud emergence associated with early flowering, but was accompanied by a significant decrease in the number of floral buds per plant.**

Prickly pear is a highly productive cactus cultivated on a small scale in tropical, subtropical, and warm-temperate regions for its fruit (Acevedo et al., 1983; Vessel, 1988). Recently, as demands for exotic fruits have increased, new plantations have been established in the Mediterranean region.

There is a wealth of technical information on the establishment and management of plantations (Alberghina, 1984; Barbera, 1984; Curtis, 1977; Portolano, 1969; Vessel, 1988), and some studies have been carried out on the effect of environmental factors on plant metabolism (Acevedo et al., 1983; Nobel and Hartsock, 1984). However, only a limited amount of research has been devoted to the effect of the environment on bud initiation and on vegetative and reproductive growth. In the Mediterranean region, the main flush of vegetative and reproductive growth starts in the spring (March–April), after the winter rest period (Portolano, 1969). Generally, floral and vegetative buds emerge from cladodes that have developed in the previous season. Flowering occurs 4 weeks after bud emergence. A late crop can be obtained by removing flowers and new cladodes at the end of the natural flowering period, which results in a new flush of floral and vegetative buds (Barbera, 1984; Portolano, 1969). Recently, growers have expressed an interest in an early fruit crop that demands high prices. Since certain fertilization and irrigation regimes, as well as covering with polyethylene, promote earlier flowering in other plants (Antonacci, 1986; Neumaier and Blessington, 1987; Nerd and Benzioni, 1988), we studied the effect of these treatments on the prickly pear.

Two experiments were conducted in 1987–88 on a plantation of the Israeli cultivar Ofer established on sandy soil at Moshav Yevul (western Negev desert of Israel) in Sept. 1986. Plants were spaced at 1.5-m intervals in rows 4 m apart. The height and diameter of the plants were 1.2 and 1.5, respectively, in Nov. 1987 (the beginning of the winter). The annual rainfall, which is restricted to winter, was 130 mm for 1987–88.

An average monthly irrigation of 30 mm between April and September and 15 mm between October and March was supplied via a drip system activated every 2nd day. Fertilizer was applied with water through the irrigation system at a concentration of 70 ppm N (NH_4NO_3 + KNO_3), 30 ppm P_2O_5 (H_3PO_4), and 70 ppm K_2O (KNO_3). The doses of the nutrients were as practiced in this region for other crops, such as grapes (*Vitis vinifera*).

The first experiment was designed to study the effect on bud emergence of interrupting the application of fertilizer with the irrigation water by use of the following treatments: 1) continuous year-round irrigation and fertilizer application (as explained above); 2) continuous irrigation and no fertilization between Nov. 1987 and mid-Mar. 1988; 3) continuous irrigation and no fertilization from Nov. 1987 onward; and 4) interruption of irrigation and fertilization between Nov. 1987 and mid-Mar. 1988. The period Nov. 1987 to mid-Mar. 1988 was characterized by retarded growth without bud emergence.

A randomized block design consisting of three blocks, each containing six plants per treatment, was used. Newly emerged floral buds were tagged each week in Spring 1988. When buds were 5 mm long, their number on each plant was recorded. Floral buds of this size are cylindrical and can be easily distinguished from vegetative buds, which are flat. The total number of new vegetative buds was recorded at the end of the period

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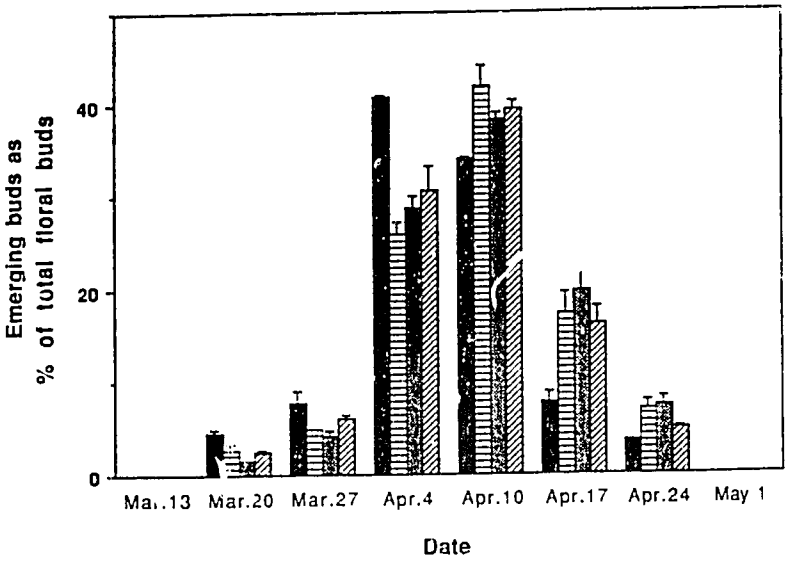

Fig. 1. Time course of floral bud emergence as percentage of total floral buds. Treatments: continuous irrigation and fertilization (■); continuous irrigation and interruption of fertilization between Nov. 1987 and mid-Mar. 1988 (▤); continuous irrigation and withholding of fertilization from Nov. 1987 onward (▦); interruption of irrigation and fertilization between Nov. 1987 and mid-Mar. 1988 (▨). Bars indicate SE.

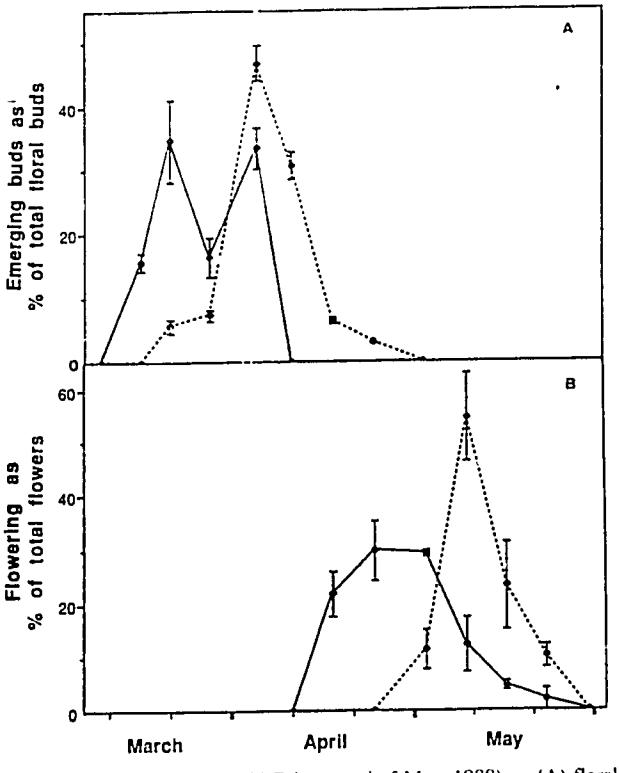

Fig. 2. Effect of polyethylene covering (mid-Feb. to end of Mar. 1988) on (A) floral bud emergence with time and (B) the time of flowering. Not covered (--●--), covered (—●—). Bars indicate SE.

of floral bud emergence. For water content determination, the upper parts of terminal full-grown cladodes was sampled in the afternoon from two plants in each replication and weighed before and after oven-drying for 48 hr at 70C. The same tissue was used for nutrient analysis. Total organic N content was determined according to Kjeldahl, NO_3 according to Szekely (1972), P according to Watanabe and Olsen (1965), and K by flame photometry.

In the second experiment, the effect of covering the plants with polyethylene on floral bud emergence and time of flowering was studied. While the control plants were left uncovered, the remainder were covered with clear polyethylene (UVA, 0.1-mm thickness) from mid-Feb. 1988 to the end of Mar. 1988, at which time anthesis started in the control plants. A randomized block design of three blocks was used, with four plants per treatment in each block. New floral and vegetative buds were recorded as for the first experiment. During the flowering period, the number of new flowers with fresh yellow petals was recorded once a week. This method of sampling ensured that flowers would not be counted more than once, since petals turn yellow 3 days before anthesis and brown 2 to 3 days after anthesis. Daily maximum and minimum temperatures were recorded at a height of 50 cm in each replication.

Irrigation and fertilization. The plants that received continuous irrigation and fertilization produced significantly more floral buds than the other three groups (Table 1). Plants that were not irrigated and were not given fertilizer during the rest and floral-emergence periods yielded significantly fewer floral buds than those in the other groups. The response of vegetative bud emergence to fertilization and irrigation also showed a similar trend to that of floral buds, but the differences were not significant.

Continuous irrigation and fertilization induced moderate, but significantly earlier, floral bud emergence than the other treatments (Fig. 1). The percentage of emerging floral buds in this group of plants was highest on 4 Apr. 1988 (41% of the total), whereas in plants of the other treatments, the number of new buds peaked 1 week later (38% to 41% of the total).

Table 2 presents the level of nutrients in cladodes sampled in mid-February before floral buds began to emerge. Nitrate, P, and K were measured for the whole sample, while the organic N level was determined in the chlorenchyma, considering the finding of Nobel (1983) that total N increases in this tissue with the activity of the plants. The NO_3 and K contents were highest in the continuously irrigated and fertilized plants, while both the total organic N and the P content did not differ significantly among the treatments (range 0.81% to 1.1% and 0.23% to 0.27%, respectively). The absence of a significant difference in total organic N content is in keeping with the lack of growth of the plants in winter.

In irrigated and fertilized plants, the relatively high levels of NO_3 and/or K in the cladodes appears to induce earlier and more massive floral bud emergence. No data are available regarding the response of nonirrigated plants to fertilizer, since fertilizer was applied exclusively through the irrigation system. Withholding irrigation in winter reduced the number of floral buds, although no significant differences in water content were determined among the treatments. The water content in the cladodes was consistently 92% to 94% of fresh weight in mid-Dec. 1987 and mid-Feb. and mid-Mar. 1988, although it may well be that our measurements were not frequent or sensitive enough to reflect changes of water status in the cladodes. According to our experiment, maintenance of soil moisture and fertility are important for flower production and, hence, high yields. It is possible that certain plantations that give good vegetative growth with poor flower production would benefit from irrigation and fertilization. In addition, we do not recommend inducement of early flowering by fertilization, since its effect on

Table 1. Effect of irrigation and fertilization on number of floral and vegetative buds. Cumulative results of counts through the end of Apr. 1988.

Treatment		No. buds per plant[z]	
Irrigation	Fertilization	Floral	Vegetative
Continuous	Continuous	266 a	86 a
Continuous	Interruption Nov. 1987 to mid-Mar. 1988	197 b	74 a
Continuous	Withheld from Nov. 1987	203 b	67 a
Interruption Nov. 1987 to mid-Mar. 1988	Interruption Nov. 1987 to mid-Mar. 1988	152 c	60 a

[z]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

Table 2. Nutrient levels in cladodes of plants subjected to various irrigation and fertilization regimes. Six plants per treatment were sampled in mid-February.

Treatment		Mean nutrient levels (dry-wt basis)[z]	
Irrigation	Fertilization	$N\text{-}NO_3$ (ppm)	K (%)
Continuous	Continuous	557 a	4.18 a
Continuous	Interruption Nov. 1987 to mid-Mar. 1988	297 b	3.38 b
Continuous	Withheld from Nov. 1987	300 b	3.02 b
Interruption Nov. 1987 to mid-Mar. 1988	Interruption Nov. 1987 to mid-Mar. 1988	321 b	3.24 b

[z]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

Table 3. Effect of polyethylene covering on number of floral and vegetative buds. Buds were counted at the termination of the spring bud emergence (end of Apr. 1988).

	No. buds per plant	
Treatment	Floral	Vegetative
Not covered	186[z] a	128 b
Covered	56 b	97 b

[z]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

the timing of flower bud emergency was not very pronounced.

Polyethylene covers. Plants covered with polyethylene for 6 to 7 weeks at the end of winter and beginning of spring produced fewer floral, but not vegetative, buds than control plants (Table 3), although the trend was similar.

Although inhibiting floral bud production, the polyethylene covering induced early emergence (Fig. 2A). For the covered plants, 53% of the floral buds had been counted by 20 Mar. 1988, by which time only 5.3% of the buds had emerged on the noncovered plants. A single distinct emergence peak was evident for the control plants, while the covered plants showed a two-peak pattern. Flowering was earlier and spread over a longer period of time in the plants that were covered than for the control plants (Fig. 2B). The early emergence and the inhibition of floral bud production can be attributed to the high temperatures under the cover. Average maxima and minima measured between mid-Feb. and the end of Mar. 1988 were 32.6 ± 4.2C and 9.1 ± 3C, respectively, for covered plants, and 23.3 ± 3.9C and 8.0 ± 3.1C, respectively, for noncovered plants. The average maximum and minimum April temperatures were 25.8 ± 1.5C and 12.0 ± 0.6C, respectively.

It appears that in the prickly pear some chilling is needed for differentiation of floral primordia and that the summer increase in temperature inhibits differentiation of new flower buds. Similarly, increased temperature enhances the development and emergence of buds that had differentiated before covering (i.e., mid-February in this experiment). Since other factors, such as fruit load or vegetative growth, may affect ripening, it is essential to determine whether early ripening also results.

Our data indicate that the application of polyethylene covering throughout the period of floral bud emergence, starting from the end of the rest period, causes reduction in the number of floral buds accompanied by early flowering. However, the yield reduction may not be an obstacle and may be beneficial in high-yielding plantations, since farmers usually thin the crop to obtain large fruits.

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