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Plant Response of Strawberry to Intra-row Spacing and Growing Conditions in South of Jordan

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Abstract: *Fragaria×ananassa*, is consumed fresh or used in making deserts and in food processing due to its high nutritive value. Thus, production practices for this crop have to be improved to meet the increasing demand for its fruits. A field study was carried out during 2010-2011 at Farah Private Farm, 25 km from Ma'am city in the southern part of Jordan to evaluate the growth of strawberries cv. Albion in response to 25 and 45 cm intra-row spacing. Small plants were transplanted early of March in rows or on raised-beds in a completely randomized block design and harvested in May. The results revealed that increasing intra-row spacing from 25-45 cm had favorable influence on biomass and growth characters of strawberries. Plants grown using 45 cm intra-row spacing recorded higher plant fresh weight (14.9 g), No. of leaves plant^{-1} (5.6) and leaves dry weight plant^{-1} (2.2 g) compared to plants grown using 25 cm intra-row spacing. Plants spaced 45 cm apart were also taller (14.7 cm) and had higher recent petiole length (8.7 cm). Strawberries spaced wide had higher total leaf area and thus are supposed to receive more light by their canopy than plants in close spacing. Flower and fruit characteristics of strawberries grown at 45 cm intra-row spacing were also enhanced compared to plants spaced 25 cm apart. The use of wide spacing had significantly increased fruits yield up to 17.4 g plant^{-1}. The study concluded that 45 cm intra-row spacing enhanced growth, plant biomass and fruit yield plant^{-1} of strawberries compared to 25 cm intra-row spacing.

Key words: *Fragaria×ananassa*, computer-controlled conditions, leaf area, light interception, open field, plant growth

INTRODUCTION

Strawberry plants (*Fragaria×ananassa*) are routinely cultivated in many countries around the globe (Putrasamedja and Asandhi, 1993; Vestberg *et al*., 2004; Milivojevic, 2005; Karajeh *et al*., 2012). This crop is increasingly gaining attention for consumers due to its high nutritional value. The fruits have been recorded to be a good source for compounds (e.g. phenolics and ascorbic acid) with antioxidant activity (Ferreyra *et al*., 2007). Therefore, strawberry is recently regarded as a high-value cash crop. In this sense, strawberries are used in agriculture for processing or sold fresh in wholesale markets, or along roadsides. The fruits are also used in dessert preparations.

Programs aiming at improving cultivation of strawberry have dealt with manipulation of agricultural practices like using organic or conventional farming systems (Camargo *et al*., 2011), microbial inoculation (Vestberg *et al*., 2004) and cultivation depth (Crisp and Beech, 1988).

Strawberries were produced using matted-row culture systems, from cold stored plants in spring in many countries including United States (Galletta and Bringhurst, 1990). However, in early nineties many farmers have adopted the plasticulture system and few of them used computer controlled-greenhouse with hanging-gutter cultivation systems. Production of strawberries under field conditions in small or medium Scale is still feasible in many countries where climate and soil conditions are suitable for the production of quality berries. The use of advanced technology is also the choice of overseas and large scale oriented production. On national scale the development of

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strategies for sustainable production of strawberries requires further research on the development of better agricultural practices in the field as well as efficient plasticulture techniques. This is true especially for developing countries where many farmers are not getting modern facilities. About 175 tons of strawberries are produced annually in Jordan as reported by producers and exports association for fruits and vegetables. This research was undertaken to investigate plant growth response of Strawberries cv. Albion under field conditions to intra-row spacing of 25 and 45 cm in rows or raised beds. The growth of strawberry in computer-controlled greenhouse is also illustrated.

MATERIALS AND METHODS

Plant material: Runners of Strawberry cv. Albion, obtained from the grower Ahmed Amer, were cold-stored for two weeks. Runners were allowed to root freely in small pots containing a mixture of perlite: Peat at (3:1) ratio for 40 days. Established small plants were transplanted on the 3rd of March in open field at Farah Private Farm in Ma'an district 25 km from Ma'an city. Soil in the cultivation site is silt clay with a pH of 8.3. Plants were grown in rows 100 cm apart. The experiment consisted of four treatments:

- Plants grown in rows with 25 cm intra-rows pacing (R25)
- Plants grown in rows with 45 cm intra-row spacing (R45)
- Plants grown on raised beds with 25 cm intra-row spacing (B25)
- Plants grown on raised beds with 45 cm intra-row spacing (B45)

Nutrient solutions were applied to the plants as described in Table 1. Plants were irrigated for one hr every three days using drip irrigation system. The mean annual temperature and total rainfall were 14.5°C and 167.7 mm during the growing season (Source: Hashemite Kingdome of Jordan Meteorological Department).

Treatments were replicated three times in a completely randomized block design. Observations were recorded on four plants from each replication 70 days after transplanting. Fruits were separated from the rest of the plant at harvest. The fresh and dry weight of plants and shoots were recorded. Data also included total weight of leaves plant^{-1} (on dry weight bases), plant height, average root depth, petiole length of the most recent leaf, No. of leaves plant^{-1} and leaf area. The flower and fruit characteristics were also recorded. Pooled data from the growing seasons 2010-2011 were analyzed with a general linear model using the Statistical Analysis System (SAS, 2001) and Least Significant Difference (LSD) test at 5% probability level was applied to compare the treatment means. Some of the irrigation pipes watering plants grown in B45 had leakage in the first growing season of 2010 and thus data from this treatment was excluded from the results.

Computerized innovative system: Small plants were also transplanted in greenhouse under computer-controlled environmental system at the experimental site. Plants were grown in hanging alternate plastic pipes (hanging gutters: HG) at a spacing of 25 cm between plants. Flowers and small fruits were thinned two weeks after planting date followed by thinning every forty days to give higher fruit fresh weight plant^{-1}. Plants were subjected to 25/15°C day/night temperature regime and about 40-45% relative humidity. Nutrients were applied every two weeks at the rates shown in Table 2. The electrical conductivity (EC) of the growth medium was within 1.2-1.7 dS m^{-1}. The pH of the nutrient solution was adjusted to 5.5. Plant growth of strawberries was measured 70 days after transplanting. These observations were not considered statistically, but were included along with that of the field experiment to illustrate how strawberry plants perform under different growing systems.

Table 1: Nutrient solutions applied to strawberry plants grown in farah private farm

Fertilizer	Rate of application	Date of application
Ammonium nitrate (NH_4NO_3) (g L^{-1})	43.3	17 March
Urea phosphate (g L^{-1})	43.3	17 March
Zinc sulphate (g L^{-1})	21.7	29 March
Iron (g L^{-1})	2.2	28 March
Humic acid (% (v:v))	1	7 April
KAPP (Potassium ammonium poly phosphate) (% (v:v))	5	29 April
Magnesium nitrate (g L^{-1})	43.3	15 May
Calcium nitrate (g L^{-1})	21.7	18 May
Potassium nitrate (g L^{-1})	43.3	22 May

Table 2: Nutrient solutions applied every two weeks to strawberry plants grown in Al Hashlamone private farm

Fertilizer	Rate of application
Calcium nitrate (g L^{-1})	50
Potassium nitrate (g L^{-1})	27.5
Monopotassium phosphate (g L^{-1})	27.5
Iron (g L^{-1})	2.5
Magnesium sulphate (g L^{-1})	12.5
Zink sulphate (mg L^{-1})	80
Manganese sulphate (mg L^{-1})	50
Molybdenum (mg L^{-1})	5
Copper sulphate (mg L^{-1})	7.5
Boric acid (mg L^{-1})	150

RESULTS

Field experiment

Weight characteristics: Plants grown in R45 and in B25 treatments recorded significantly higher fresh and dry weight for the whole plant, shoot and root compared to plants grown in R25 (Fig. 1a-f). The highest fresh weight for plant, shoot and root were 14.9 (R45), 11.5 (B25) and 3.8 g (R45), respectively. However, plants grown in R45 and B25 were on the same level of significance for fresh and dry weight of the whole plant, shoot and root.

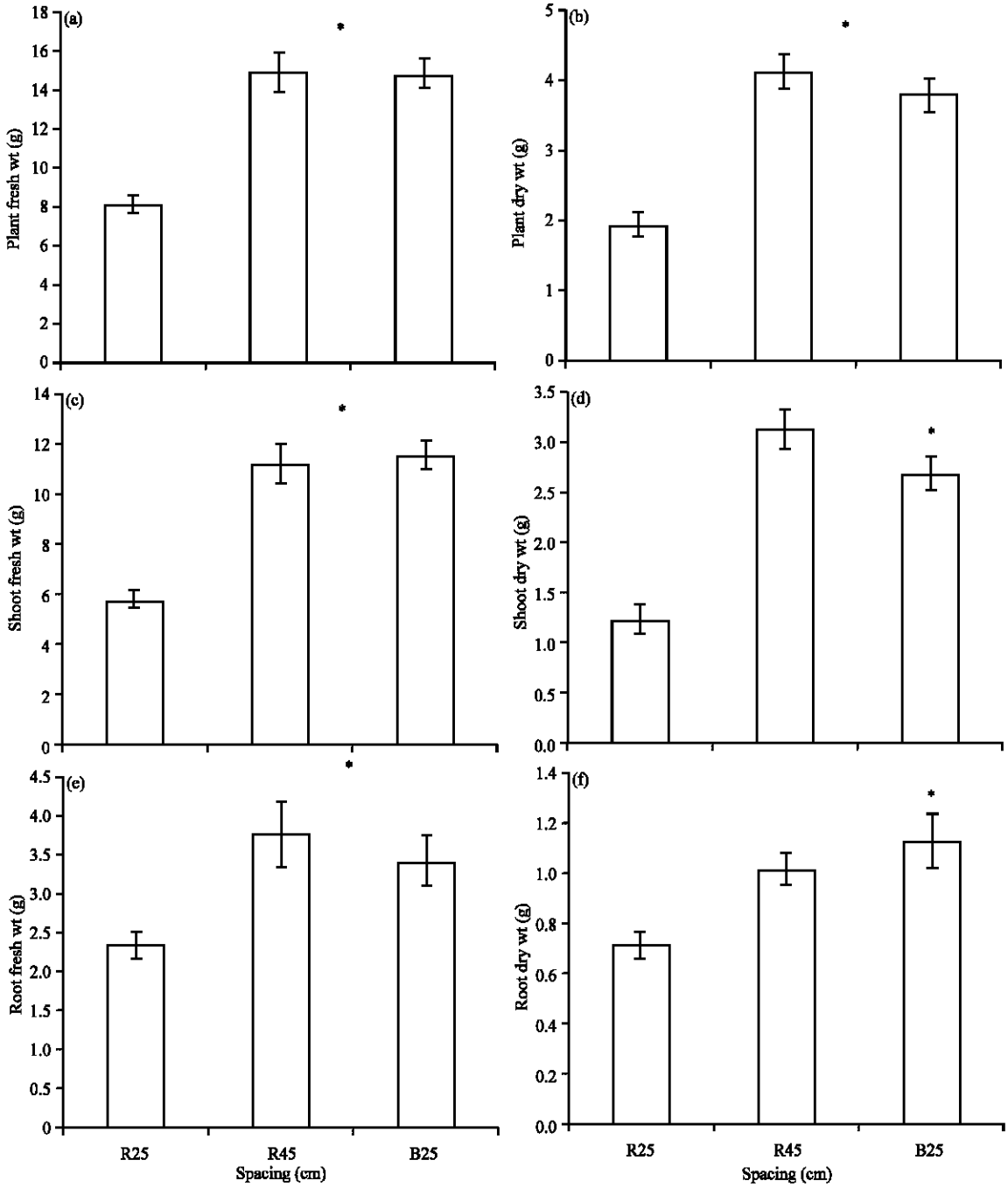

Fig. 1(a-f): The effects of intra-row spacing (R25, R45 and B25) on, (a) Plant fresh weight, (b) Plant dry weight, (c) Shoot fresh weight, (d) Shoot dry weight, (e) Root fresh weight and (f) Root dry weight of strawberry 'cv. Albion' cultivated at Farah farm in the southern part of Jordan, Strawberries were harvested 70 days after transplanting date *Means (R25, R45, B25) are significantly different at $p<0.05$

Growth characteristics: Plants grown in R45 and B25 treatments were significantly taller (14.7 and 15.1 cm, respectively) than plants grown in R25 (11.1 cm) (Fig. 2a). However, the effect of spacing in rows or raised beds was not significant for average root depth (Fig. 2b). Petiole length was significantly higher in R45 (8.7 cm) and B25 (8.7 cm) than in R25 (7.2 cm) (Fig. 2c). No. of leaves plant^{-1} was significantly the highest in B25 (6.1) and the lowest in R25 (4.7) (Fig. 2d). Leaf area was significantly the highest for plants grown in R45 (60.0 cm^2) and lowest

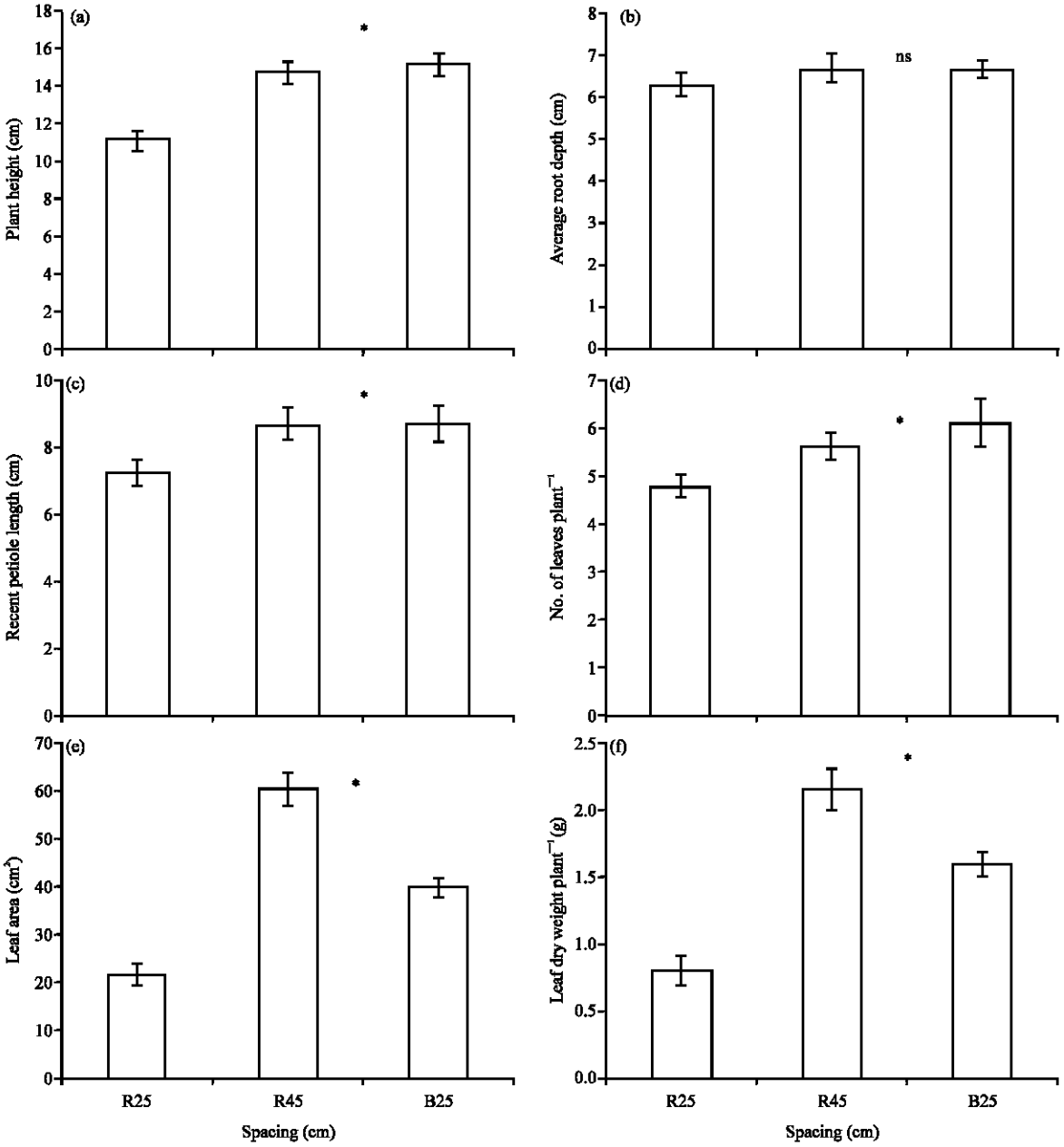

Fig. 2(a-f): The effects of intra-row spacing (R25, R45 and B25) on the following growth characteristics of strawberry 'cv. Albion' cultivated at Farah farm in the southern part of Jordan (a) Plant height, (b) Average root depth, (c) Petiole length of the most recent leaf, (d) No. of leaves plant^{-1}, (e) Leaf area and (f) Total dry weight of leaves plant^{-1}, Strawberries were harvested 70 days after transplanting date, *Means (R25, R45, B25) are significantly different at $p<0.05$, ^{ns}Means (R25, R45, B25) are not significantly different at $p<0.05$

for plants grown in R25 (21.3 cm^2) (Fig. 2e). Leaves total dry weight plant^{-1} was 0.8, 2.2 and 1.6 g for plants grown in R25, R45 and B25 in that order respectively (Fig. 2f).

Flower and fruit characteristics: Numbers of flowers and fruits plant^{-1} ware significantly the highest in R45 (5.3 and 3.7, respectively) (Fig. 3a, b). Plants grown in R25 and B25 were on the same level of significance for numbers of both flowers (4 and 4.2, respectively) and fruits (1.4 and 1.8, respectively) plant^{-1}. Average fruit fresh weight and fruits total fresh weight plant^{-1} were significantly the highest in R45 (5.1 and 17.4 g, respectively) (Fig. 3c, d). However, plants grown in R25 recorded significantly the least fruit yield with only 1.0 g fruit fresh weight plant^{-1}. Plants grown in B25 had significantly the highest inflorescence length (4.6 cm) (Fig. 3e). Inflorescence length was 3.8 and 3.7 cm for plants grown in R25 and R45, respectively. The highest fruit length was significantly recorded in plants grown in R45 (3.2 cm) and the lowest fruit length was significantly recorded in R25 (1.3 cm) (Fig. 3f).

Computer controlled greenhouse

Biomass and growth characteristics: Plants grown in HG in computer-controlled green-house showed substantial growth with whole plant, shoot and root fresh weights of 195.0, 135.7 and 59.3 g, respectively (Table 3). The corresponding dry weights for whole plant, shoot and root in plants grown in HG were 24.0, 11.4 and 12.6 g, respectively (Table 3a). Plants grown in HG under green-house controlled environment were taller with higher No. of leaves plant^{-1} than plants grown in open field (Table 3a). Plants in HG had also leaves with taller petioles and were higher for leaf area and total dry weight of leaves plant^{-1} compared to plants grown in open field (Table 3a).

Table 3: Plant growth response of strawberry 'cv. Albion' grown under computer-controlled greenhouse in Al Hashlamone private farm

Trait	Mean
(a) Biomass and growth characteristics	
Plant fresh weight (g)	*195±10.0
Plant dry weight (g)	24.0±2.9
Shoot fresh weight (g)	135.7±8.4
Shoot dry weight (g)	11.4±0.6
Root fresh weight (g)	59.3 ±8.8
Root dry weight (g)	12.6±2.8
Plant height (cm)	26.6±1.4
Root depth (cm)	15.1±0.8
Petiole length of most recent leaf (cm)	15.7±1.7
No. of leaves plant^{-1}	8.8±0.9
Leaf area (cm^2)	148.9±18.7
Leaves total dry weight plant^{-1} (g)	6.6±0.7
(b) Inflorescence and fruit characteristics	
No. of flowers plant^{-1}	4.3±0.4
No. of fruits plant^{-1}	3.4±0.8
Average Fruit fresh weight (g)	7.9±0.9
Fruits total fresh weight plant^{-1} (g)	23.8±4.0
Inflorescence length (cm)	11.7±1.1
Fruit length (cm)	3.9±0.2

*The results are the Mean±SD error

Inflorescence and fruit characteristics: With the exception of the No. of flowers and fruits plant^{-1}, the fruit and growth parameters were higher in controlled-environment HG grown plants than in field grown plants (Table 3b). Controlled-environment grown plants had average fruit fresh weight and total fruits fresh weight plant^{-1} of 7.9 and 23.8 g, respectively (Table 3b).

DISCUSSION AND CONCLUSION

The response of strawberries 'albion' to intra-row spacing was studied in South of Jordan. Increasing intra-row spacing from 25 to 45 cm had favorable effects on the biomass and growth characters of strawberries grown in rows under field conditions. These results are in agreement with those of Milivojevic, 2005, who reported that planting distances of 30×30 and 40×30 cm enhanced vegetative growth of strawberries 'Marmolada' and 'Elsanta' compared to the smaller planting distances of 15×30 and 20×30 cm. The results of the present finding showed that strawberries grown in R45 had higher leaf area, No. of leaves plant^{-1} than strawberries grown in R25. Therefore, strawberries grown in wider spacing are supposed to receive more light by their photosynthetic leaves than strawberries grown in closer spacing due to their higher canopy total leaf area. Thus, strawberries grown in wider spacing as shown in the present study accumulated more biomass in their leaves compared to strawberries grown in closer spacing. Abdel-Mawgoud *et al.* (2010) related the increase in growth of strawberries, as indicated by the increment in dry weight and yield components, to higher photosynthesate production that resulted from increasing leaf area and No. of leaves. The increase in the vegetative growth of strawberries grown in R45 compared to strawberries grown in R25 in the present study was further reflected on better flower and fruit characteristics. In this respect, strawberries grown in R45 had significantly higher No. of both flowers and fruits plant^{-1} compared to strawberries grown in R25. Furthermore, fruit characteristics like single fruit fresh weight, total fruits fresh weight plant^{-1} and fruit length were significantly higher for strawberries grown in R45 than strawberries grown in R25.

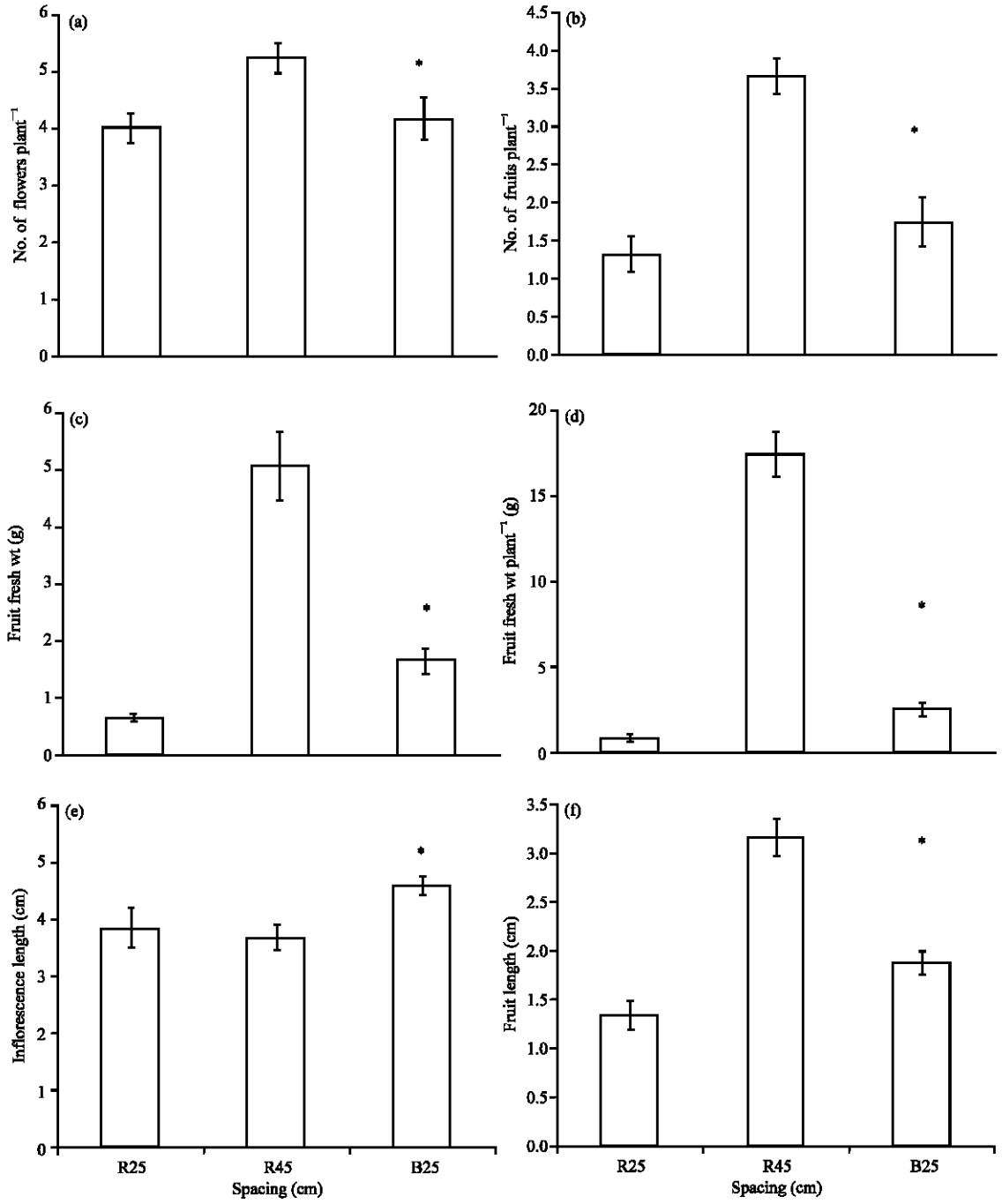

Fig. 3(a-f): The effects of intra-row spacing (R25, R45 and B25) on, (a) No. of flowers plant^{-1}, (b) No. of fruits plant^{-1}, (c) Average fruit fresh weight, (d) Total fresh weight of fruits plant^{-1}, (e) Inflorescence length and (f) Fruit length of strawberry 'cv. Albion' cultivated at Farah farm in the southern part of Jordan. Strawberries were harvested 70 days after transplanting date, *Means (R25, R45, B25) are significantly different at $p<0.05$

The response of strawberries in the field differed between plants grown in rows and those grown on raised beds. Strawberries grown using 25 cm intra-row spacing showed a better performance on raised beds than in rows under field conditions. Growing plants on raised beds was reported to increase water use efficiency (Akbar *et al*., 2009), control disease incidence and severity (Maloney *et al*., 1993), stimulate microbial activity in soil

rhizosphere and thus increase available nutrients for plants (Zhang *et al*., 2012). In fact, plants in B25 were significantly comparable to plants grown in R45 for fresh and dry weight of plants, plant height, petiole length and No. of leaves plant^{-1}. However, strawberries grown in R45 had significantly higher No. of flowers and fruits plant^{-1}. Moreover, strawberries in R45 had higher yield as shown by the higher fruits fresh weight plant^{-1} compared to strawberries in B25. The better performance of strawberries grown in R45 compared to strawberries in B25 can be explained by the higher total leaf area of plant canopy in R45 in comparison to strawberries in B25. The results of the present finding also showed that leaves formed higher proportion of the plant's body on dry weight bases in strawberries grown in R45 than in B25. It is thus possible that leaves of strawberries grown in R45 had provided higher assimilates to the reproductive organs compared to strawberries in B25 which may provide an explanation to the higher yield of strawberries grown in R45.

The present investigation also showed an example of growing strawberries 'albion' using HG under computer-controlled greenhouse in South of Jordan. Strawberries were spaced 25 cm apart under both controlled temperature and humidity. Plants in this model were collected after 70 days and showed higher growth response than plants grown under field conditions. However, harvesting of strawberries by the grower using this system in real practice began 30 days after planting date. Then strawberries were harvested every three days in summer and every ten days in winter. The total annual yield of strawberries under this system was 250 to 500 g of fruits fresh weight plant^{-1}. Generally, growing horticultural crops in computer-controlled greenhouse using HG results in higher yields and product quality with a reduced consumption of water and fertilizers than growing plants under field conditions. This system requires also less labor and, thus, production using this system can be the choice of International horticultural growers despite the high initial cost.

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