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Overcoming seasonality in the tropics by growing tomato (*Lycopersicon esculentum* Mill.) varieties under cooled conditions

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ABSTRACT

The main objective of this work was to overcome seasonality in tomato production under hot tropical summer conditions, as well as to evaluate the adaptability and productivity of cherry and normal size indeterminate tomato varieties. The tested varieties were the standard varieties, Chanoa, Merel, Sensie and Yusra and the cherry varieties, Tomi and Elitrro. The cherry variety Elitrro recorded the highest plant height followed by the normal Merel. The cherry varieties over-numbered the classic varieties for mean number of fruits per cluster and mean number of fruits per meter square. There was no significant difference between the best yielders, the classic varieties Chanoa (25.63 kg/m^2) and Yusra (24.13 kg/m^2) and the cherry variety Elitrro (24.00 kg/m^2). Yusra recorded the highest fruit diameter (60 - 70 mm). The classic type tomatoes are well known and of high demand in Sudan that give Chanoa and Yusra better adoption chances. Our results clearly indicated that production of summer tomato under cooled plastic house conditions is a new technique that has the potential to overcome the seasonality of tomato production under Sudan and similar tropical condition.

Keywords: Indeterminate Tomato; Cherry; Cooled Plastic House; Off-Season; Sudan; Tropics

1. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is a member of the family Solanaceae and is native to Central, South and Southern North America from Mexico to Peru. It is a perennial, often grown out doors in temperate climates as an annual, typically reaching 1 - 3 m in height, with a weak, woody stem that often vines over other plants [1].

Worldwide, tomato comes second to potato as the most widely grown vegetable crop [2]. In the Sudan, tomato is second to onion among the most important vegetable crops grown, producing about 294 thousand tons of fruits annually representing about 27% of the country's total vegetable production [3].

Tomatoes are grown under irrigation in the arid tropics where, commercial tomato production is limited to relatively short periods of favorable climate during the winter months of November-March. In Sudan, vegetative growth and flowering of tomato plants is adversely affected with the advent of high temperature in summer (April-September). In this period, large number of flowers fails to set fruits and tomatoes are not available in the market, except for limited supplies produced as an off-season crop along the Nile. Reports by [4] indicated that high temperature conditions cause tomato plants to be generally small, with thin elongated branches, resulting in reduced truss capacity to set and carry fruits of good size. The number of flowers per inflorescence varies over a wide range of temperature [5].

Cherry tomatoes are known as tasty, numerous small size fruits in clusters along the stem and branches of the plants. A cherry tomato is a smaller garden variety of tomato. Cherry tomatoes range in size from a thumb-tip up to the size of a golf ball, and can range from being spherical to slightly oblong in shape [6]. Prof. Haim Rabinowitch and Prof. Nachum Kedar from Israel developed the cherry tomato in 1973. Looking for a way to slow down the rapid ripening of ordinary tomatoes in a hot climate, they identified the genetic combination to slow down maturation and also a way to exploit the genes to produce cherry tomatoes [7]. Most of the commercially grown varieties of cherry tomato belong to the indeterminate group. Yields of normal tomato under the conditions of Spain was 280.00 tons/ha [8]. Moreover, yields of 300 tons/ha under greenhouse conditions were reported in Egypt [9]. Higher yields of 360.00 - 400.00 tons/ha were reported in USA [10], 650.00 tons/ha in Canada [11] and 470.00 tons/ha in Holland [2].

High temperature is considered as a major environmental stress that limits tomato production during summer under arid conditions. A variety of control measures and techniques including cultural practices in the field have been tested previously under Sudan conditions [12]. Protected vegetable production under cooled plastic house is a newly introduced technology in the Sudan. It was introduced rather late in the early nineties of last century and was successfully used to produce tomatoes and cucumbers at El Hasahesa, Gezira State. Recently tomatoes, cucumbers and strawberries were produced under cooled plastic house at Morgan and other scattered farms around Khartoum State. Many investors are now interested in this type of production. But before this system is widely adopted it needs to be locally adapted and economically evaluated [13].

During summer months, the productivity of tomato is markedly decreased in Sudan and consequently there is a drastic shortage in the availability of tomato to consumers and so, high increase in prices. This leads to frequent importation of tomato from countries such as Jordan, Syria and Egypt. Moreover, almost all cultivars which were grown in Sudan are determinate and they were characterized by low productivity of approx 24 - 43 ton/ha [14].

Accordingly, introduction and evaluation of indeterminate cultivars which are characterized by high productivity, good quality fruits in flavor, color, size, and post harvest should be one of the main goals of off-season tomato production in Sudan.

Therefore, the objectives of this study were to:

1) Over-come seasonality of production and hence avail tomato during off-season (summer) in the tropics and thus extend the season of tomato production year round.

2) Evaluate the performance of some normal size indeterminate tomato varieties for productivity under cooled plastic house conditions during off-season in Khartoum State, Sudan.

3) Explore the potentialities of different cherry tomato varieties under cooled plastic house condition in the tropics.

2. MATERIALS AND METHODS

The experiments were conducted in summer season (Feb. to July), 2007, in Khartoum State, in two different cooled plastic houses. The climate information for summer months of 2007: mean minimum temperature was (18.1˚C - 27.7˚C), mean maximum was (36.6˚C - 43.6˚C) and mean relative humidity was (15.00% - 45.6%), with total sun shine of (10.5 - 11.5 hours). The weekly temperature readings under the cooled plastic houses ranged (15.5˚C - 18.9˚C) as mean minimum and (26.0˚C - 28.1˚C) for mean maximum. Soil of experiment was subjected to two types of analysis, physical and chemical. The Physical and chemical characteristic of soil in the experimental site were as follows pH = 7.0, E.C. =1.2 mmoh/cm, sand = 32.06%, silt = 47.5% and clay = 20.44%.

Plant material was composed of six introduced indeterminate tomato varieties. Two cherry tomato types, Tomi and Elitrro, and four normal tomato types, Merel, Sensie, Chanoa and Yusra were used. In these experiments, randomized complete block design (RCBD) with the blocks against the cooled air flow direction replicated four times was used. Treated seeds were sown in nursery in Jan 25, 2007. The germinated seedlings were covered by Agreels to prevent white fly infestation. Seedlings were then transplanted to the cooled plastic houses 40 days after seeds sowing. Seedlings were transplanted in black plastic bags (40 × 30) cm in North-South rows. The distance of plastic bags from the plastic house walls was 150 cm in all directions. Transplanting was 70 cm between lines and 40 cm between plants in the line.

Replanting was done after 7 days from transplanting. Drip irrigation system was used in this experiment and irrigation was applied daily according to plant requirements. The tomato seedlings were foliar fertilized with Singeral (2 g/liter water) after 30 days from planting. NPK (20:20:20) was added after transplanting at the rate of 3g/plant in 10 days intervals for 8 times in the season. Spraying with Calpro foliar fertilizer at rate 3 g/liter water was applied at 10 days interval for five times. It was applied only at appearance of calcium deficiency (Blossom end rot symptoms). The foliar fertilizer Sequestene was sprayed when chlorosis appeared.

Diseases and insects were controlled chemically using Actara (insecticide), Bayleton, and Olegenbro (fungicide) at the rates of 1 g/2 liter, 1 g/liter, and 7 g/liter water, respectively. Plants were oriented to grow vertically by climbing on ropes, which hang downwards from top. This process was done continuously at 3 days intervals.

Crop harvest for the first pick was made about two months after transplanting. The harvest season continued for 2.5 months at picking interval of 3 - 4 days.

Parameters measured were Plant height (cm), number of leaves/plant, number of internodes/plant, number of branches/plant, number of clusters/plant, number of flowers/cluster, number of fruits/cluster, number of fruits /meter square, total yield/meter square (Kg) and diameter of fruits (mm).

The collected data were analyzed using SAS software program and means separated using Duncan multiple range test.

3. RESULTS AND DISCUSSION

3.1. Plant Height (cm)

Plant heights for both sites are shown in **Table 1**. There were significant differences among varieties. Elitrro recorded the highest plant height, followed by Merel, Chanoa, Yusra and Tomi, respectively, while Sensie recorded the lowest plant height. This parameter is known to be genetically controlled and different plant varieties differ in internodes length and number of internodes.

3.2. Number of Clusters per Plant

There were no significant differences between Elitrro and Tomi, and they ranked first while, Yusra, Chanoa, Merel and Sensie behaved similarly and recorded fewer numbers of clusters/plant on the both sites (**Table 2**). All tested varieties were under similar environmental and nutritional conditions. Accordingly, variations in number of clusters per plant, is mostly reflection of the genetic variation between cherry and normal types. These findings are supported by those of [9] who found that there is a variation between cherry and normal cultivars in number of flowers per cluster. This is also in agreement with the results of [15] who found that normal cultivars do not differ in number of clusters per plant and likewise in cherry sets. It might also be attributed to cultivars characteristic.

3.3 Number of Fruits per Cluster

There was significant difference in number of fruits/cluster between standard and cherry varieties but no differences were noticed within each group. Namely, Elitrro and Tomi yields were comparable and gave more number of fruits compared to Merel, Sensie, Chanoa and Yusra that gave similar number of fruits (**Table 3**). The variation in number of clusters per plant between the two types of tomato varieties explains the consequent variation in number of fruits per cluster. These findings are in agreement with those of [9] who found that there is a variation between cherry and normal cultivars in number

Table 1. Plant height (cm), 20 weeks after transplanting, for six normal and cherry tomato varieties grown under cooled plastic house conditions at two sites in Khartoum State, summer season 2007.

Varieties	Plant height (cm)	Sites		Combined Means
		Site (1)	Site (2)	
Normal	Merel	255.10 b	274.40 a	259.75 b
	Sensie	229.35 f	232.95 d	231.15 f
	Chanoa	246.38 c	264.58 b	255.48 c
	Yusra	235.10 d	237.43 c	236.26 d
Cherry ry ry y	Tomi	231.50 e	237.30 c	234.40 e
	Elitrro	265.50 a	275.40 a	270.45 a
	SE ±	0.17	0.16	0.17
	C.V %	0.28	0.26	0.27

Means with the same letters along each column and for each of the two tomato categories are not significantly different at (0.05).

Table 2. Mean number of clusters per plant, 20 weeks after transplanting, for four standard tomato varieties and two cherry tomato varieties under cooled plastic house conditions at two sites in Khartoum State, summer season 2007.

Variety	Clusters/plant	Sites		Combined Means
		Site (1)	Site (2)	
Standard	Merel	15 b	15 b	15 b
	Sensie	16 b	16 b	16 b
	Chanoa	17 b	16 b	16 b
	Yusra	16 b	15 b	16 b
Cherry	Tomi	20 a	21 a	20 a
	Elitrro	22 a	23 a	22 a
	SE ±	0.7	0.40	1.52
	C.V %	16.28	10.52	13.43

Means with the same letters along each column and for each of the two tomato categories are not significantly different at (0.05).

Table 3. Mean number of fruits per cluster, 20 weeks after transplanting, for four standard tomato varieties and two cherry tomato varieties under cooled plastic house conditions at two sites in Khartoum State, summer season 2007.

Fruits/cluster Variety		Site		Combined Means
		Site (1)	Site (2)	
Standard	Merel	5 c	5 c	5 b
	Sensie	6 c	5 c	5 b
	Chanoa	5 c	5 c	5 b
	Yusra	5 c	4 c	4 b
Cherry	Tomi	21 b	17 b	19 a
	Elitrro	24 a	21 a	22 a
SE ±		0.39	1.15	1.30
C.V %		14.08	14.21	33.37

Means with the same letters along each column and for each of the two tomato categories are not significantly different at (0.05).

of flowers per cluster.

3.4. Number of Fruits/m^2

Cherry varieties yields were significantly higher in number of fruits/m^2 compared to standard varieties. Elitrro cultivar recorded the highest number of fruits/m^2 in both sites followed by Tomi. The standard varieties also varied in yield and Chanoa overyielded Merl and Sensie, while Yusra cultivar gave the lowest number of fruits/m^2 (**Table 4**). The number of plants per unit land was the same for all tested varieties, so the final variation in number of fruits per meter square is the result of differences in number of fruits per cluster for the two tested types.

3.5. Fruits Diameter (mm)

Standard varieties fruits diameter (54.78 - 63.83 mm) was significantly higher than cherry varieties (20.88 - 24.73 mm). For the standard varieties, Yusra recorded the largest fruits diameter in both sites (63.8 - 66 mm), followed by Chanoa and Sensie, while Merel cultivar recorded the smallest fruit diameter in both sites (54.78 - 56 mm) (**Table 5**). For the cherry varieties, there was no significant difference between them in both locations (**Table 5**), Elitrro (22.73 - 22.92 mm) and Tomi (20.88 - 22.92 mm). Cherry tomatoes fruits are small in size that makes it difficult to notice significant differences. Our findings are similar to those reported by [16].

3.6. Yield of Fruits/m^2

Tomato yield ranged between 19.25 - 26.50 and 19.50 - 26.25 Kg per m^2 for the first and second sites, respectively. The average yield of Chanoa, Elitrros and Yusra at both sites was similar and they over yielded Tomi, Merel and Sensie cultivars that also gave comparable yield, (**Table 6**). Yielding ability is closely linked with the genetic background of different varieties, environmental conditions and cultural practices. These findings are in agreement with results of [16] who attributed differences between the yields of tomato cultivars to variation in genetic constitution of these cultivars.

Chanoa the best yielder among varieties was characterized by producing the highest number of fruits and the fruit weight was not significantly different from that recorded by Yusra. These results suggest that the number of fruits and fruit weight are critical yield parameters and are not affected by plant height or number of leaves and internodes. Although the yield of normal (Yusra) and cherry (Elitrros) varieties was almost similar, the cherry size varieties are not popular by consumers and accordingly, the normal tomato sets should be adopted for production under cooled plastic house conditions to guarantee good returns. Yusra, a normal size variety, gave the lowest number of fruits/m^2, but big size fruits that exceeded the other varieties that give it a better marketing chance as large sized fruits are more popular in Sudanese markets.

The harvest period in this study was only 2.5 months and the yield is not far from yield in some countries. Relatively higher yield of normal tomato under the conditions of Spain [2], Egypt [9], USA [10], Canada [11] and Holland [2] may be due to the long harvest periods that extends up to 4 - 5 months, variety differences and the relatively cool and humid agro-climatic conditions surrounding the greenhouse year round or better cultural practices resulting from advanced research and accumulated experience. Farmers generally fetch high returns from the off-season tomatoes produced under greenhouse that cover the expenses of production and secure worthy gains. Compared to the low yields under field conditions of Sudan that ranges between 23.81 - 35.71 tons/ha [14] the implementation of plastic house technology seems economically sound.

Table 4. Mean number of fruits per meter square, 20 weeks after transplanting, for four standard and two cherry tomato varieties under cooled plastic house conditions at two sites in Khartoum State, summer season 2007.

Variety	Fruits/ m^2	Site		Combined Means
		Site (1)	Site (2)	
Standard	Merel	207 d	222 d	214 d
	Sensie	210 d	215 e	212 d
	Chanoa	236 c	240 c	238 c
	Yusra	179 e	183 f	181 e
Cherry	Tomi	1107 b	1108 b	1107 b
	Elitrro	1249 a	1261 a	1255 a
SE ±		0.83	1.11	1.94
C.V %		0.63	0.32	0.71

Means with the same letters along each column and for each of the two tomato categories are not significantly different at (0.05).

Table 5. Mean fruits diameters (mm) for four standard and two cherry tomato varieties under cooled plastic house conditions at two sites in Khartoum State, summer season 2007.

Variety	Fr. Diameter(mm)	Site	
		Site (1)	Site (2)
Standard	Merel	54.78 b	56.00 b
	Sensie	57.30 ab	57.55 b
	Chanoa	59.6 ab	58.95 b
	Yusra	63.83 a	66.03 a
Cherry	Tomi	22.25 c	20.88 c
	Elitrro	24.73 c	22.92 c
SE ±		2.09	1.4
C.V %		10.91	7.29

Means with the same letters along each column and for each of the two tomato categories are not significantly different at (0.05).

Table 6. Fruit yield (kg/m2) 20 weeks after transplanting for four standard and two cherry tomato varieties under cooled plastic house conditions at two sites in Khartoum State, summer season -2007.

Variety	Fruit yield (kg/m^2)	Site		Combined Means
		Site (1)	Site (2)	
Standard	Merel	19.25 c	20.00 bc	19.63 b
	Sensie	19.50 c	19.50 c	19.50 b
	Chanoa	26.50 a	26.25 a	26.37 a
	Yusra	24.25 ab	24.00 ab	24.13 ab
Cherry	Tomi	21.25 bc	20.00 bc	20.63 b
	Elitrro	25.00 a	23.00 abc	24.00 ab
SE ±		0.56	0.66	1.53
C.V %		9.83	11.86	10.48

Means with the same letters along each column and for each of the two tomato categories are not significantly different at (0.05).

4. CONCLUSIONS

- The production of both normal and cherry sized tomato varieties under cooled plastic condition in Sudan as an offseason crop in summer resulted in good yields.
- The yields obtained in this study, compared to yields under field conditions of Sudan seem to be encouraging for the adoption of greenhouses for the offseason tomato production.
- Further detailed economic feasibility studies on tomato production under cooled plastic houses, as an offseason crop during summer months, need to be carried.

5. RECOMMENDATIONS

Based on the above mentioned conclusions:

- Cooled plastic houses can be used for production of off season tomato under Khartoum conditions and similar tropical conditions.
- Normal and cherry type tomatoes perform well and gave higher yields under cooled plastic house conditions.
- However, more information is needed about specifications suitable to local conditions and optimum production packages.

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