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Sex ratio, growth and yield of Squash (*Cucubita pepo* L.) cultivars under stresses of different light regimes

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Abstract

This study was conducted in 2013/2014 at the greenhouse of Agriculture Research Station at King Abdulaziz University, Saudi Arabia. The aim of the presented work was to test sex ratio of four squash cultivars "Caserta", "Rivera," "Claudina" and "Cue-Ball" under stresses of different light regimes. Three different lighting systems 5000 – 10000lux (80%shade), 1000-15000lux (60%shade) and full light (15000-20000lux) were designed using fluorescent lamp and net with different shade levels. Squash cultivars were planted in open field for comparison. The experiments were laid out in split plot design and the treatments were distributed using randomized complete block using four replicates (RCBD). The Results revealed superiority of all tested cultivars when grown in open field at all measured parameters except plant height (cm) and number of leaves/plant with a marked superiority of the variety "Claudina". Plant height and no. of leaves were significantly increased under light regimes 80% and 60% shade. Sex ratio was highly affected by light regimes and balanced ration of male: female flowers was observed for squash plants grown in open field. Reducing light intensity by using 60% shade increased male flowers of all cultivars, while 80% shade inhibited formation of female flowers. The squash cultivar “Claudina” scored the highest yield components and yield parameters under open field conditions and full light regime (15000-20000lux). All cultivars formed no fruits under light regime 80% shade (5000-10000lux).

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Introduction

Squash (*Cucubita pepo* L.) is one of the most important vegetable in the world and Saudi Arabia. Squash is almost cultivated in Saudi Arabia in autumn and winter and rarely grown in spring and summer due to high temperature and long photoperiod. These climatic conditions and genetically factors affect the sex expression of summer squash. For instance, the summer squash cultivated in autumn and winter usually have more female and fewer male flowers which significantly affect the pollination and fruit setting (Robinson and Decker-Walters, 1997; Agbaje *et al.,* 2012).

In summer and spring, the high temperatures and long photoperiods, squash usually exhibit more male and fewer female flowers which decreases pollination and fertilization chances and thereafter fruit yield (Achakzai and Kayani, 2002; Achakzai, 2012). The number of harvested squash fruits differ based on the number of female flowers per plant. The environmental conditions, including photoperiod, temperature, nutrient availability and plant hormones greatly control the ratio of staminate to pistillate flowers. Therefore, regulating environmental factors influencing the ratio of male to female flowers in *Cucurbita* sp plants (Lau and Stephenson, 1993; Swiader *et al.*, 1994; Yin and Quinn, 1995). Overall, low temperature, low nitrogen supply, short photoperiod and high moisture availability promote female sex expression by increase carbohydrates build up and affect levels of endogenous hormones (i.e. ethylene, auxin and gibberellic acid). There was limited information about the effects of light regimes, intensity and light types on sex expression of squash (*Cucubita pepo* L.). The present work discusses deeply and explains the effects of different light regimes on the sex ratio, growth and yield of squash (*Cucubita pepo* L.).

The expected results of the presented study will be utilized to better understanding of sex expression of the monoecious *Cucurbitacea* crops especially squash. Also, the expected outcomes of this work will help in identify the better climatic conditions for better growth and yield of the squash cultivars in Saudi Arabia. The present work discusses deeply and explains the effects of different light regimes on the sex ratio, growth and yield of squash (*Cucubita pepo* L.). The expected results of the presented study will be utilized to better understanding of sex expression of the monoecious *Cucurbitacea* crops especially squash. Also, the expected outcomes of this work will help in identify the better climatic conditions for better growth and yield of the squash cultivars in Saudi Arabia.

Materials and methods

Experimental site and climate

A field experiment was carried out in 2013/2014 at the Agriculture Experimental Station of King Abdulaziz University which located at Hada Alsham village, 120 km north east of Jeddah, Saudi Arabia. The experiment was conducted to investigate test the effects of applying different light systems on sex ratio, growth, yield components and yield of four squash cultivars from distinct genetic background.

The soil texture of the experimental sites was classified as sandy loam (Sand 84.21%: silt 14.05%: clay 1.74%). The physical prosperities of the soil were pH 7.8 unit, EC 1.79 dsm-1, organic matter 0.453%, organic carbon 0.5% and available macro nutrients N (0.215%), K (0.781%) and P (0.07%). The dominant climate of the area is arid, with high temperatures and long photoperiods during summer season.

Meteorological data

Meteorological data of the different light regimes sections were measured using environmental sensors with display meters and data loggers (LI-COR, 4647 Superior Street Lincoln, Nebraska USA). The sensors were light meter (Lux), Temperature and Humidity. These sensors were connected to five channels and three through external sealed BNC connectors LI1400 data logger. The Metrological data of open field at Hada Al-Sham were obtained from the Meteorological Station of Centre of Excellency of Cclimatic Change, King Abdulaziz University, Jeddah, Saudi Arabia (http://ceccr.kau.edu.sa/Default.aspx?Site_ID=902&Lng=EN) (Table 1).

Plant materials and experimental design

Four squash cultivars of different genetic backgrounds were evaluated at different plant growth stages under the effects of different light systems treatments. The four squash hybrid varieties were *Cucurbita pepo* L. cv. Zucckini Caserta (PETOSEED company, 2700 Camino del Sol oxand, CA 93030 USA), *Cucurbita pepo* L. cv. Revera (Seminis Co., USA), *Cucurbita pepo* L. cv. Claudina (Asgrow Co., USA) and *Cucurbita pepo* L. cv. Cue Ball (Hollar Co., USA). These cultivars were grown commercially in the Kingdom of Saudi Arabia and obtained from the seed markets of western regions, Jeddah, Saudi Arabia. Seeds of all cultivars were subjected to purity, germination and viability tests at the lab of horticulture, Department of Arid Land Agriculture, Faculty of Meteorology, Environment & Arid Land Agriculture, King Abdulaziz University Saudi Arabi. The experiment was laid out in split plot design and the treatments were distributed over plots using the Randomized Complete Block design (RCBD) (Gomez and Gomez, 1984).

Applied light systems

The greenhouse was divided to three similar strips using black sheets. Then light systems were installed using fluorescent labs and green net sheets of different shade percentages (0% shade, 60% shade and 80% shade). The first light regime was designed to provide plants with full required light (without shade and additional fluorescent lambs were added to reach 15000 -20000 lux. Second light regime was designed to provide plants with 40% light and 60% shade (10000-15000 lux). The green net of 60% shade was used to cover squash plants in this strip of the greenhouse. The third light regime was designed using green net of 80% shade to provide the plants with 20% light and 80% shade (5000 -10000 lux).

Drip irrigation system

For installing the drip irrigation systems, the greenhouse was precisely leveled then the dripper lines were installed on soil surface. The distance between the dripper lines (rows spacing) was 1 m and the distance between drippers (distance between each two plants in the same line) was 0.6 m.

The type of the dripper lines was RAIN BIRD LD- 06-12-1000 Landscape drip 0.9 G/h (4L/h) @18"(obtained from the irrigation accessories market in Jeddah, Saudi Arabia). The downstream end of each dripper line was connected to a manifold for convenient flushing. Inlet pressure on each tape was about 1.5 bars. The system uses 125 micron disk filter. The water source was from two containers always full of water via main irrigation network installed in the location.

Measurements

The following parameters were assessed using 5 squash plants selected randomly at the end season: Plant height (cm), no. of leaves/plant, no. of male flowers/plant, no. of female flowers/plant and no. of fruits/plant Weight of fruits/plant (g). Days to flowering was measured when 50% of squash plants of each treatment produced flowers, and total yield (ton/ha).

Data analysis

Analysis of variance related to split plot design and RCBD experiments was conducted using the Statistical Analysis System (SAS) program verg (ver. 9.00, SAS Institute, Cary, NC, USA). The treatment means were compared by F-test and the Least Significant Differences test (LSD) at 5% probability level. (Gomez and Gomez, 1984).

Results and discussion

Plant height(cm)

There were significant differences due to light regimes and genetics of squash cultivars and their interaction on the plant height at end of season. The light regimes 80%shade (50000-10000lux) and 60% shad (10000-15000 lux) enhanced significantly heights of squash plant. The least height of squash was observed under open field condition and light regime (15000-20000 lux) (62.07cm) (Table 2). The cv. Claudina produced the highest plant (94.92 cm), while the shortest plants were produced by the cv. Zucckini Cacerta (71.48 cm). Regarding interaction, the cultivar “Cue ball’ revealed highest plant under light regime (15000-20000lux) with 109.67cm followed by 105.53cm for open field light regime.

The shortest plants were produced by 'Revera' under open field condition and light regime (15000-20000lux) with 55.77cm and 59.23cm, respectively (Fig 1). These results attributed to the low temperature and humidity inside the greenhouse which resulting significant increase in plant height as compared to the open field condition at Hada Al-Sham. It was reported that plant genetics and environmental conditions largely affected growth, productivity and quality of vegetable crops (Rajasekar *et al*., 2013).

Table 1. Metrological data recorded from Hada Alsham Meteorology station and Environmental sensors during the time of experiment.

Location/Months	Min. temp.(C°)	Max. temp. (C°)	Sunshine (h)	Wind speed (km/day)	Relative humidity (%)
Open field (Hada Al-Sham)[1]					
February	13.25	35.9	9.03	192.54	58.28
March	14.99	36.9	8.37	193.07	56.15
April	14.40	38.02	9.93	200.59	46.97
May	20.43	44.49	10.81	194.48	49.44
June	21.03	45.17	11.93	190.58	35.88
Greenhouse (Hada Al-Sham)[2]					
February	17.3	27.5	-[3]	-	72.6
March	16.6	28.8	-	-	70.5
April	18.2	28.5	-	-	71.4
May	19.9	31.2	-	-	63.5
June	20.4	30.6	-	-	60.7

[1]Meteorological Station at Hada Al-sham (Excellency Centre for climatic change, King Abdulaziz university).

[2]Environmental sensors with Data logger (LI-COR Company, USA)

[3] sun shine differed based on applied light regimes.

Table 2. Growth parameters of four squash cultivars grown under different climate conditions at three locations at western region of Saudi Arabia.

Treatments	At end of season			During the season	
	Plant height (cm)	No. of leaves/plant	Flowering date	No. of male flowers	No. of Female flowers
Light regimes (lux)					
Open field light	62.07b[2]	35.21a	25.92c	12..92a	7.083a
Full light (15000-20000)[1]	64.07b	36.10a	27.67c	11.75a	5.916b
60% shade (10000-15000lux)	87.83a	38.92a	32.42b	10.92b	2.416c
80% shade (5000-10000)	94.92a	37.58a	35.92a	7.92c	1.083d
F test	***	NS	***	**	***
$LSD_{0.05}$	8.934	-	1.426	0.872	0.790
Squash Cultivars (cv)					
Zucckini Caserta[3]	71.48c	36.08b	27.55c	10.33a	5.33a
Revera[4]	87.50ab	42.12a	28.00bc	9.78a	6.78a
Claudina[5]	90.97a	36.38ab	28.78b	10.55a	7.33a
Cue Ball[6]	76.47bc	35.55b	30.33a	10.11a	5.44a
F test	**	NS	***	NS	NS
$LSD_{0.05}$	11.728	6.018	0.976	-	-
Interaction (L* cv.)					
F test	**	NS	***	NS	*

[1]The light intensity was measured using Lux meter (Lux Meter SO 200K, PCE Instruments UK Ltd., 1 London Road, Southampton, SO15 2AE., UK).

[2]Means with the same letter within each column are not significantly different, (NS) = not significant; (-) = not calculated.

[3] *Cucurbita pepo* L. cv. Zucckini Caserta (PETOSEED company, 2700 Camino del Sol oxand, CA 93030 USA)

[4] *Cucurbita pepo* L. cv. Revera (Seminis Co., USA),

[5] *Cucurbita pepo* L. cv. Claudina (Asgrow Co., USA)

[6]*Cucurbita pepo* L. cv. Cue Ball (Hollar Co., USA). (P.S. Co., USA)

They reported that the low temperature and humidity inside the protected house resulting significant increase in plant growth traits i.e. plant height, number of branches as well as internodal distance as compared to the open field condition.

Higher temperatures were reported to have more adverse influence on net photosynthesis than lower temperatures resulting in particular decrease in photosynthates production (Reddy *et al.*, 1999; Ganesan, 2004; Ramesh and Arumugam, 2010).

Table 3. Yield component and yield parameters of four squash cultivars grown under different climate conditions at three locations at western region of Saudi Arabia.

Treatments	No. fruits/plant	Wight of fruits/plant (kg)	Total yield (ton/ha)
Light rigmes			
Open field light	9.33a	1.341a	16.26a
Full light (15000-20000 lux)	6.86b	0.942b	9.32b
60% shade (10000-15000lux)	4.25c	0.576	4.56c
80% shade (5000-10000 lux)	0.00[1]d	0.00d	0.00d
F test	***	**	*
$LSD_{0.05}$	1.541	0.143	5.324
Squash Cultivars (cv)			
Zucckini Caserta	8.17a	1231.3ab	18.37b
Revera	9.00a	1318.70ab	23.75ab
Claudina	9.33a	1626.70a	28.73a
Cue Ball	4.67b	847.70b	17.04b
F test	**	*	**
$LSD_{0.05}$	2.385	0.540	6.784
Interaction (L* cv.)			
F test	**	*	*

No. of leaves/plant

The results revealed no significant differences due to light regimes and genetics of squash cultivars and their interaction on no .of leaves/plant at end of season. However, The squash plants grown under light regime (10000-150000lux) produced taller plants as compared to other growing condition.

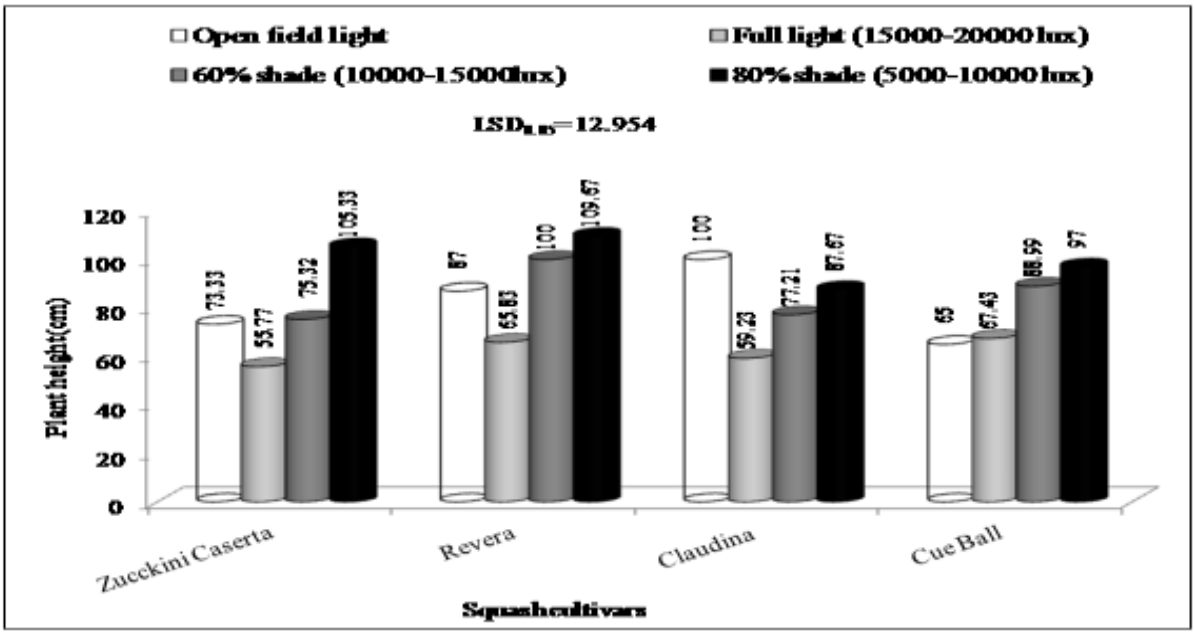

Fig. 1. Plant height (cm) at end of season as affected by interaction between four light regimes and four squash cultivars grown under greenhouse conditions.

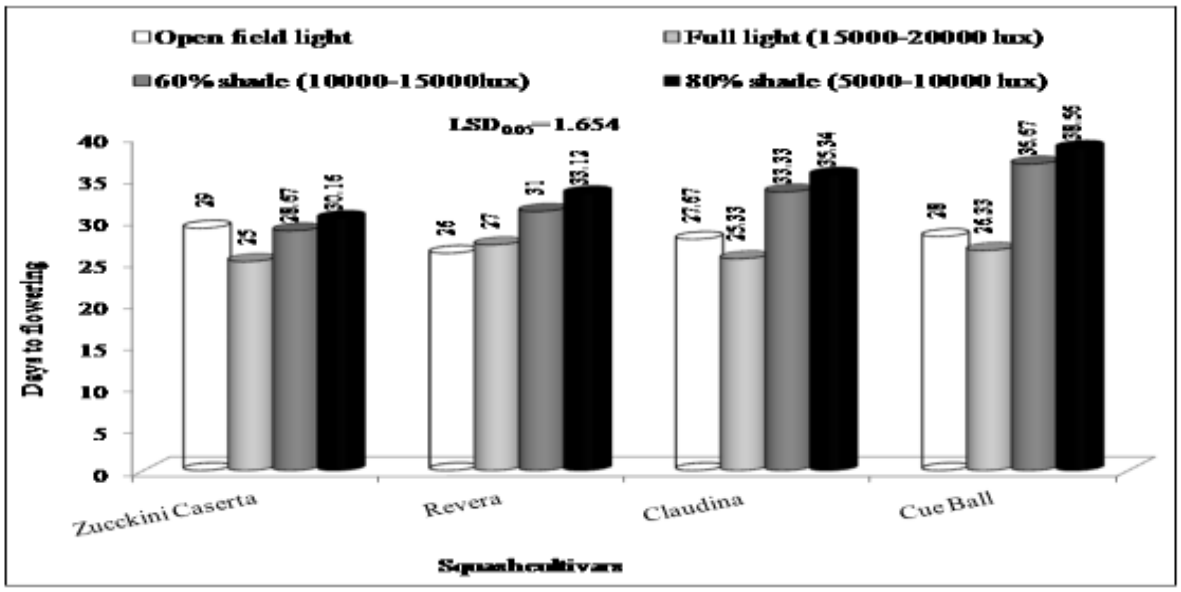

Fig. 2. Effects of four light regimes on days to flowering of four squash cultivars of different genetic background and grown under greenhouse conditions.

Also, plants of the cultivar 'Revera' formed maximum number of leaves (Table 2). Increased number of leaves/plant was observed by Ramesh and Arumugam (2010) on vegetables grown under poly house and El-Aidy *et al.* (1988) in sweet pepper under shadenet house. Ramesh and Arumugam (2010) observed increases in numbers of branches per plant under poly house, in tomato, eggplant and chillies. Rajasekar *et al.* (2013) reported that numbers of leaves per plant was highest under shadenet house in all vegetables during summer and winter seasons. Also, Nimje and Shyam (1993) observed increased number of leaves of sweet pepper and eggplant under polyethylene houses.

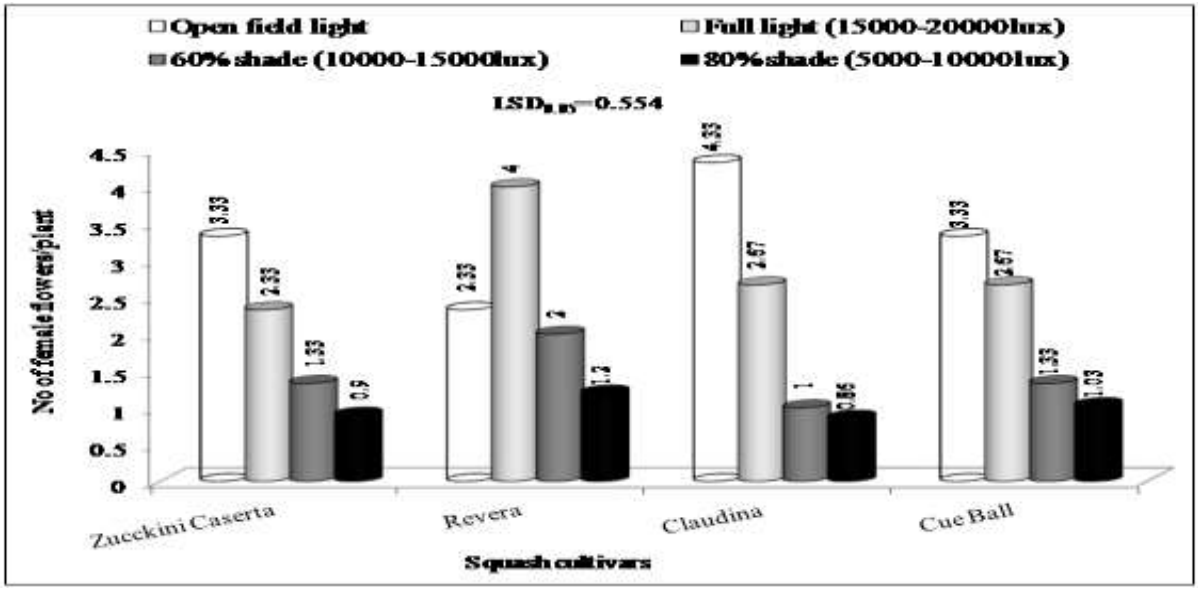

Fig. 3. Interaction effects between four light regimes and four squash cultivars grown under greenhouse conditions on number of female flowers/plant.

Flowering parameters

The light regimes were significantly affected on days to flower of squash cultivars. Early flowering was observed for the squash plants grown under open field and light regime (15000-20000lux), whereas a significant delaying if flowering was observed under

light regime (5000-10000lux). The squash cultivar Zucckini Caserta was the earliest to flower (27.55), whereas the cv. Cue Ball registered significant delay to produce flower (30.33) (Table 2). There were significant interaction between the squash cultivars and the light regimes regarding days to flowering and number of female flowers (Fig 2). The tested squash cultivars were significantly enhanced to flowering under open field light and light regime (15000-20000 lux). Under high temperature, low humidity and high light intensity at open field at Hada Al-Sham the squash cv.' Revera' recorded the lowest days to flowering (25.00), while the cv. Cue Ball started flowering after 38.56 days under the light regime 80% shade (5000-10000 lux) (Fig 2). The light regimes were significantly affected no. of female and male flowers per squash plant.

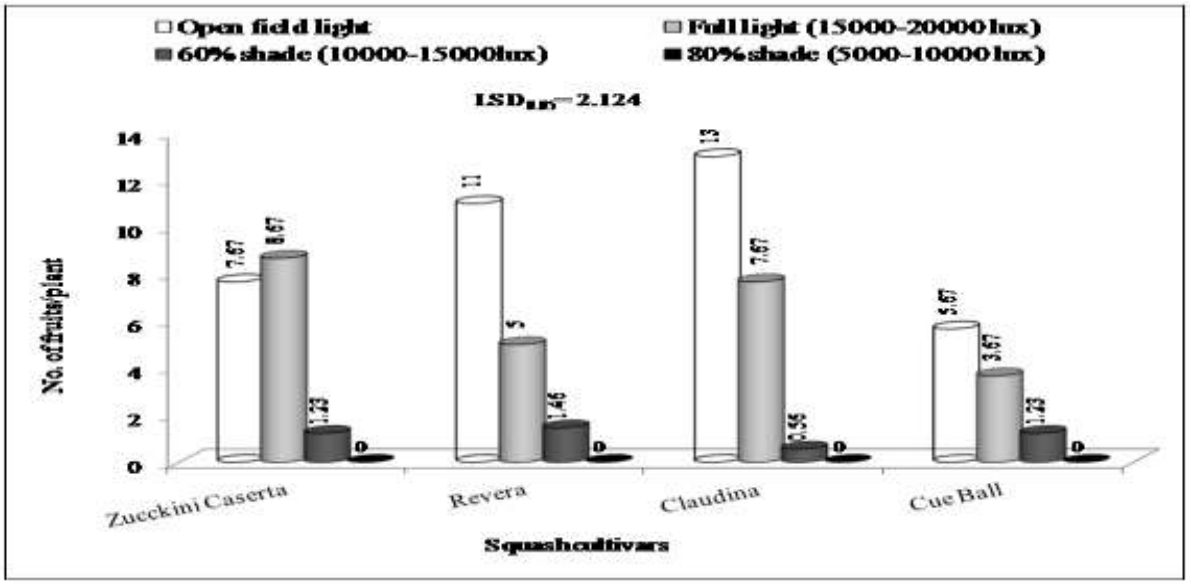

Fig. 4. No. of fruits/plant as affected by interaction between four light regimes and four squash cultivars grown under greenhouse conditions.

However, insignificant effects were observed for the between squash cultivars on sex ratio (no. of female: no of male flowers). The maximum ratio of male: female flowers (7.92 M: 1.083 F) were obtained under the weather of open field at Hada Al-sham. The minimum male: female ratio was observed under light regime 80% shade (5000-10000lux) (Table 2). The cultivar 'Zucckini Caserta' and 'Revera' produced maximum number of female flowers under light regimes 60% shade (10000-15000lux) and full light regime (15000-20000lux) without significant differences. In addition, 'Cue Ball' revealed the least no. of female flowers under all tested light regimes (Fig 3). Johanna and der Vlugt (1983) concluded that fewer buds were formed at high than at low temperature, however the differences in numbers of buds between temperatures did not disappear. Svein and Frimanslund (1993) studied Effect of different day and night temperature regimes on greenhouse cucumber young plant production, flower bud formation and early yield. They found that the rate of development was dependent on the temperature regime. Also, they reported that low day temperature (DT) result lower number of female flowers/plant as compared to low night temperature (NT). Increasing the average day temperature (ADT) affected the elongation to a larger extent than an equal raise of day (DT) and night (NT) temperature. They also observed that low day temperature (DT) reduced the number of flower buds as compared to low night temperature (NT).

Yield component and yield parameters

The squash cultivars were not able to produce fruits under light regime 80% shade (5000-10000lux) as compared to other tested light regimes.

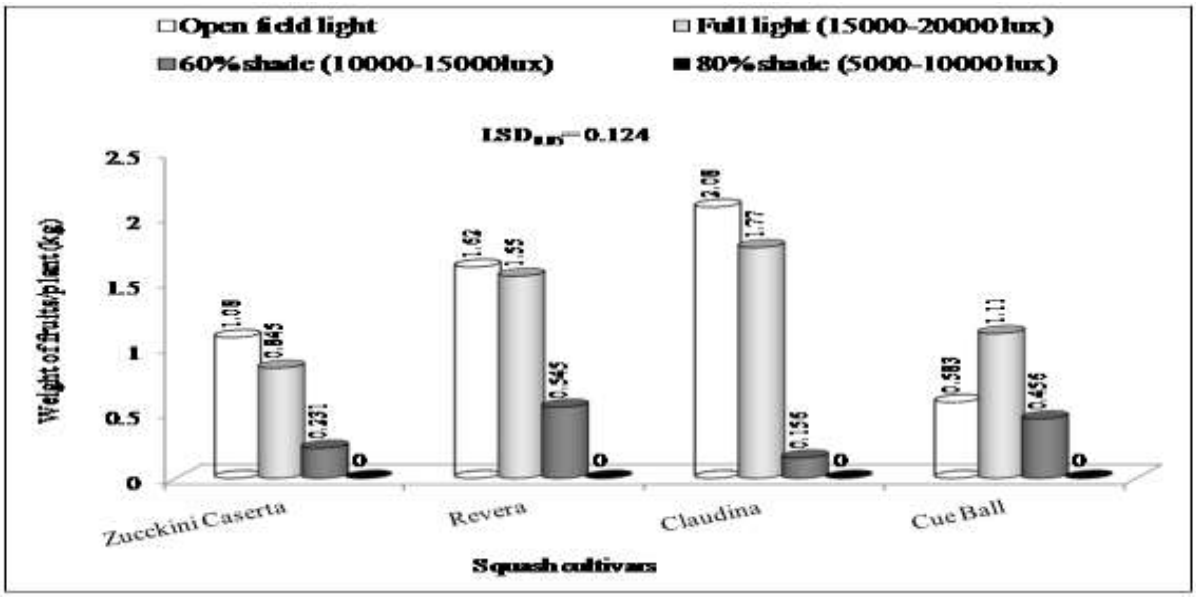

Fig. 5. Plant yield (kg) as affected by interaction between four light regimes and four squash cultivars grown under greenhouse conditions.

The reason can be attributed to the low temperature, low light intensity and high humidity were significantly affected the number of female flowers and the pollen grain viability and germination. It was reported that the squash sex ratio, fruit set and yield affected significantly by the environmental conditions (Bakker, 1993; Rajasekar *et al.*, 2013). The values of yield component and yield traits of squash were significantly higher under open field light as compared to other tested light regimes (Table 3). These results illustrated to the weather of open field site at 'Hada Al-Sham' which provided stable moderate day and night temperature, low wind speed, moderate relative humidity, suitable sunshine per/day (photoperiod) and suitable light intensity to the squash plants during the growing season (Table 1). These climate conditions allowed over expression of the genetics of the squash cultivars resulting high growth and yield component and yield. Oppositely, the applied light regimes especially those with high shade and low light intensity (60% and 80% shade) may be reduced the growth, yield component and yield parameters of the tested squash. Regarding the genotypic effects of squash cultivars, there were significant effects on the yield component and yield parameters of the tested squash cultivars. The squash cv. 'Claudina' produced the highest number of fruits/plant, highest fruits weight/plant and highest yield (ton/ha). The cv. 'Cure Ball' produced the least number of fruits/plant, weight of fruits/plant and total yield (ton/ha) (Table 3). Significant interaction was observed between the light regimes and squash cultivars regarding yield component and yield. The cv 'Claudina' produced highest no. of fruits, weight of fruits/plant and total yield of fresh fruits when cultivated under light regimes of open field, followed by light regime 15000-20000lux. Yield and yield components of all tested cultivars were significantly reduced under light regimes of 60% shade (10000-15000lux) particularly the cultivar 'Claudina'. All cultivar produced no fruits under light regime with 80% shae (5000- 10000lux). The squash plants grown under open field climate received stable moderate day and night temperature, low wind speed, moderate relative humidity, suitable sunshine per/day (photoperiod) and suitable light intensity during the growing season (Tables 1). These climate conditions may be stimulated the genetics of the squash tested cultivars and over-expressed to produce high growth and yield component and yield. On the other hand, the dominant climate of the applied light regimes included low light intensity, low day length (sunshine/day), wide differences between the minimum and maximum temperatures and high humidity. These climatic conditions may be reduced the growth, yield component and yield parameters of

the tested squash cultivars (Table 1). It was reported that the environment including temperature, air relative humidity and photoperiod and light intensity has significant role in plant growth, development and yield (van Hasselt and Strikwerda, 1976; Feierabend, 1977). Hess *et al.,* (1992) and Bakker (1991) concluded that high humidity affected yield of cucumber through two ways: a) light interception resulting from the enlargement (through number of leaves and leaf expansion) and the decrease of the LAI and b) and the effects on photosynthesis rates.

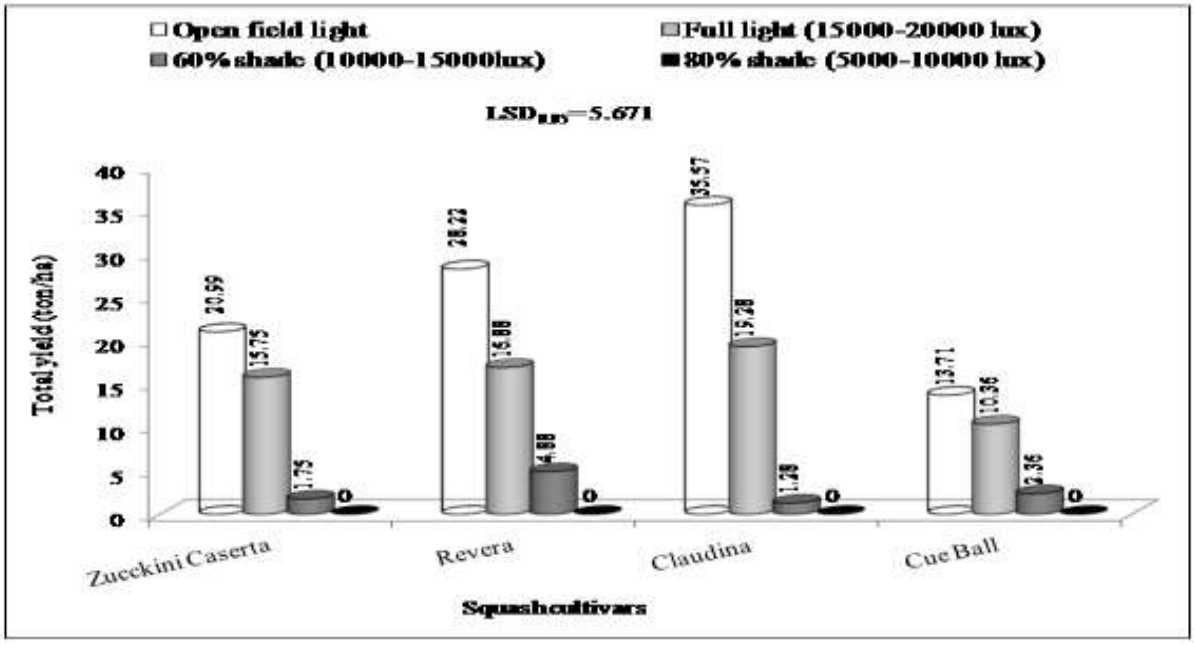

Fig. 6. Yield of fresh fruits (ton/ha) of four squash cultivar grown under greenhouse conditions as affected by light regimes.

Higher temperatures have more adverse influence on net photosynthesis than lower temperatures leading to decreased production of photosynthates above a certain temperature (Reddy *et al.,* 1999). This might be explaining the low yield component and yield of squash cultivars under the weather of open field experimental site at Hada Al-Sham. Rajasekar *et al.* (2013) and Hawthron and Pollard (1957) reported that the high reduction of capsicum yield under open field might be due to high temperature.

Conclusion

There are genetic differences between the test squash cultivars with regard sex ratio and yield component and yield under the tested light regimes. The squash cultivar 'Claudina' revealed the highest performance under open field and different light regimes suggesting the tolerance behavior of this cultivar to light stresses. We are recommending not grow squash under shade higher than 60% and 80% shade inhibited fruit formation of squash.

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