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Modification of Microclimate for Better Growth and Develop of Summer Tomato Crop

Asma A. M. Makeen[1] , Habiballa A. Mohamed[1] and Sadig Omara[2]

[1]Faculty of Agricultural Sciences, University of Gezira, Wad Medani, Sudan.
[2] Ministry of Agriculture and Forestry, Khartoum, Sudan.

ABSTRACT

Tomato cultivars grown in Sudan are affected by the hot dry summer climate and are highly susceptible to Tomato Yellow leaf Curl Virus disease (TYLCV). Modification of the microclimate may decrease the effects of the hot dry conditions and improve development and yield of summer tomatoes. The present study was conducted ducted during the summer of 1998 and 1999 at the Gezira University Farm, Wad Medani, Sudan, to investigate the effects of two type of shelterbelts (Abusabeen and pigeon pea) and two irrigation intervals 3)and 7 days) on growth and development of five tomato cultivars (Omdurman, Gezira 96, Summerset 98, Strain B and Peto 86). The results showed that the short irrigation interval was effective in reducing the air temperature compared to long irrigation interval Abusabeen shelter coupled with the short irrigation interval was effective in improving the microclimate, and that the pigeon pea shelter was effective in conserving soil moisture content under the two irrigation intervals. Tomato cultivars Omdurman, Gezira 96 and Summerset 98 had more vigorous growth, larger canopies and low percentage of. flower shedding per plant within the two types of shelters under the shorter irrigation interval compared to both long irrigation interval and the control.

INTRODUCTION

Tomato (*Lycopersicon esculentum*. Mill) is one of the most popular and widely grown vegetables in the world where 45 million metric tons of tomato are produced each year from 2.2 million hectares of which 15% is produced in the tropics (Villareal, 1980). This is mostly due to its acceptable flavour and high nutritive value. The fruit is also a good source of vitamins A, B and C and minerals. Tomato is grown under various conditions, including open fields, protected plastic greenhouses and heated glasshouses. Despite its wide adaptation through genetic variability, field production of tomato in the tropical and sub-tropical regions is restricted to the cooler seasons of the year. The production of the crop in summer season faces some serious challenges. High temperature is the main factor that limits or prevents field production of tomato during the summer seasons in many regions of the world. Temperatures greater than $34/29^0$C (day/night) or 4 hours treatment at 40^0C, 9 days before anthesis, usually causes blossom drop (Elahmadi and Stevens, 1979).

Temperatures as high as 45^0C and relative humidity as low as 10% could lead to low photosynthetic rates, poor carbohydrates reserves، non viability or high mortality of pollens, reduced style elongation، failure of pollen grain to germinate due to dry stigmatic surface، failure of germ tube to reach and fertilize ovules, flowers and fruit shedding and poor quality fruits due to sun scald and reduced fruit size (Abdalla and Verkerk, 1968). The end result is usually poor yields or total crop failure and this is especially true if the crop is also attacked by the leaf curl virus early in the season.

In the Sudan, the tomato is a major salad crop and widely used in the processed form as tomato paste, ketchup and sauce. The crop represents one of the main cash vegetable crops and ranks second to onion in terms of cultivated area. Winter is the main season of production of the crop. However, as an off-season crop, tomato is produced during summer and autumn. Farmers in the tropics، therefore, have developed several methods of influencing microcli. -mate so as to improve the conditions under which the crop can grow. Shelterbelts are used to modify the microclimate to protect plants from the desiccating dry winds and high temperature To minimize excessive heating of the soil around the root system and to increase air humidity and reduce temperature, some farmers shorten the irrigation intervals.

The present study aims at investigating the effect of shelterbelts and irrigation intervals on the performance of some tomato cultivars during summer season.

METHODS AND MATERIALS

Site and climate

The research was conducted at the Gezira University Experimental Farm, Lat. $14^0$24' N, Long. 33^0 29' E, wad Medani, Sudan. The area falls within the dry zone with a short rainy season (July to September) where, the average annual rainfall is about 300 mm, the mean air temperature is 29˚ C, the mean relative humidity is 39% and the annual evaporation is about 2500mm year-I (Adam, 1998). The soil is heavy، alkaline, with 50% clay, 28% silt, 13% fine sand, 9% coarse sand and has very low water permeability. It is low in organic matter (0.5%) deficient in nitrogen (300-400 ppm) and low in available phosphorous

Experimental layout and treatments

The experiment was conducted during the summer seasons of 1998 and 1999 to investigate the performance of the tomato cultivars: Omdurman, Gezira 96, Peto 86 and Strain B (Peto Seed Company, USA) in the first season and Omdurman, Gezira 86, Peto 86 and UG Summerset 98 (National Institute for Promotion of Horticultural Exports, University of Gezira, Sudan) in the second season. These cultivars were compared under three different microclimates hereafter referred to as environments (two types of shelters and a control) and under two irrigation intervals (3 and 7 days). These treatments were arranged in a split-split plot design with three replications where the environments were allotted to the main plots with an area of 55.5x13xm^2 each. Irrigation intervals represented by the sub-plots with an area of 27.7x13m^2 each, and the tomato cultivars represented by the sub-sub plots with an area of 5.0x13m^2 each.

A margin of 2 meters width was left between the main plots and 4 meters width between the sub-plots to avoid the interaction between the watering treatments. Two types of shelter crops were used: Sorghum bicolor (Abusabeen) and Cajanus cajan (pigeon pea). Abusabeen and pigeon pea seeds were sown at a rate of 3 seeds per hole and a spacing of 15cm between holes and 30cm between rows. The seeds were obtained from the local market and were planted l5 days ahead to the sowing of the tomato crop in order to provide a shelter to crop at its early stages of growth. Irrigation was carried out immediately after sowing. Abusabeen shelter was regularly chopped to maintain the required height of one to two meters. The seeds of the four tomato cultivars were sown on the 15th of April in the two seasons. Seeds were directly sown in beds at a rate of one kg/ha، at 5 seeds per hole, and at a spacing of 25 cm between holes. Plants were thinned after one month to about 2 to 3 plants per hole. Nitrogen and phosphorus were applied at the recommended rates. The crop was manually weeded throughout the season. The control of TYLCV was done by spraying the vector (*Bemisia tabaci* Genn) using the insecticides Danitol and Sumicidine at the recommended dose of 0.7 liter of insecticide per hectare every week.

Data collection

Physical measurements

a) Maximum and minimum air temperatures were measured using a CASELLA type thermohygrograph. Day and night temperatures were 1998obtained from the chart.
b) Relative humidity (RH%) was measured using dry and wet bulb thermometers and also the data were obtained from the chart of the d thermohygrograph especially for day and night RH.%
c) Evaporation was measured using a Piche tube read at 8:00 am (local time). All of the above instruments were fixed in the center of each sub-plot in the Stevenson's screen at the height of 1 m from the soil surface.
d) Soil temperature was measured four times a day, at 6:30, 12:00، 14:.00 and 18:30 (local time) at 5 cm depth, using mercury in glass thermometer.
e) Soil moisture was determined using the gravimetric method in the layer 0-20 cm and 20-40 cm at randomly selected three points in each sub plot.

Biological measurements

a) Dry weight (g): A sample consisting of three plants was randomly harvested from each sub-sub plot after one month from sowing and repeated every 15 days. The whole material was oven dried at a temperature of 85^0C for 48 hrs, until a constant weight was reached and recorded as the dry weight of the sample.

b) Leaf area was measured as an average for the above mentioned three plants, using a leaf area meter, model DELTA-T DEVICES LTD, and leaf area index was calculated as the product of the mean leaf area per plant and the number of plants per square meter divided by the ground area.

c) Plant height (cm): Measurements were taken as an average of another set of three plants which were randomly chosen from each sub-sub plot and labeled.

d) Percentage of the flowers shed/plant: Number of shed flowers in each of the three plants mentioned in (c) was calculated and related the total number of flowers in the plant and then the average was obtained for three plants.

RESULTS AND DISCUSSION

Modification of the thermal environment

Reduction of the maximum air temperature: The maximum air temperature was reduced in the control, pigeon pea and Abusabeen shelters under the short irrigation intervals compared to that under long irrigation intervals. However, the Abusabeen sheltered area under the long irrigation interval recorded higher values of maximum temperature compared to other treatments (Table 1). The Abusabeen sheltered area recorded significantly lower temperature, compared to all other treatments under the short irrigation conditions. The lowest night time temperatures were also recorded in the sheltered area under the short irrigation interval. These results were in agreement with Van Eimern *et al*. (1964) and Rosenberg (1974).

Table 1. Effects of shelterbelts and irrigation intervals on the maximum air temperature (^{o}C).

Season	1998			1999		
Treatments	Open	Pigeon Pea shelter	Abusabeen shelter	Open	Pigeon Pea shelter	Abusaeen shelter
Irrigation interval(7days) 20 — 30 April (10 days)	42.2	41.8	41.8	43.2	36.8	41.8
May (31 days)	39.3	38.6	40.4	38.5	36.4	39.7
June (30 dayS)	38.3	37.2	39.5	37.5	35.5	38.5
I — 20 July (20 days)	34.8	34.5	36.5	35.4	37.4	34.4
Mean	38.7	38.5	39.5	38.7	36.8	38.6
Irrigation interval(3days) 20 — 30 April (10 days)	42.0	41.5	41.7	44.3	43.2	43.2
May (31 days)	38.9	36.5	36.5	37.6	35.7	36.5
June (30 days)	35.9	36.7	35.5	35.1	34.5	32.7
I — 20 July (20 days)	32.8	32.7	31.8	33.8	32.3	31.1
Mean	37.4	36.9	41.7	37.7	36.4	35.9

Reduction of soil temperature: The lowest values of the average maximum soil temperature were observed in the sheltered areas under the short irrigation interval compared to both the sheltered area under the long irrigation interval and the open areas in both seasons (Table 2) This result is in agreement with Allen *et al*. (1998) who reported that when the interval between irrigations became large, the ability of the soil to conduct moisture near the surface became less and this influenced soil evaporation as well as soil temperature.

Table 2. Effects of shelterbelts and irrigation intervals on the maximum air temperature (˚C)

Season	1998			1999		
Treatments	Open	Pigeon Pea shelter	Abusabeen shelter	Open	Pigeon Pea shelter	Abusabeen shelter
Irrigation interval(7days)						
May (31 days)	39.3	38.6	40.4	38.5	36.8	39.7
June (30 dayS)	38.3	37.2	39.5	37.5	36.4	38.5
I — 20 July (20 days)	34.8	34.5	36.5	35.4	35.5	34.4
Mean	38.7	38.5	39.5	38.7	37.4	38.6
Irrigation interval (3days)	42.0	41.5	41.7	44.3	43.2	43.2
20 — 30 April (10 days)						
May (31 days)	38.9	36.5	36.5	37.6	35.7	36.5
June (30 days)	35.9	36.7	35.5	35.1	34.5	32.7
I — 20 July (20 days)	32.8	32.7	31.8	33.8	32.3	31.1
Mean	37.4	36.9	36.1	37.7	36.4	35.9

Conservation of soil moisture: Soil moisture content was higher in the sheltered areas compared to the open areas and this holds for both irrigation intervals and seasons (Figures la and b and 2a and b). This result was in agreement with Rosenberg (1974). The differences between the percentage of soil moisture content of the sheltered and the open areas ranged from 1% to 15%, and the percentage of soil moisture content within the pigeon pea sheltered area exceeded that of Abusabeen sheltered area by 1% to 11%. This was attributed to the high density of the pigeon pea shelter near the soil surface compared to Abusabeen, and hence more coverage and effectiveness in conserving the soil moisture content. Figures 2a and b show that the soil moisture was greater at 20-40 cm depth in all treatments. This was

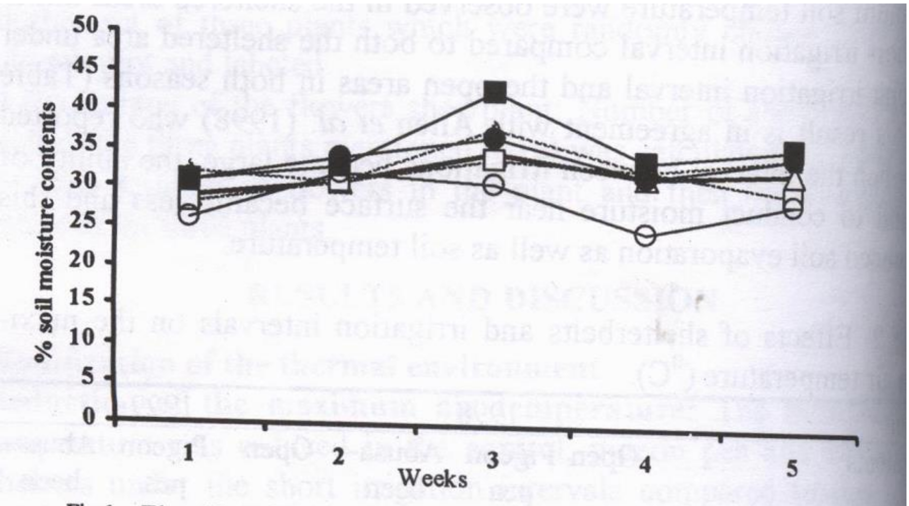

Fig.1a. The effect of shelters of Abusabeen(triangles)and pigeon pea (circles)on the % of soil moisture of the profiles 0-20(open symbols)and 20-40cm (closed symbols) compared to the open (squares) under the short irrigation for season 1998.

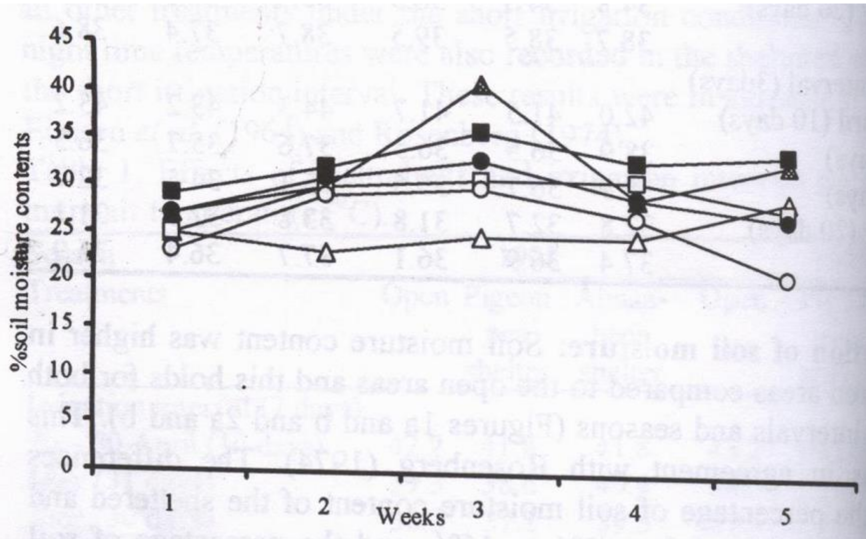

Fig.1b. The effect of shelters of Abusabeen(triangles)and pigeon pea (circles)on the % of soil moisture of the profiles: 0-20 cm (open symbols) and 20-40 cm (closed symbols) compared to the open(squares) under long irrigation interval for season 1998

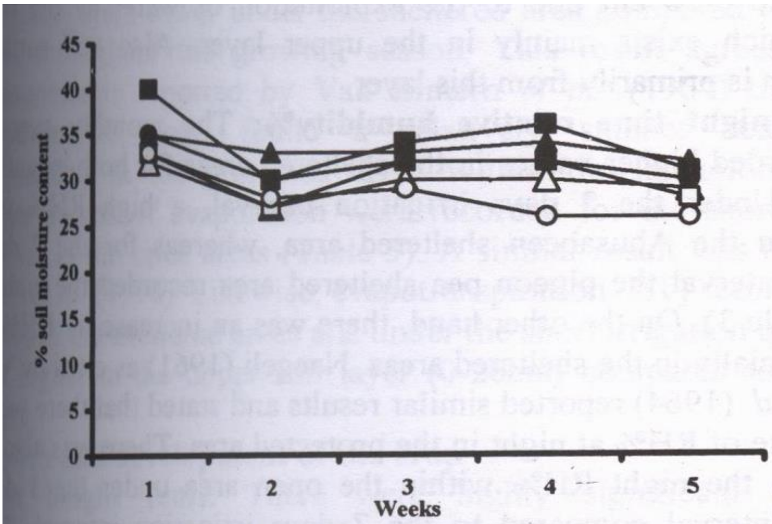

Fig.2a. The effect of shelters of Abusabeen(triangles) and pigeon pea (circles) on % soil moisture of the profiles 0-20 (open symblos) and 20-40 cm (closed symbols) compared to the open (squares) under the short irrigation interval for season 1999.

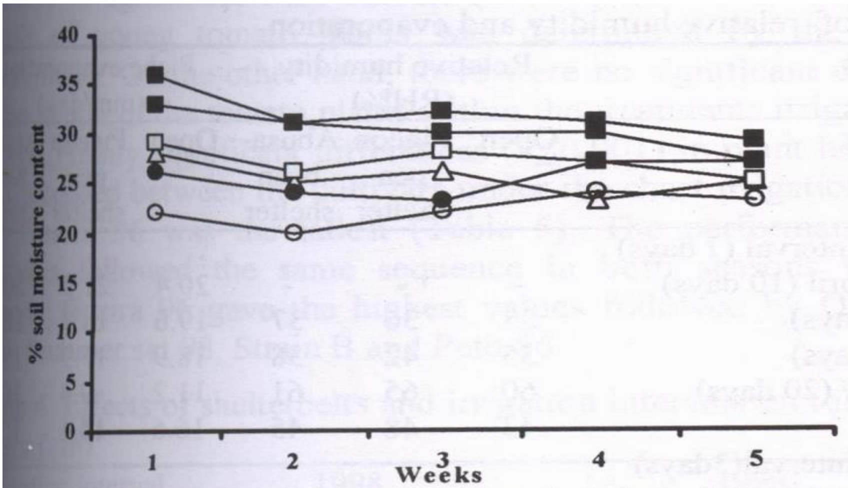

Fig.2b. The effect of shelters ofAbusabeen (traingles) and pigeon pea (circles) on the % soil miosture of the profiles 0-20 (open symbols) and 20-40cm (closed symbols) compared to the open (squares) under the long irrigation interval for season 1999.

mainly due to the higher rate of evapotranspiration from the upper layer of the 0-20 cm due to the exploitation of water by the root system which exists mainly in the upper layer. Also soil surface evaporation is primarily from this layer.

Day and night time relative humidity%: The monthly average RH% recorded higher values in the sheltered areas for both irrigation intervals. Under the 3 days irrigation interval, a high RH% was observed in the Abusabeen sheltered area, whereas for the 7 days irrigation interval the pigeon pea sheltered area recorded the highest RH% (Table 3). On the other hand, there was an increase in RH% at night, especially in the sheltered areas. Naegeli (1961) as cited by Van, Eimern *et al.* (1964) reported similar results and stated that there was a higher value of RH% at night in the protected area. There was also increase in the night RH% within the open area under the 3 days irrigation interval compared to the 7 days irrigation interval. This result agrees with the findings of Ware and McCollum [1980) who reported that irrigation lowered temperature, raised relative humidity and prevented blossom drop in tomato.

Table 3. Effects of shelterbelts and irrigation intervals on the month averages of relative humidity and evaporation.

Parameters	Relative humidity (RH%)			Piche evaporation (mm/day)		
Treatments	Open	Pigeon Pea shelter	Abusabeen shelter	Open	Pigeon Pea shelter	Abusabeen shelter
Irrigation interval (7 days) 20- 30 April (10 days)	-	-	-	20.4	21.0	20.3
May (3 1 days(	33	36	37	19.6	18.7	18.2
June (30 days(	35	42	38	18.9	15.9	17.0
1 - 20 July (20 days)	60	65	61	11.2	9.4	10.3
Mean	43	48	45	16.6	14.6	15.2
Irrigation interval(3days) 20 — 30 April (10 days)	-	-	-	21.0	19.0	19.1
May (31 days(	35	38	41	20.7	16.1	17.3
June (30 days(	37	46	47	19.8	16.6	14.6
1 20 July (20 days)	60	65	68	12.0	9.5	7.7

Redution of evaporation: On the average, the values of evaporation (mm/day)were lower under the sheltered area compared to the open Areas throughout the growing season. This result agrees with the measurements reported by Van Eimern *et al*. (1964) using Piche evaporimeters, who found a relatively smaller reduction of evaporation in the protected area. Within the irrigation intervals, higher values of evaporation were recorded for the short irrigation interval in the open areas (Table 3). A similar result was reported by Allen *et al*. (1998). Likewise, evapotranspiration (ET) recorded higher Values in the sheltered areas and under the short irrigation interval. ET was higher in the upper soil layer (0-20cm) compared to the lower Layers

Growth and development of the crop

Plant height (cm): There were highly significant difference($P \leq 0.001$) in the height of the tomato plants between the shelter treatments under 3 days irrigation interval in both seasons. The tallest tomato plants were obtained with the Abusabeen sheltered area in both seasons (Table 4). This was mainly due to a lower air temperature in the Ausabeen sheltered area under the short irrigation interval. This results in agreement with Calvert (1964) who found that the stem length of young tomato plants was determined by the day-time temperature. On the other hand, there were no significant differences in the height of the tomato plants within the treatments irrigated every 7 days. Highly significant differences (PSO.OOI) in plant height were Also recorded between the cultivars under the short irrigation interval، And Gezira 96 was the tallest (Table 5). The performance of the cultivars followed the same sequence in both seasons where the cultivar Gezira 96 gave the highest values followed by Omdurman، U. G. Summer set 98, Strain B and Peto 86.

Table 4. Effects of shelterbelts and irrigation intervals on tomato plant(cm).

Irrigation interval	1998			1999		
	3 days	7 days	Mean	3 days	7 days	Mean
Abusabeen shelter	27.6b	32.Oa	29.8a	37.2b	41.6a	39.4 a
Pigeon pea shelter	26.4b	27.1 b	26.8b	37.8b	38.0b	37.9b
Control	27.8b	30.7 a	29.3 a	36.8b	38.3b	37.6b
Mean	27.3b	29.9 a		37.3b	39.3 a	

Means having the same letters(s) are not significantly differient according to Duncan's Multiple Range Test

Table 5 Effects of irrigation intervals on the growth and development of the tomato cultivars.

Parameters	Leaf area index		Plant height		Dry weight		Total number flowers/plant		Flowers shed/plant%	
Cultivars/irrigation intervals	7days	3day	7days	3day	7days	3day	7days	3day	7days	3day
Season 1998										
Gezira 96	1.2 c	1.6 a	b28.6	31.4 a	12.1 b	13.2 a	38 a	39 a	34	26
Omdurman	1.0 d	1.3 b	28.1 b	30.3b	10.6 c	12.3 b	34 b	38 a	38	26
Peto 86	0.8 e	0.5 f	26.2 c	27.3 c	6.5 g	7.8 f	22 e	25 d	50	28
Strain B	0.9 d	0.9b	26.2 c	30.6b	8.6 e	9.8 d	28 c	34 b	43	28
Season 1999										
Gezira 96	2.0 c	2.1 a	40.0 b	45.0 a	20.2 b	23.6 a	71 b	94 a	31	15
Omdurman	1.6f	1.8b	37.9 b	39.8b	16.6 c	20.6 b	52 d	67 b	35	13
Peto 86	1.3 g	1.1d	31.8 c	33.4 c	10.5 f	11.8 e	33 f	37 f	42	19
U.G. Summerset 98	1.7 e	1.9b	38.3 b	39.0b	15.2 d	16.2 c	44 f	59 c	27	20

Means within the same column followed by different letters were significantly different at (P≤O.05) according to Duncan's Multiple Range Test.

Leaf area index (LAI): Table 6 shows that leaf area index of the tomato crop was significantly affected by the shelters where the highest values were obtained within the sheltered area compared to the open area. Under the long irrigation interval, the highest values of LAI were recorded for the pigeon pea sheltered area in both seasons. Under the short irrigation interval, the highest LAI was recorded for Abusabeen sheltered area.

Table 6. Effects of shelterbelts and irrigation intervals on leaf area index of tomato crop for the two seasons

Irrigation interval	1998			1999		
	7days	3days	Mean	7days	3days	Mean
Abusabeen shelter	0.7 d	1.2 a	0.95 b	1.5e	1.9 b	1.65b
Pigeon pea shelter	1.2 a	1.1 a	1.15 a	2.0 a	1.8 b	1.90 a
Control	1.0 b	0.9 c	0.95 b	1.5 e	1.6d	1.55 c
Mean	0.97 b	1.0 a		1.67 b	1.73 a	

Means having the same letters(s) are not significantly different according to Duncan's Multiple-Range Test.

Total dry matter production: Results about dry matter showed similar trends to that of LAI regarding the shelters. Under the short irrigation interval, values of dry matter of the sheltered areas were significantly higher ($P \leq 0.05$) than those of the open area. This was mostly due to the favourable conditions caused by the lower air and soil temperatures, high soil moisture contents, and higher relative humidity within the sheltered areas. Similar findings were reported by Suto and Ando (1975). Gezira 96 and Omdurman gave the highest dry matter values and occupied the first and second positions, respect-ively, followed by Strain B in the first season and summer set in the second season (Table 5). The cultivar Peto 86 recorded the lowest values of dry matter in both seasons. Generally, the same sequence was observed in plant height and leaf area index, and both were indicators of total dry matter production. The results in Table 5 showed that plant height and LAI contributed significantly (P≤O.05) to total dry weight for all cultivars.

Percentage of flower shedding/plant

The number of flowers shed per plant was significantly (P≤O.05) affected by the presence of shelterbelts and irrigation intervals (Table7). Lower numbers of shed flowers per plant were obtained under the short irrigation interval compared to the long irrigation interval. In both seasons, the open area under the long irrigation interval shed significantly (P≤O.OI) more flowers. In the first season, the open area shed more than 57% of flowers compared to 32% and 34% in the Abusabeen shelter area and pigeon pea, respectively. In the second season, more than 45% of the flowers were shed from the plants in the open area compared to 33% and 25% of shed flowers in the Abusabeen shelter area and pigeon pea shelter area, respectively. The higher percentage of flower shedding could be attributed to the higher wind speed in the open area, and to the higher air temperature in the treatments under the long irrigation interval that affected directly the number of flowers per plant. Similar findings were reported by Augastine *et al*. (1976). Cultivar Peto 86 under 7 days irrigation interval shed more than 50% of its flowers in the first season and 42% in the second season compared to a lower percentage of flowers shed by cultivar Gezira 96 followed by Omdurman and Strain B in the first season. In the second season the lowest values of flowers shed per plant were recorded by the cultivar Summerset 98, followed by Gezira 96and Omdurman. Under the short irrigation interval the cultivars Gezira 96 and Omdurman recorded the lowest values compared to the standard cultivars (Strain B and Peto 86) and the cultivar Summerset.

Table 7 Effects of shelterbelts and irrigation intervals on the total number of the flowers and flowers shed per plant for seasons 1998 and 1999.

interval Irrigation	Season 1998			
	Shelter type	Total no. of Flowers/plant	Number of shed flowers/ plant	Percentage of shedding
7 days	Abusabeen Shelter	31b	10b	32
	Pigeon pea Shelter	32b	11b	34
	Open Area	28b	16 a	57
3 days	Abusabeen Shelter	37 a	10b	27
	Pigeon pea Shelter	37 a	08 b	22
	Open Area	32b	10b	31
		Season 1999		
7 days	Abusabeen shelter	51 d	17 a	33
	Pigeon pea Shelter	48 d	12 b	25
	Open area	51 d	23 a	45
3 days	Abusabeen Shelter	72 a	10 b	14
	Pigeon pea Shelter	61 b	10 b	16
	Open area	59 c	12 b	26

Means having the same letter (s) within each column are not significantly different according to Duncan's Multiple Range Test.

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