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# Effect of Planting Dates on Growth, Yield and Physiological Traits of Okra (*Abelmoschus esculentus* L. *Moench.*), and Field Evaluation for Heat Tolerance

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## ABSTRACT

In Egypt, okra is one of the most common summer vegetable crops. High temperature is affecting significantly on okra growth, yield and fruit quality. The purpose of this study was to examine the genetic diversity of fifteen okra cultivars grown at three different planting dates. The experiment was designed in a randomized complete block with spilt plot, incorporated three replications. In the 2018 and 2019 seasons, seeds of okra cultivars were planted on 1st March (normal), 1st April (slightly late) and 1st May (late). The results revealed that planting dates had a significant impact on growth and yield characteristics. All of the growth, yield, and yield components studied traits, *i.e.*, plant height, number of branches, number of pods per plant, fresh pod weight, total pod yield, as well as physiological trait, chlorophyll content index, were significantly reduced by late planting date on May 1st, which had extreme high temperature (> 46ºC). While relative cell injury (RCI%) increased significantly. The current study's findings indicate that relative cell injury (RCI%) could be used as an effective selection criteria for selecting the cultivars with lower value of (RCI%). Also, supports the hypotheses since some okra cultivars *i.e.*, Qena-1, Qena-2, Luxor, Qena-3 and Aswan have outstanding performance in high-temperature environments.

***Keywords:*** genotypes; okra; heat stress; thermostability.

## INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench.] is one of the most common summer vegetable crops, and it is largely consumed in Egypt due to its outstanding nutritional quality (Abdel-Fattah *et al*., 2020). Okra fruit is a valuable source of calcium, protein, carbohydrates, fats as well as vitamins such as A (retinol), B (thiamin, riboflavin, and niacin), and C (ascorbic acid) (Adiroubane and Letachoumanane, 1992). Also, in some Asian and African countries dried okra seeds used as an alternative for coffee, and the fruits are eaten fresh, frozen, dried or as pickles (Matlob *et al*., 1989; Hussein *et al*., 2011). In Egypt, Okra is cultivated in 4460.4 hectares producing 54051 tones, with a productivity of (12.12 ton/ha), and occupied the seventh producer country after India, Nigeria, Mali, Sudan, Iraq, Cote d'Ivoire (FAO, 2014).

Currently global climate change is regarded as the most serious environmental threat, and it is causing significant concern among farmers, researchers, and policymakers due to its significant impact on the agriculture sector and food safety (Hasanuzzaman *et al*., 2013). Plant response to abiotic stress (salinity, drought, and heat) is depends on several factors such as intensity and duration of exposure, plant age and growth stage, and genotype (Nuruddin *et al*., 2003; Ripoll *et al*., 2016; Grozeva *et al*., 2018; Bashandy and El-Shaieny, 2021). Heat stress is one of the most acute environmental stresses, which has pronounced adverse effects on plant growth and development (Soliman *et al*., 2011; 2012). The impacts of high temperature are presumed to excess cellular injuries, leading to cell death, which can occur as a result of a heinous collapse of cellular organization. Additionally, heat stress usually leads to many morphological, physiological, biochemical and molecular changes in plants (Bita and Gerats, 2013). High temperature, day length, and light intensity, which have pronounced adverse effects on grown vegetables in the summer season in Egypt, particularly in Upper Egypt. Generally, when plants are exposed to high temperature, the seed germination, number of leaves, branches, and stem were decreased. Also, extremely heat stress causes scorching and burning of different plant parts. Besides that, heat stress inhibits shoot and root growth, discoloration of fruit fibroses, and, finally, yield losses and death of the plant. Furthermore, photosynthesis and respiration processes in plants were affected by heat stress, which can lead to decrease plant productivity and diminish the life cycle. Several documents confirmed that extreme heat has a negative impact on plant growth, which can result from various damages such as enzymatic hydrolysis, protein synthesis inhibition, increased liquidity of membrane lipids, and protein denaturation. (Howarth, 2005; Soliman *et al*., 2011). Also, heat stress causes varied irregularities of flower such as tiny flower, lessening conjunction in reproductive organs, weakness of pollen grains produced of the anther, and stigma execration in case of opened flowers (Brown and Zeiher, 1998). Physiological and agro-morphological effects of high-temperature have been studied previously, the investigations have revealed that heat stress have a significant impact on the morphological, physiological, and proteomic processes of okra plants, reducing photosynthetic

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rate, damaging plasma membrane structure, and hastening the ageing process. Recently, six okra varieties were evaluated under different planting dates by (Abdel-Fattah *et al.*, 2020). In okra, the reproductive stage is acutely vulnerable to changes in the external conditions, and exposure to both heat and drought stress during this stage minimizing agricultural yields. (Mousa *et al.*, 2012; El-hag and Ahmed, 2014; Abdel-Fattah *et al.*, 2020). Okra grows better when temperature was above 26°C, especially in arid and semi-arid regions with warm nights (>20°C), and executes good when its reproductive phase coincides with the average day temperatures of 25–35 °C, Whereas, heat waves (temperatures > 42 °C) during the flowering and pod-filling stages cause damage to reproductive organs, leading to flower drop, pollen inability, pod fall and reducing the total No. of seeds in okra, causing growth and yield losses (Incalcaterra and Vetrano, 2000; Tripathi *et al.*, 2011; Ahmad *et al.*, 2016; Hayamanesh *et al.*, 2016). Many investigations reported that various genotypes of a single plant species demonstrate high levels of variation for heat tolerance; hence, the selection of varieties with high thermo-tolerance. Thus, the goal of this study was to evaluate the growth and yield attitude of 15 lady's finger cultivars at three different planting dates in Qena Governorate.

## MATERIALS AND METHODS

### Experimental site and experimental design

Field experiments were done during 2018 and 2019 growing seasons at the Agricultural Experimental Farm of Horticulture Department, Faculty of Agriculture, South Valley University, Qena (latitude 26° 11' 22.2" N to Longitude 32° 44' 25.5" E and at an elevation of 81 m above sea level). Average monthly temperature degree maximum and minimum of Qena, Egypt were listed in Figure 1. The soil was sandy loam, having pH 8.0. The soil contents of NPK and some micronutrients were 0.015 mg/kg (total N), 3.41 mg/kg (P), 114 mg/kg ($K^+$), and OM 0.74%. The experiments were positioned using a split-plot design with three replicates. The planting dates were distinguished in the main plots, with three different planting dates, viz., normal planting date (1st March), slightly late planting date (1st April) and late planting date (1st May), whereas lady's finger cultivars were allotted to the sub-plots.

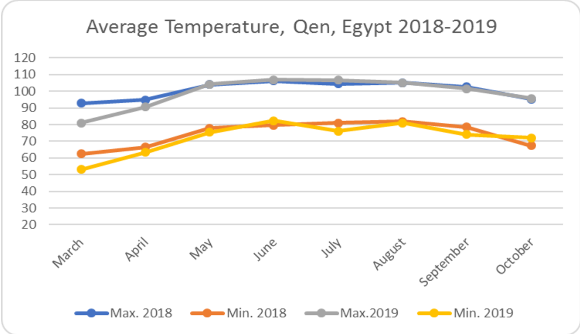


**Fig. 1. Monthly temperature degree °F maximum and minimum of Qena, Egypt**

### Plant materials and growth conditions:

Seeds of the 15 lady's finger cultivars were collected from different locations of Egypt and were used in the present study (Table 1). The experimental site was prepared as recommended for okra planting, according Egyptian Ministry of Agriculture. Phosphorus was applied during soil preparation at a rate (357.14 kg/ha), in the form calcium super phosphate (15.5 %, $P_2O_5$), while three doses of N (357.14 kg/ha), in the form of ammonium nitrate (33.5 % N), and K (120 kg/ ha), in the form of potassium sulphate (48% $K_2O$), were applied at different stages i.e. one dose at vegetative growth (one month after sowing), second dose at the beginning of flowering phase and the third dose was applied when the crop managed to the stage of pod formation. Okra seeds were sown in three rowed 3.5 m long and 3 m width, subplots in which space between the hills was 0.70 m while space within the hills was 0.30 m. Plants were thinned out after 14 days from sowing to one seedling per hill. All the recommended practices required for agronomic and plant protection purpose was done as recommended by Egyptian Ministry of Agriculture.

**Table 1. Morpho-agronomic characterization based on qualitative descriptors of 15 okra (*Abelmoschus esculentus* (L.) Monach) cultivars.**

| Code | Cultivars | Original place of collection* | Morpho-agronomic characterization | | | |
|---|---|---|---|---|---|---|
| | | | Leaf Color | Fruit Color | Stem Color | Flower Color |
| C 1 | Matrouh | Matrouh, Egypt | Light Green | Light green | Light Green | Yellowish |
| C 2 | Qena 1 | El Maana, Qena, Egypt | Light Green | Green | Green | Yellow |
| C 3 | Giza 1 | El-Saaf, Giza, Egypt | Light Green | Red | Red | Yellow |
| C 4 | Giza 2 | El Ayaat, Giza, Egypt | Light Green | Light green | Green | Yellow |
| C 5 | Luxor | Esna, Luxor, Egypt | Light Green | Dark green | Green | Yellow |
| C 6 | Qena 2 | Dandara, Qena, Egypt | Light Green | Dark green | Green | Yellow |
| C 7 | Qena 3 | Nag-Hammadi, Qena, Egypt | Light Green | Dark Green | Green | Yellow |
| C 8 | Sohag | El-Monshaa, Sohag, Egypt, | Light Green | Dark green | Green | Yellow |
| C 9 | Aswan | Komombo, Aswan, Egypt | Light Green | Dark green | Green | Yellow |
| C 10 | Assuit | El-Badary, Assuit, Egypt | Light Green | Green | Green | Yellow |
| C 11 | Beni Suef | El-Fashan, Beni Suef, Egypt | Light Green | Green | Green | Yellow |
| C 12 | El Minia | Bani Mazar, El Minia, Egypt | Light Green | Green | Green | yellow |
| C 13 | Alexandria | Alexandria, Egypt | Light Green | Light green | Light Green | Yellowish |
| C 14 | Mansoura | Mansoura, Dakahlia, Egypt | Light Green | Light green | Light Green | Yellowish |
| C 15 | Damietta | Damietta, Egypt | Light Green | Light green | Light Green | Yellowish |

*** all collections were obtained by Prof. A. M. Rashwan, Horticulture department, Faculty of Agriculture, South Valley University, Qena, Egypt**

### Data collection:

The following vegetative parameters were measured for okra plants at flowering and harvesting stages: days to flowering, plant height, number of branches/plant, number of fresh pods/plant, average fresh pods length, pod diameter, fresh pods weight/plant, dry pods weight per plant, total pod yield, and leaf area index.

Relative chlorophyll content index (SPAD) was used for measuring the relative leaf greenness (level of chlorophyll) in okra leaves using SPAD chlorophyll meter (SPAD-502 plus, Konica Minolta, INC., Osaka, Japan).

Relative cell injury (RCI %) was used to determine cellular membrane stability. The cell stability was determined by measuring conductivity of the solutions before and after boiling using a conductivity meter (Cyberscan100; Iuchi, Tokyo, Japan) as described previously (Soliman and El-Shaieny, 2014). RCI % was calculated from conductivity's readings as:

$$RCI\% = [1-(T1/T2)/(1-C1/C2)]\times 100.$$

**Statistical Analysis**

Data obtained in this study were analyzed using the Statistix 8.1 statistical software package (Statistix 8.1., 2003), data analysis was performed combined for two growing seasons. Means were compared using Tukey's test at the 0.05 probability level. Correlation coefficients (Pearson's) were calculated by multivariate analysis for three different planting dates, the correlation significances were tested at the 0.05 probability level. The cluster analysis was carried out based on Euclidean distance of the three different planting dates. Principal component analysis (PCA) was performed using R programme (R Core Team 2020) to determine the multivariate ordination of 12 morphological and physiological traits of 15 okra cultivars at each planting date.

## RESULTS AND DISCUSSION

**Results**

**Morphological and yield attributes responses of 15 okra cultivars to different planting dates**

The analysis of variance (ANOVA) showed significant differences among cultivars for all traits under normal , slightly late and late planting dates in both seasons (Table 2). Furthermore, a highly significant variation ( $P < 0.001$) was observed for all traits among three different planting dates. The analysis also revealed significant Cultivars × Planting Dates interactions for all the traits at both seasons and combined analysis.

**Table 2. Analysis of variance (ANOVA) for different traits among 15 okra cultivars growing under three planting date during 2018–2019 seasons.**

| Source | DF | PH | NB | LAI | FPL | NFP | FPW | TFY | FPD | DM | CCI | RCI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2018 | | | | | | |
| Planting dates(PD) | 1057.82$^{**}$ | 10188.10$^{**}$ | 86.90$^{**}$ | 5.52$^{**}$ | 2.41$^{**}$ | 5586.61$^{**}$ | 631109.10$^{**}$ | 1524.812$^{**}$ | 32.72$^{**}$ | 47.28$^{**}$ | 569.41$^{**}$ | 214.58$^{**}$ |
| Cultivars (C) | 171.54$^{**}$ | 3826.71$^{**}$ | 7.14$^{**}$ | 2.39$^{**}$ | 26.50$^{**}$ | 135.89** | 14246.67$^{**}$ | 41.652$^{**}$ | 95.65$^{**}$ | 57.28$^{**}$ | 86.93$^{**}$ | 6.72$^{**}$ |
| PD × C | 13.713$^{**}$ | 39.64$^{**}$ | 0.651$^{**}$ | 0.10$^{**}$ | 0.32$^{**}$ | 16.02** | 1397.45$^{**}$ | 6.91$^{**}$ | 1.33$^{**}$ | 1.57$^{**}$ | 1.78$^{**}$ | 1.24$^{**}$ |
| | | | | | | 2019 | | | | | | |
| Planting dates(PD) | 1090.86$^{**}$ | 10164.91$^{**}$ | 83.46$^{**}$ | 5.26$^{**}$ | 3.89$^{**}$ | 5407.77$^{**}$ | 639686.75$^{**}$ | 1552.23$^{**}$ | 32.09$^{**}$ | 48.13$^{**}$ | 585.67$^{**}$ | 222.75$^{**}$ |
| Cultivars (C) | 121.02$^{**}$ | 3801.92$^{**}$ | 7.70$^{**}$ | 2.56$^{**}$ | 25.34$^{**}$ | 129.31$^{**}$ | 14961.52$^{**}$ | 43.52$^{**}$ | 106.43$^{**}$ | 54.88$^{**}$ | 91.29$^{**}$ | 6.10$^{**}$ |
| PD × C | 14.04$^{**}$ | 36.974$^{**}$ | 0.56$^{**}$ | 0.11$^{**}$ | 0.39$^{**}$ | 19.87$^{**}$ | 1470.36$^{**}$ | 7.34$^{**}$ | 1.334$^{**}$ | 1.19$^{**}$ | 2.00$^{**}$ | 1.52$^{**}$ |
| | | | | | | combined | | | | | | |
| Planting dates(PD) | 1073.80$^{**}$ | 10176.20$^{**}$ | 85.17$^{**}$ | 5.39$^{**}$ | 3.09$^{**}$ | 5497.53$^{**}$ | 635388.00$^{**}$ | 1538.36$^{**}$ | 32.39$^{**}$ | 47.69$^{**}$ | 569.11$^{**}$ | 218.62$^{**}$ |
| Cultivars (C) | 143.89$^{**}$ | 3812.20$^{**}$ | 7.38$^{**}$ | 2.48$^{**}$ | 25.84$^{**}$ | 131.97$^{**}$ | 14590.60$^{**}$ | 42.52$^{**}$ | 92.33$^{**}$ | 55.79$^{**}$ | 87.16$^{**}$ | 6.36$^{**}$ |
| PD × C | 12.44$^{**}$ | 37.30$^{**}$ | 0.59$^{**}$ | 0.10$^{**}$ | 0.29$^{**}$ | 17.61$^{**}$ | 1422.60$^{**}$ | 7.10$^{**}$ | 1.33$^{**}$ | 1.26$^{**}$ | 1.85$^{**}$ | 1.34$^{**}$ |

**DF: days to flowering; PH: plant height; NB: number of branches per plant; NFP: number of fresh pods per plant; FPL: fresh pod length; FPD: fresh pod diameter; FPW: fresh pod weight; TFY: total pod yield; DM: dry matter; LAI: leaf area index; CCI: chlorophyll content index; RCI: cellular membrane stability. Significant difference at: ** $p < 0.001$.**

There was a wide range of variability among okra cultivars in morphological traits at both seasons (Table 3).

Days to flowering in 1st planting date ranged from 58.87 for El-Minia to 70.83 days for Qena-3 . For the slightly late planting date (1st April), days to flowering ranged from 51.00 days for Matrouh-1 , to 67.00 days for Luxor . Under heat stress as exposed by the late planting date, days to flowering ranged from 60.50 for Damietta to 72.33 for Qena-3, .

**Table 3. Growth parameters of okra cultivars as affected by different planting dates.**

| Okra Cultivars | Days to Flowering | | | | Plant height (cm) | | | | Number of branches | | | | Leaf area index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st March | 1st April | 1st May | Mean | 1st March | 1st April | 1st May | Mean | 1st March | 1st April | 1st May | Mean | 1st March | 1st April | 1st May | Mean |
| Matrouh | 70.96$^{EF}$ | 51.00$^{Y}$ | 60.83$^{Q}$ | 60.93$^{I}$ | 126.61$^{c}$ | 158.41$^{R}$ | 138.88$^{X}$ | 141.30$^{K}$ | 3.74$^{N}$ | 2.58$^{W}$ | 1.92$^{a}$ | 2.75$^{H}$ | 1.21$^{f}$ | 1.37$^{e}$ | 0.97$^{h}$ | 1.18$^{N}$ |
| Qena-1 | 70.17$^{G}$ | 58.12$^{T}$ | 65.73$^{L}$ | 64.67$^{F}$ | 98.03 i | 135.95$^{Y}$ | 117.92$^{f}$ | 117.30$^{O}$ | 7.09$^{A}$ | 4.55$^{I}$ | 3.07$^{S}$ | 4.90$^{A}$ | 2.14$^{R}$ | 2.62$^{K}$ | 1.91$^{W}$ | 2.22$^{G}$ |
| Giza-1 | 70.58 F | 60.50$^{Q}$ | 64.83$^{M}$ | 65.31$^{E}$ | 155.06$^{S}$ | 176.17$^{H}$ | 163.03$^{N}$ | 164.75$^{G}$ | 3.09$^{S}$ | 2.07$^{Z}$ | 1.90$^{a}$ | 2.35$^{K}$ | 1.70$^{b}$ | 1.80$^{Y}$ | 1.21$^{f}$ | 1.57$^{L}$ |
| Giza-2 | 63.21$^{N}$ | 55.67$^{V}$ | 60.67$^{Q}$ | 59.85$^{K}$ | 123.85$^{d}$ | 155.70$^{S}$ | 133.86$^{Z}$ | 137.80$^{L}$ | 3.40$^{Q}$ | 2.50$^{X}$ | 1.74$^{c}$ | 2.54$^{J}$ | 1.69$^{b}$ | 1.76$^{Z}$ | 1.13$^{g}$ | 1.53$^{M}$ |
| Luxor | 71.42$^{CD}$ | 67.17$^{JK}$ | 73.67$^{A}$ | 70.75$^{A}$ | 128.42$^{b}$ | 167.34$^{L}$ | 140.84$^{W}$ | 145.53$^{J}$ | 5.60$^{E}$ | 3.47$^{PQ}$ | 3.06$^{S}$ | 4.04$^{C}$ | 2.02$^{U}$ | 2.42$^{M}$ | 1.53$^{d}$ | 1.99$^{K}$ |
| Qena-2 | 71.17$^{DE}$ | 61.67$^{P}$ | 69.17$^{I}$ | 67.33$^{D}$ | 108.83$^{h}$ | 145.50$^{V}$ | 120.84$^{e}$ | 125.06$^{N}$ | 6.05$^{C}$ | 4.54$^{I}$ | 4.08$^{K}$ | 4.89$^{A}$ | 2.00$^{V}$ | 2.39$^{N}$ | 1.64$^{c}$ | 2.01$^{J}$ |
| Qena-3 | 72.33$^{B}$ | 66.00$^{L}$ | 70.83$^{EF}$ | 69.72$^{B}$ | 109.92$^{g}$ | 148.19$^{U}$ | 129.91$^{a}$ | 129.34$^{M}$ | 6.48$^{B}$ | 4.87$^{G}$ | 3.25$^{R}$ | 4.87$^{A}$ | 2.10$^{S}$ | 2.40$^{N}$ | 1.72$^{a}$ | 2.07$^{I}$ |
| Sohag | 71.75$^{C}$ | 61.50$^{P}$ | 69.67$^{H}$ | 67.64$^{C}$ | 145.82$^{V}$ | 177.04$^{G}$ | 160.59$^{P}$ | 161.15$^{I}$ | 5.45$^{F}$ | 4.43$^{J}$ | 2.88$^{U}$ | 4.25$^{B}$ | 2.90$^{F}$ | 3.16$^{C}$ | 2.03$^{U}$ | 2.70$^{C}$ |
| Aswan | 65.67$^{L}$ | 53.00$^{X}$ | 61.26$^{P}$ | 59.98$^{K}$ | 155.24$^{S}$ | 185.50$^{D}$ | 165.90$^{M}$ | 168.88$^{E}$ | 4.81$^{G}$ | 3.31$^{R}$ | 1.83$^{b}$ | 3.32$^{F}$ | 3.00$^{E}$ | 3.23$^{B}$ | 3.05$^{D}$ | 3.09$^{A}$ |
| Assuit | 64.50$^{M}$ | 54.80$^{W}$ | 60.50$^{Q}$ | 59.93$^{K}$ | 172.61$^{I}$ | 190.38$^{A}$ | 180.33$^{E}$ | 181.11$^{A}$ | 5.77$^{D}$ | 3.66$^{O}$ | 2.33$^{Y}$ | 3.92$^{D}$ | 3.23$^{B}$ | 3.58$^{A}$ | 2.05$^{T}$ | 2.95$^{B}$ |
| Beni Suef | 71.17$^{DE}$ | 63.00$^{N}$ | 67.51$^{J}$ | 67.22$^{D}$ | 151.05$^{T}$ | 178.83$^{F}$ | 160.91$^{P}$ | 163.60$^{H}$ | 5.81$^{D}$ | 4.00$^{L}$ | 2.00$^{Z}$ | 3.94$^{D}$ | 2.48$^{L}$ | 2.65$^{J}$ | 2.06$^{T}$ | 2.40$^{E}$ |
| El Minia | 62.50$^{O}$ | 54.83$^{W}$ | 58.87$^{S}$ | 58.73$^{L}$ | 155.11$^{S}$ | 180.33$^{E}$ | 161.67$^{O}$ | 165.71$^{F}$ | 5.56$^{E}$ | 3.50$^{P}$ | 2.28$^{Y}$ | 3.78$^{E}$ | 2.67$^{I}$ | 2.84$^{G}$ | 2.26$^{P}$ | 2.59$^{D}$ |
| Alexandria | 66.83$^{K}$ | 58.83$^{S}$ | 61.50$^{P}$ | 62.39$^{G}$ | 163.45$^{N}$ | 189.00$^{B}$ | 170.33$^{K}$ | 174.26$^{C}$ | 3.88$^{M}$ | 2.72$^{V}$ | 1.38$^{d}$ | 2.66$^{I}$ | 2.06$^{T}$ | 2.40$^{N}$ | 1.84$^{X}$ | 2.10$^{H}$ |
| Mansoura | 67.50$^{J}$ | 56.67$^{U}$ | 60.00$^{R}$ | 61.39$^{H}$ | 159.49$^{Q}$ | 187.83$^{C}$ | 171.50$^{J}$ | 172.94$^{D}$ | 4.67$^{H}$ | 2.98$^{T}$ | 1.37$^{d}$ | 3.01$^{G}$ | 2.34$^{O}$ | 2.69$^{H}$ | 2.05$^{T}$ | 2.36$^{F}$ |
| Damietta | 64.67$^{M}$ | 56.00$^{V}$ | 60.50$^{Q}$ | 60.39$^{J}$ | 165.71$^{M}$ | 190.33$^{A}$ | 175.50$^{H}$ | 177.18$^{B}$ | 4.08$^{K}$ | 2.53$^{WX}$ | 1.29$^{e}$ | 2.63$^{I}$ | 2.00$^{V}$ | 2.20$^{Q}$ | 1.76$^{Z}$ | 1.99$^{K}$ |
| Mean | 64.37$^{B}$ | 58.58$^{C}$ | 68.30$^{A}$ | | 141.28$^{C}$ | 171.10$^{A}$ | 152.80$^{B}$ | | 5.03$^{A}$ | 3.45$^{B}$ | 2.29$^{C}$ | | 2.24$^{B}$ | 2.50$^{A}$ | 1.82$^{C}$ | |

**Values followed by the same letter in the columns and in the rows are not significantly different at $P < 0.05$ according Duncan's test**

Under normal planting date (1st March), plant height ranged from 98.0. to 172.61 cm, for Qena-1 with the overall mean of 141.28 cm and from 135.95 to 190.38 cm, for Qena-1 and Assiut with a mean of 171.10 cm , for slightly late planting date . In late planting date, the plant height reduced by 5.28% for Assiut, and 16.95% for Qena-2 as compared with slightly late planting date. Cultivar Qena-1 produced the highest number of branches at normal planting date with 7.09 . Moreover, Qena-3 and Qena-1 cultivars obtained the highest No. of branches/plant at slightly late and late planting dates ( 4.87, 4.55 and 3.25, 3.07 respectively). As presented in (Table 3), the least number of branches observed for plants was Damietta at planting late planting date ( 1.29).

The leaf area index showed significant differences due cultivars, planting dates and their interaction. Planting seeds of Assiut cultivar at slightly late planting date significantly increased leaf area index (3.58 cm) as compared to the other cultivars. The smallest value of leaf area index (0.97 cm) was achieved at 1$^{st}$ May planting date. The leaf area index reduced by 36.53 and 42.73 % in Assuit as compare with normal and slightly late planting dates, respectively (Table 3).

Regarding of pods length, the okra cultivar Qena-1 achieved the tallest pods at slightly late planting date with an average (9.69cm). The Mansoura and Alexandria recorded the shortest pods at late planting date (3.95 and 3.94cm). In addition, the length of pods reduced by7.90 and 7.43%, as compared with normal and slightly late planting date (Table 4).

Data presented in (Table 4) show that at 1$^{St}$ March planting date, the No. of fresh pods/plant ranged from 27.27 to 43.50 for Alexandria and Giza-1, the No. of fresh pods/plant decreased by 52.15% under late planting date and 42.78 % under slightly late planting date as compared with normal planting date. In contrast, planting cultivar Qena-1 at slightly late planting date increased significantly No. of fresh pods per plant (48.41) the cultivar Alexandria achieved the least No. of fresh pods per plant, when the plants sown in slightly late planting date ( 15.35).

Data in (Table 4). Showed that Planting okra cultivar Qena-1 at the normal planting date significantly increased average pod weight in (375.34 g), with an average ( 290.44 g) (Table4). Planting the okra cultivars, 'Damietta and Mansoura-2, at late planting date, recoded the lowest values (71.32 and 72.50 g) for weight of pods per plant respectively.

The studied okra cultivars, planting dates, and their interaction presented that, the total yield of fresh pods varied significantly (Table 4). Planting Qena-1 cultivar at slightly late planting date significantly increased total yield of fresh pods (19.41 ton/ha) and as compared with the other cultivars under study. The minimum yield of fresh pods was achieved by Mansoura and Damietta when planted at late planting date (1.16 ton/ha). The total yield reduced by 80.04% and 84.82% as compare with normal slightly late planting dates respectively.

**Table 4. Yield parameters of okra cultivars as affected by different planting dates.**

| Okra Cultivars | Average pod length (cm) | | | | No. of Fresh pods | | | | Fresh pods weight/plant (g) | | | | Total Fruit yield ton/ha | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1$^{st}$ March | 1$^{st}$ April | 1$^{st}$ May | Mean | 1$^{st}$ March | 1$^{st}$ April | 1$^{st}$ May | Mean | 1$^{s}$ March | 1$^{st}$ April | 1$^{st}$ May | Mean | 1$^{s}$ March | 1$^{st}$ April | 1$^{st}$ May | Mean |
| Matrouh | 7.11$^{H}$ | 6.86$^{J}$ | 5.55$^{O}$ | 6.51$^{E}$ | 35.48$^{O}$ | 40.41$^{H}$ | 18.98$^{f}$ | 35.48$^{O}$ | 232.68$^{U}$ | 260.79$^{S}$ | 85.98$^{k}$ | 193.15$^{L}$ | 8.31$^{W}$ | 10.57$^{P}$ | 1.64$^{j}$ | 6.84$^{L}$ |
| Qena-1 | 9.24$^{B}$ | 9.69$^{A}$ | 9.20$^{B}$ | 9.38$^{A}$ | 39.75$^{I}$ | 48.41$^{B}$ | 25.68$^{Z}$ | 39.75$^{I}$ | 375.34$^{C}$ | 400.86$^{A}$ | 125.15 c | 300.45$^{A}$ | 14.92$^{F}$ | 19.41$^{A}$ | 3.21$^{c}$ | 12.51$^{A}$ |
| Giza-1 | 7.55$^{G}$ | 7.00$^{I}$ | 6.54$^{K}$ | 7.03$^{D}$ | 43.50$^{E}$ | 45.61$^{D}$ | 20.39$^{c}$ | 43.50$^{E}$ | 306.82$^{P}$ | 326.34$^{J}$ | 95.29$^{g}$ | 242.82$^{I}$ | 13.34$^{J}$ | 14.88$^{F}$ | 1.94$^{g}$ | 10.06$^{E}$ |
| Giza-2 | 5.28$^{P}$ | 5.00$^{Q}$ | 4.66$^{U}$ | 4.98$^{H}$ | 30.75$^{V}$ | 39.87$^{I}$ | 18.83$^{fg}$ | 30.75$^{V}$ | 288.77$^{R}$ | 310.83$^{N}$ | 89.89 ij | 229.83$^{K}$ | 8.88$^{V}$ | 12.39$^{M}$ | 1.70 i | 7.66$^{K}$ |
| Luxor | 8.60$^{E}$ | 9.00$^{C}$ | 8.81$^{D}$ | 8.80$^{B}$ | 35.04$^{P}$ | 45.80$^{C}$ | 23.33$^{a}$ | 35.04$^{P}$ | 300.04$^{Q}$ | 345.27$^{F}$ | 114.58$^{d}$ | 253.30$^{E}$ | 10.51$^{Q}$ | 15.82$^{E}$ | 2.67$^{f}$ | 9.67 F |
| Qena-2 | 7.14$^{H}$ | 7.84$^{F}$ | 7.53$^{G}$ | 7.50$^{C}$ | 33.54$^{R}$ | 38.88$^{K}$ | 21.35$^{b}$ | 33.54$^{R}$ | 310.67$^{N}$ | 351.71$^{E}$ | 128.83$^{b}$ | 263.74$^{D}$ | 10.42$^{R}$ | 13.67 I | 2.75$^{e}$ | 8.95 G |
| Qena-3 | 4.60$^{V}$ | 5.00$^{Q}$ | 4.81$^{S}$ | 4.80$^{I}$ | 34.74$^{Q}$ | 45.65$^{CD}$ | 29.00$^{X}$ | 34.74$^{Q}$ | 331.22$^{I}$ | 365.71$^{D}$ | 110.38$^{e}$ | 269.10$^{C}$ | 11.51$^{O}$ | 16.69$^{B}$ | 3.20 c | 10.47$^{B}$ |
| Sohag | 5.92$^{M}$ | 6.00$^{L}$ | 5.54$^{O}$ | 5.82$^{F}$ | 32.34$^{T}$ | 40.70$^{G}$ | 18.34$^{h}$ | 32.34$^{T}$ | 308.12$^{O}$ | 343.71$^{G}$ | 100.97$^{f}$ | 250.93$^{F}$ | 9.97$^{T}$ | 13.99$^{G}$ | 1.85$^{h}$ | 8.60$^{H}$ |
| Aswan | 4.60$^{V}$ | 5.00$^{Q}$ | 4.78$^{ST}$ | 4.79 I | 37.68$^{L}$ | 41.10$^{F}$ | 19.26$^{e}$ | 37.68$^{L}$ | 323.82$^{L}$ | 385.85$^{B}$ | 155.10$^{a}$ | 288.26$^{B}$ | 12.20$^{N}$ | 15.86$^{D}$ | 3.01$^{d}$ | 10.36$^{D}$ |
| Assuit | 4.60$^{V}$ | 4.21$^{Y}$ | 3.99$^{a}$ | 4.27$^{L}$ | 41.01$^{F}$ | 49.50$^{A}$ | 19.92$^{d}$ | 41.01$^{F}$ | 313.03$^{M}$ | 335.61$^{H}$ | 90.77$^{hi}$ | 246.47 G | 12.84$^{K}$ | 16.61$^{C}$ | 1.81$^{h}$ | 10.42$^{C}$ |
| Beni Suef | 5.84$^{N}$ | 5.52$^{O}$ | 4.75$^{T}$ | 5.37$^{G}$ | 33.08$^{S}$ | 40.98$^{F}$ | 18.78$^{g}$ | 33.08$^{S}$ | 306.10$^{P}$ | 335.75$^{H}$ | 91.50$^{h}$ | 244.45$^{H}$ | 10.12$^{S}$ | 13.76$^{H}$ | 1.72$^{i}$ | 8.53$^{I}$ |
| El Minia | 5.03$^{Q}$ | 4.89$^{R}$ | 4.21$^{Y}$ | 4.71 J | 32.50$^{T}$ | 39.15$^{J}$ | 15.67$^{k}$ | 32.50$^{T}$ | 300.28$^{Q}$ | 324.86$^{K}$ | 89.77$^{j}$ | 238.31$^{J}$ | 9.76$^{U}$ | 12.72$^{L}$ | 1.41$^{k}$ | 7.96$^{J}$ |
| Alexandria | 4.32$^{X}$ | 4.08$^{Z}$ | 3.95$^{ab}$ | 4.12$^{M}$ | 27.27$^{Y}$ | 32.34$^{T}$ | 15.35$^{l}$ | 27.27$^{Y}$ | 226.70$^{W}$ | 237.87$^{T}$ | 79.32$^{l}$ | 181.30$^{M}$ | 6.18$^{b}$ | 7.69$^{Y}$ | 1.22$^{l}$ | 5.03$^{O}$ |
| Mansoura | 4.67$^{U}$ | 4.20$^{Y}$ | 3.94$^{b}$ | 4.27$^{L}$ | 32.12$^{U}$ | 37.34$^{M}$ | 16.00$^{j}$ | 32.12$^{U}$ | 213.52$^{Z}$ | 222.85$^{X}$ | 72.50$^{m}$ | 169.63$^{O}$ | 6.86$^{Z}$ | 8.32$^{W}$ | 1.16$^{m}$ | 5.45$^{M}$ |
| Damietta | 4.83 S | 4.44$^{W}$ | 3.98$^{ab}$ | 4.42$^{K}$ | 30.48$^{W}$ | 35.70$^{N}$ | 16.35$^{i}$ | 30.48$^{W}$ | 219.50$^{Y}$ | 229.33$^{V}$ | 71.32$^{n}$ | 173.38$^{N}$ | 6.69 a | 8.18$^{X}$ | 1.16$^{m}$ | 5.35$^{N}$ |
| Mean | 5.95$^{A}$ | 5.92$^{B}$ | 5.48$^{C}$ | | 34.62$^{B}$ | 41.43$^{A}$ | 19.81$^{C}$ | 34.62$^{B}$ | 290.44$^{B}$ | 318.44$^{A}$ | 100.0C | | 10.17$^{B}$ | 13.37$^{A}$ | 2.03$^{c}$ | |

**Values followed by the same letter in the columns and in the rows are not significantly different at $P < 0.05$ according Tukey's test**

Under normal planting date, pod diameter ranged from 10.40 to 22.53 mm, for Qena-2 and Qena-1 with the overall mean of 15.01 mm, at slightly late planting date the greatest pod diameter recoded by cultivar Qena-1 was 19.78 mm. In late planting date the pod diameter reduced by 11.26%, as compared with normal planting date (Table 5).

Cultivar Aswan recorded the highest percentage of dry matter (16.00%) at 1$^{st}$ March planting date (Table 5). Moreover, Aswan recorded the highest percentage of dry matter at slightly late and late planting dates ( 16.74 and 17.49%, respectively), The minimum dry matter content (6.80%) was observed when okra cultivars planted at normal planting date in cultivar Matrouh.

ANOVA analysis revealed that okra cultivars differed significantly in terms of chlorophyll content index (CCI) (Table 5). The values of CCI were ranging from (43.31 to 26.36) in case of cultivar Qena-1 and Damietta at normal and late planting dates respectively. Very high CCI was shown by cultivars like Qena-1 (43.31), Aswan (42.71), Qena-2 ( 41.35) and Qena-3 (40.68). On the other hand, cultivars Damietta (26.36), Mansoura (27.98), Alexandria (28.12) and Matrouh (29.32) showed the lowest values for (CCI) SPAD readings.

Data presented in (Table 5), indicated that the low RCI% reflected high cell membrane thermostability, whereas the high RCI% reflected low cell membrane thermostability. The mean values for RCI % of cultivars ranged from (19.42 to 87.57%). Above 80% RCI% level was observed in six okra cultivars; while it ranged from 70 to 80% in other nine cultivars. The results presented in (Table 5) indicted that RCI% was greater when plants exposed to heat stress at the late planting date, Qena-1 had a low RCI% (72.64%), resulted in high cell membrane thermostability.

**Table 5. Quality parameters of okra cultivars as affected by different planting dates.**

| Okra Cultivars | Fresh pod diameter (mm) | | | | Dry matter content % | | | | Chlorophyll index SPAD | | | | Relative cell injury % | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1st March | 1st April | 1st May | Mean | 1st March | 1st April | 1st May | Mean | 1st March | 1st April | 1st May | Mean | 1st March | 1st April | 1st May | Mean |
| Matrouh | 10.50 a | 10.37$^{b}$ | 10.00 c | 10.29$^{M}$ | 6.80$^{Y}$ | 9.68$^{RS}$ | 10.8$^{OP}$ | 9.10$^{K}$ | 35.37$^{R}$ | 32.53$^{Z}$ | 29.32$^{i}$ | 32.41$^{K}$ | 20.27$^{UVWX}$ | 43.16$^{R}$ | 82.19$^{C}$ | 48.54$^{D}$ |
| Qena 1 | 22.53$^{A}$ | 19.78$^{C}$ | 17.78$^{F}$ | 20.03$^{A}$ | 8.07$^{W}$ | 10.71$^{OP}$ | 12.68$^{J}$ | 10.49$^{G}$ | 43.31$^{A}$ | 40.23$^{F}$ | 38.31$^{K}$ | 40.62$^{A}$ | 19.47$^{Za}$ | 41.63$^{S}$ | 72.64$^{K}$ | 44.58$^{K}$ |
| Giza 1 | 17.00$^{G}$ | 15.80$^{K}$ | 13.00$^{W}$ | 15.27$^{E}$ | 6.83$^{Y}$ | 8.80$^{U}$ | 10.8$^{O}$ | 8.83$^{L}$ | 37.20$^{N}$ | 34.31$^{UV}$ | 31.20$^{c}$ | 34.24$^{H}$ | 19.85$^{XYZa}$ | 42.82$^{R}$ | 74.23$^{J}$ | 45.63$^{J}$ |
| Giza 2 | 11.77$^{Y}$ | 10.40$^{b}$ | 9.60$^{d}$ | 10.59$^{L}$ | 8.85$^{U}$ | 9.59$^{S}$ | 10.3$^{Q}$ | 9.58$^{I}$ | 36.72$^{O}$ | 33.71$^{X}$ | 30.21$^{e}$ | 33.55$^{J}$ | 20.68$^{U}$ | 48.00$^{L}$ | 87.57$^{A}$ | 52.14$^{A}$ |
| Luxor | 14.50$^{O}$ | 13.50$^{T}$ | 13.00$^{W}$ | 13.67$^{I}$ | 8.84$^{U}$ | 9.87$^{R}$ | 11.3$^{MN}$ | 10.02$^{H}$ | 40.37$^{E}$ | 37.40$^{M}$ | 33.61$^{Y}$ | 37.13$^{D}$ | 20.43$^{UV}$ | 46.55$^{M}$ | 82.76$^{B}$ | 49.91$^{B}$ |
| Qena 2 | 10.40$^{b}$ | 10.00$^{c}$ | 9.50$^{e}$ | 9.97$^{O}$ | 12.62$^{J}$ | 13.00$^{I}$ | 13.60$^{G}$ | 13.07$^{C}$ | 41.35$^{C}$ | 38.06$^{L}$ | 34.37$^{T}$ | 37.93$^{C}$ | 21.27$^{T}$ | 44.56$^{P}$ | 77.38$^{H}$ | 47.74 G |
| Qena 3 | 14.08$^{Q}$ | 13.50$^{T}$ | 13.00$^{W}$ | 13.53$^{J}$ | 11.49$^{M}$ | 13.25$^{H}$ | 14.25$^{F}$ | 13.00$^{C}$ | 40.68$^{D}$ | 36.45$^{P}$ | 32.31$^{a}$ | 36.48$^{E}$ | 21.38$^{T}$ | 45.55$^{N}$ | 77.25$^{H}$ | 48.06$^{EF}$ |
| Sohag | 15.00$^{M}$ | 14.50$^{O}$ | 14.00$^{R}$ | 14.50$^{F}$ | 10.63$^{P}$ | 11.93$^{L}$ | 12.66$^{J}$ | 11.74$^{D}$ | 39.55$^{G}$ | 35.38$^{R}$ | 30.12$^{f}$ | 35.02$^{G}$ | 21.13$^{T}$ | 45.53$^{N}$ | 77.08$^{H}$ | 47.92$^{FG}$ |
| Aswan | 14.75$^{N}$ | 14.25$^{P}$ | 13.38$^{U}$ | 14.13$^{H}$ | 16.00$^{C}$ | 16.74$^{B}$ | 17.49$^{A}$ | 16.74$^{A}$ | 42.71$^{B}$ | 38.48$^{J}$ | 35.27$^{S}$ | 38.82$^{B}$ | 19.92$^{WXYZ}$ | 43.92$^{Q}$ | 77.95$^{G}$ | 47.26$^{H}$ |
| Assuit | 21.75$^{B}$ | 19.25$^{D}$ | 18.75$^{E}$ | 19.92$^{B}$ | 14.75$^{E}$ | 15.28$^{D}$ | 15.80$^{C}$ | 15.28$^{B}$ | 38.79$^{H}$ | 36.22$^{Q}$ | 30.37$^{d}$ | 35.13$^{F}$ | 20.35$^{UVW}$ | 44.00$^{Q}$ | 75.46$^{I}$ | 46.60$^{I}$ |
| Beni Suef | 14.75$^{N}$ | 14.50$^{O}$ | 13.75$^{S}$ | 14.33$^{G}$ | 10.71$^{OP}$ | 11.30$^{MN}$ | 12.33$^{K}$ | 11.45$^{E}$ | 38.56$^{I}$ | 35.27$^{S}$ | 31.61$^{b}$ | 35.15$^{F}$ | 19.77$^{YZa}$ | 45.13$^{NO}$ | 78.93$^{F}$ | 47.94$^{FG}$ |
| El Minia | 16.75$^{I}$ | 16.25$^{J}$ | 15.75$^{L}$ | 16.25$^{D}$ | 10.25$^{Q}$ | 10.67$^{OP}$ | 11.24$^{N}$ | 10.72$^{F}$ | 38.26$^{K}$ | 34.31$^{UV}$ | 29.50$^{h}$ | 34.02$^{I}$ | 19.42$^{a}$ | 45.11$^{NO}$ | 81.22$^{D}$ | 48.58$^{D}$ |
| Alexandria | 16.93$^{H}$ | 16.75$^{I}$ | 16.25$^{J}$ | 16.64$^{C}$ | 8.84$^{U}$ | 9.25$^{T}$ | 9.89$^{R}$ | 9.33$^{J}$ | 34.36$^{TU}$ | 30.17$^{ef}$ | 28.12$^{k}$ | 30.89$^{L}$ | 20.08$^{VWXY}$ | 44.97$^{OP}$ | 79.63$^{E}$ | 48.22$^{E}$ |
| Mansoura | 13.75$^{S}$ | 13.25$^{V}$ | 12.75$^{X}$ | 13.25$^{K}$ | 8.50$^{V}$ | 8.96$^{U}$ | 9.34$^{T}$ | 8.93$^{L}$ | 33.81$^{W}$ | 29.82$^{g}$ | 27.98l | 30.54$^{M}$ | 19.72$^{YZa}$ | 45.15$^{NO}$ | 81.83$^{C}$ | 48.90$^{C}$ |
| Damietta | 10.75$^{Z}$ | 10.00 c | 9.25$^{f}$ | 10.00$^{N}$ | 7.48$^{X}$ | 8.18$^{W}$ | 8.89$^{U}$ | 8.18$^{M}$ | 34.29$^{V}$ | 28.57$^{j}$ | 26.36$^{m}$ | 29.74$^{N}$ | 19.51$^{Za}$ | 44.88$^{OP}$ | 81.30$^{D}$ | 48.57$^{D}$ |
| Mean | 15.01$^{A}$ | 14.14$^{B}$ | 13.32$^{C}$ | | 12.10$^{A}$ | 11.15$^{B}$ | 10.04$^{C}$ | 12.10$^{A}$ | 38.36$^{A}$ | 34.73$^{B}$ | 31.24$^{C}$ | | 20.22$^{C}$ | 44.73$^{B}$ | 79.13$^{A}$ | |

**Values followed by the same letter in the columns and in the rows are not significantly different at P < 0.05 according Tukey's test**

**Correlation of morphological yield attributes of different okra cultivars under heat stress**

The correlation data among variables under normal plating date were presented in (Table 6). The results revealed a highly significant positive correlation (*P*< 0.01) of total pod yield (TFY) with relative chlorophyll content index, dry matter, fresh pod weight, and number of pods per plant. Also, significant positive correlation was recorded between total pod yield and fruit pod diameter. However, total pod yield was negatively correlated with plant height. Days to flowering were significant positively correlated with relative chlorophyll content index. On the other side, plant height was negatively correlated with chlorophyll content, days to flowering and fresh pod length. Leaf area index was negatively correlated with days to flowering.

**Table 6. Pearson's correlation coefficients among growth, yield and yield attributes of 15 okra cultivars as affected by planting dates.**

| | CCI SPAD | DF | DM | FPD | FPL | FPW | LAI | NB | NFP | PH | RCI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | A- 1st March | | | | | |
| DF | 0.546* | | | | | | | | | | |
| DM | 0.774** | 0.212 | | | | | | | | | |
| FPD | 0.346 | -0.054 | 0.325 | | | | | | | | |
| FPL | 0.417 | 0.508* | -0.080 | 0.151 | | | | | | | |
| FPW | 0.920** | 0.4778 | 0.682** | 0.521* | 0.414 | | | | | | |
| LAI | 0.363 | -0.062 | 0.611* | 0.493 | -0.419 | 0.335 | | | | | |
| NB | 0.723** | 0.510* | 0.513* | 0.403 | 0.231 | 0.656** | 0.458 | | | | |
| NFP | 0.476 | 0.106 | 0.501 | 0.522* | 0.452 | 0.583* | 0.123 | 0.165 | | | |
| PH | -0.545* | -0.539* | -0.117 | 0.130 | -0.608* | -0.500 | 0.458 | -0.442 | -0.099 | | |
| RCI | 0.275 | 0.578* | 0.319 | -0.332 | 0.212 | 0.061 | 0.18 | 0.187 | --0.109 | --0.447 | |
| TFY | 0.805** | 0.333 | 0.664** | 0.619* | 0.486 | 0.910** | 0.269 | 0.492 | 0.863** | -0.355 | 0.021 |
| | | | | | | B- 1st April | | | | | |
| DF | 0.299 | | | | | | | | | | |
| DM | 0.647** | -0.056 | | | | | | | | | |
| FPD | 0.350 | 0.024 | 0.251 | | | | | | | | |
| FPL | 0.625* | 0.359 | -0.105 | 0.069 | | | | | | | |
| FPW | 0.967 | 0.327 | 0.650** | 0.371 | 0.513* | | | | | | |
| LAI | 0.346 | 0.029 | 0.675** | 0.569* | -0.249 | 0.372 | | | | | |
| NB | 0.666** | 0.491 | 0.541* | 0.244 | 0.300 | 0.658** | 0.507* | | | | |
| NFP | 0.711** | 0.238 | 0.392 | 0.485 | 0.481 | 0.705** | 0.224 | 0.375 | | | |
| PH | -0.567* | -0.277 | -0.017 | 0.146 | -0.692** | -0.506 | 0.397 | -0.476 | -0.377 | | |
| RCI | -0.230 | 0.079 | -0.075 | -0.561 | -0.102 | -0.245 | -0.359 | -0.091 | -0.266 | -0.191 | |
| TFY | 0.929** | 0.320 | 0.577* | 0.482 | 0.548* | 0.946** | 0.343 | 0.595* | 0.892** | -0.496 | -0.291 |
| | | | | | | C- 1st May | | | | | |
| DF | 0.389 | | | | | | | | | | |
| DM | 0.554* | 0.041 | | | | | | | | | |
| FPD | 0.248 | -0.112 | 0.335 | | | | | | | | |
| FPL | 0.755** | 0.579* | 0.017 | 0.019 | | | | | | | |
| FPW | 0.883** | 0.274 | 0.733** | 0.081 | 0.546* | | | | | | |
| LAI | 0.223 | -0.286 | 0.598* | 0.459 | -0.263 | 0.414 | | | | | |
| NB | 0.656** | 0.554* | 0.422 | 0.056 | 0.667** | 0.592* | -0.053 | | | | |
| NFP | 0.698** | 0.580* | 0.379 | 0.092 | 0.597* | 0.548* | -0.165 | 0.698** | | | |
| PH | -0.639* | -0.472 | -0.045 | 0.261 | -0.697** | -0.468 | 0.413 | -0.698** | -0.696** | | |
| RCI | -0.543* | -0.355 | -0.533 | -0.552* | -0.309 | -0.481 | -0.372 | -0.363 | -0.405 | 0.004 | |
| TFY | 0.907** | 0.472 | 0.621* | 0.107 | 0.656** | 0.888** | 0.170 | 0.728** | 0.867 | -0.663** | -0.507 |

**DF: days to flowering; PH: plant height; NB: number of branches per plant; NFP: number of fresh pods per plant; FPL: fresh pod length; FPD: fresh pod diameter; FPW: fresh pod weight; TFY: total pod yield; DM: dry matter; LAI: leaf area index; CCI: chlorophyll content index; RCI: cellular membrane stability. Significant difference at: ** *p* < 0.001.**

Under slightly late planting date, total pod yield was correlated positively ($P < 0.01$) with chlorophyll content index, fresh pod weight and number of fresh pods per plant. Furthermore, total pod yield had a significant positive correlation among dry matter, fresh pod length, number of branches. Total pod yield was correlated negatively with plant height and (RCI%).

Under late planting date, total pod yield was a highly significant positively correlated with relative chlorophyll content index, fresh pod length, fresh pod weight and number of branches. Moreover, total pod yield was positive correlated with dry matter. On the other hand, total pod yield with negatively correlated with plant height and RCI%. Plant height was negatively correlated among CCI, FPL, NB, and NFP. RCI% was negatively correlated among all variables except plant height.

**Multivariate analysis of morphological and physiological responses of different okra cultivars under different planting dates**

The principal component analysis (PCA) was applied on 3 planting dates, the data presented in (Table 7). Explain the variation obtained among 15 cultivars of okra for morphological and physiological traits. PCA recorded twelve PCs, out of which 3 PCs for each planting date revealed that the eigenvalue > 1 and 81.36% cumulative variability for the attributes at normal planting date, 78.40% for slightly late planting date and 82% for late planting date were seen in these three PCs for each one.

**Table 7. Eigenvalue, percentage of variability and cumulative variability**

| | 1st planting date | | | 2nd planting date | | | 3rd planting date | | |
|---|---|---|---|---|---|---|---|---|---|
| | **PC I** | **PC II** | **PC III** | **PC I** | **PC II** | **PC III** | **PC I** | **PC II** | **PC III** |
| Statistical variables | | | | | | | | | |
| Eigenvalue | 5.45 | 2.57 | 1.74 | 5.64 | 2.51 | 1.26 | 6.05 | 2.71 | 1.08 |
| Percent variability | 45.44 | 21.42 | 14.51 | 47.03 | 20.88 | 10.50 | 50.42 | 22.61 | 8.97 |
| Cumulative percentage | 45.44 | 66.85 | 81.36 | 47.03 | 67.91 | 78.40 | 50.42 | 73.03 | 82.00 |
| Traits | | | | | | | | | |
| DF | 0.241 | -0.364 | -0.178 | 0.161 | 0.227 | -0.224 | 0.238 | -0.247 | -0.383 |
| PH | -0.220 | 0.470 | 0.037 | -0.213 | 0.477 | -0.027 | -0.286 | 0.353 | -0.181 |
| NB | 0.316 | 0.002 | 0.230 | 0.314 | -0.011 | -0.427 | 0.337 | -0.109 | -0.013 |
| NFP | 0.280 | 0.151 | -0.389 | 0.338 | -0.025 | -0.273 | 0.344 | -0.125 | -0.090 |
| FPL | 0.208 | -0.325 | -0.459 | 0.236 | -0.397 | -0.309 | 0.310 | -0.235 | -0.175 |
| FPD | 0.225 | 0.369 | -0.241 | 0.209 | 0.341 | -0.394 | 0.069 | 0.396 | -0.548 |
| FPW | 0.409 | 0.018 | -0.011 | 0.400 | -0.029 | 0.061 | 0.346 | 0.169 | 0.351 |
| TFY | 0.393 | 0.098 | -0.219 | 0.407 | -0.025 | -0.099 | 0.392 | 0.033 | 0.154 |
| DM | 0.318 | 0.208 | 0.289 | 0.269 | 0.306 | 0.348 | 0.234 | 0.395 | 0.263 |
| LAI | 0.149 | 0.472 | 0.352 | 0.189 | 0.494 | 0.255 | 0.041 | 0.541 | 0.188 |
| CCI SPAD | 0.405 | -0.033 | 0.109 | 0.404 | -0.067 | 0.037 | 0.379 | 0.072 | 0.074 |
| RCI | 0.110 | -0.326 | 0.477 | -0.141 | -0.321 | 0.490 | -0.236 | -0301 | 0.474 |

**DF: days to flowering; PH: plant height; NB: number of branches per plant; NFP: number of fresh pods per plant; FPL: fresh pod length; FPD: fresh pod diameter; FPW: fresh pod weight; TFY: total pod yield; DM: dry matter; LAI: leaf area index; CCI: chlorophyll content index; RCI: cellular membrane stability. Significant difference at: ** $p < 0.001$.**

At the normal planting date, the three components PC1, PC2 and PC3 contributed 45.44, 21.42 and 14.51% of the total variation, respectively (Figure 2). The fresh pod weight, relative chlorophyll content index, total pod yield, number of branches, and dry matter recoded high on the PC1, while , leaf area index, plant height, fresh pod diameter recoded high on the PC2, relative cell injury, leaf area index, dry matter and number of branches were high in the PC3 (Table 7).The eigenvalue for PC1 was 5.45, 5.64 and 6.05 of 1st, 2nd and 3rd planting dates, respectively, and its percent variability was 45.44, 47.03 and 50.42%, for three different planting dates.

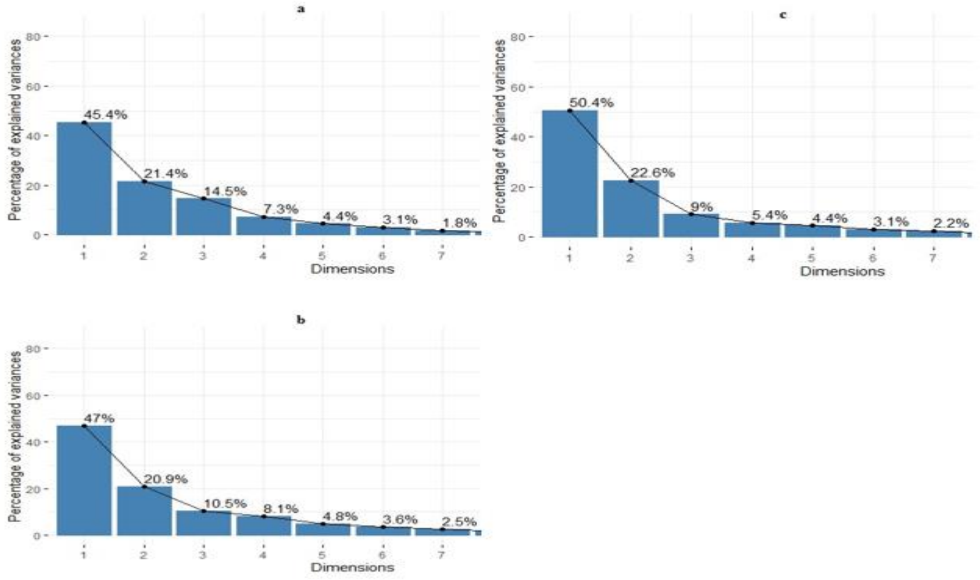


**Fig. 2. Scree plot for traits of okra cultivars under (a) first planting date, (b) second planting date and (c) third planting date.**

The correlations between the factors and variables was presented in (Table 7). The correlations (factor loading) were positive with days for flowering, number of branches, number of fresh pods, fresh pod length, pod diameter, fresh pod weight, total fresh pod yield, dry matter, leaf area index, chlorophyll content index, relative cell injury (RCI%), for normal, slightly late and late planting dates, except RCI% at normal planting date only. While negative attitude in case of plant height, in three different planting dates respectively, and RCI% in slightly and late planting dates. plant height recoded the highest negative value (-0.286), in late planting date (Table 7). Eigenvalue for PC2 was also higher than one *i.e.* 2.57, 2.51 and 2.71, in addition variability percentage was 21.42, 20.88 and 22.61 %, for the three different planting dates respectively. The cultivars of PC2 were positive for plant height, pod diameter, dry matter, leaf area index, in the three different planting dates. While, traits (number of branches, number of fresh pods ), were positive at the normal planting date, and fresh pod weight and total fresh pod yield were positive in the normal and late planting date. On the other side, chlorophyll content index (CCI) was positive in the late planting date only. While the PC2 revealed negative values in different planting date (Table 7). The values of PC3 were 1.74, 1.26 and 1.08 for three different planting dates respectively, while its variability was 14.51, 10.50 and 8.97 %. Cultivars residing in PC3 exhibited positive outcomes for plant height, number of branches, dry matter, leaf area index, chlorophyll content index and RCI% traits, for 1st planting date, and fresh pod weight, dry matter, leaf area index, chlorophyll content index and RCI%, for slightly late planting date. Fresh pod weight, total fresh pod yield, dry matter, leaf area index, chlorophyll content index and RCI% for late planting date. All the remaining traits achieved negative values, the highest negative value was observed by fresh pod diameter, pod length, and number of branches.

The cultivars Qena-1, Qena-3, Qena-2, and Beni Suef were grouped on a high number of branches per plant, while cultivars Assuit, Damietta and Alexandria were grouped based on high plant height. The cultivars Giza-1, Assuit and Qena-1 were grouped on a high number of fresh pod and total of fresh pod yield. The cultivars Qena-1, Luxor, and Giza-1 were grouped based on fresh pod length, while cultivars Qena-1, Qena-3 and Aswan were groped based on fresh pod weight. The cultivars Assiut, Aswan and Sohag were grouped based on leaf area index. The cultivars Qena-1, Aswan and Qena-2 were grouped based on high amount of chlorophyll, while cultivars Qena-3, Sohag and Giza-2 were grouped based on cell membrane injury.

Under the slightly late planting date, the cultivars Assiut, Damietta and Alexandria grouped on plant height, while cultivars Qena-3, Qena-1 and Qena-2 grouped on high number of branches per plant, the cultivars Giza-1, Assiut and Qena-1 were grouped on a high number of fresh pods, the cultivars Qena-1, Luxor and Qena-2 were grouped based on fresh pod length. While cultivars Qena-1, Qena-3 and Aswan were groped based on fresh pod weights. The cultivars Qena-1, Qena-3 and Assuit were grouped on total fruit yield, while, cultivars Assiut, Aswan and Sohag were grouped on high leaf area index. The cultivars Qena-1, Aswan and Luxor were grouped based on high amount of chlorophyll. The cultivars Sohag, Qena-2 and Alexandria were grouped based on cell membrane injury.

Under the late planting date, the cultivars Assiut, Damietta and Alexandria grouped on plant height, while cultivars Qena-2, Qena-3 and Qena-1 grouped on high number of branches per plant, the cultivars Qena-3, Qena-1 and Qena-2 were grouped on a high number of fresh pods, the cultivars Qena-1, Luxor and Qena-2 were grouped based on fresh pod length, while cultivars Aswan, Qena-2 and Qena-1 were groped based on fresh pod weight. The cultivars Qena-1, Qena-3 and Aswan were grouped on total fruit yield, while, cultivars Assuit, Aswan and Sohag were grouped on high leaf area index. The cultivars Qena-1, Aswan and Luxor were grouped based on high amount of chlorophyll. The cultivars Sohag, Qena-1, Qena-2 and Alexandria were grouped based on relative cell membrane injury.

One interesting contribution of the PCA score plot (Figures 3 and 4) is that the Qena-1, Qena-2, Luxor, Qena-3 and Aswan cultivars were placed very closely indicating that the responses of these cultivars to planting dates treatments were similar to somewhat. With regard to this fact that the origin of these cultivars is in the south of Egypt, it can be a concluded that the same climate and environmental conditions in this geographical area had similar effects on their reactions to heat stress, as an adaptation strategy over the years.

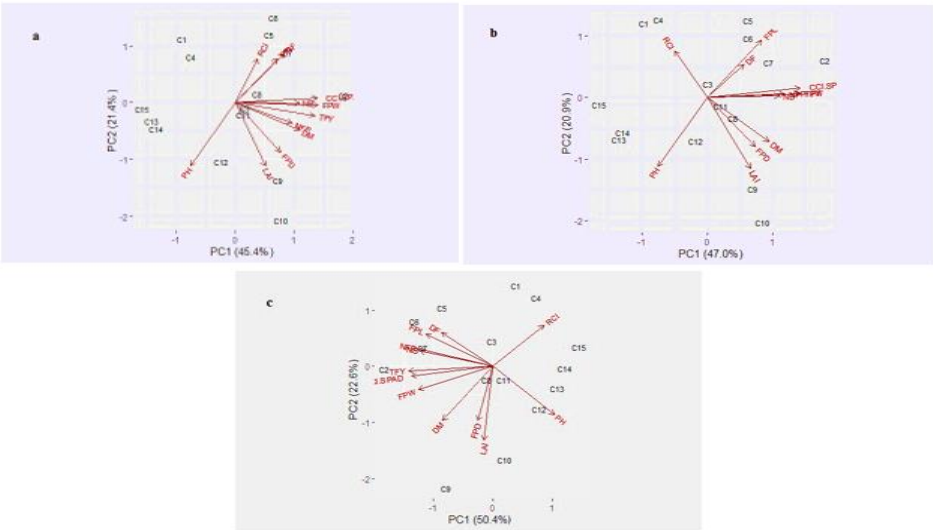


**Fig. 3. Principal component analysis PCA of agro-physiological traits of 15 cultivars under different planting dates (a) 1st March, (b) 1st April, and (c) 1st May.**

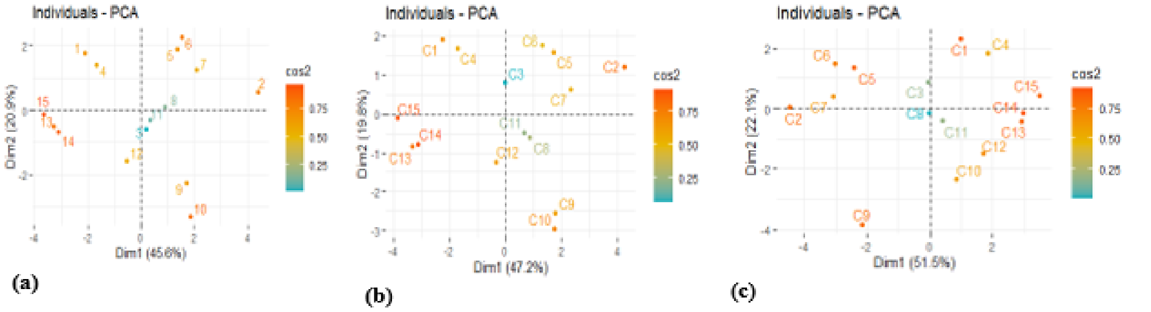


**Fig. 4. Individuals' Principal Component Analysis Pca of 15 Okra Cultivars Under Different Planting Dates (A) 1st March, (B) 1st April, And (C) 1st May.**

**Discussion**

okra is a summer season vegetable, the temperature ranged from 30 to 35°C is preferred for germination and 25 to 30 °C for growth and quality (Mousa *et al*., 2012; Abdel-Fattah *et al*., 2020). Furthermore, according to Upper Egypt weather mid-March is ideal for sowing seeds and growing okra in Upper Egypt, particularly in the Assiut region (Abdel-Fattah *et al*., 2020). Growing (Pusa Sawani cv) on March 15th had the highest growth metrics when compared to the other five cultivars examined. Dash *et al.* (2013) found that okra growth parameters were affected significantly by genotype and planting dates. Also, they indicated that growing okra during February increased growth and vigor of okra plants. However, sowing okra seeds during end of March significantly decreased growth parameters and had negative effect on days to flowering. Our findings showed that high temperature degree adversely affected plant height, number of branches, number of fresh pods, and total fresh pod yield, which reach agreement with numerous investigations in okra (Mousa *et al*., 2012; Dash *et al*., 2013; El-hag and Ahmed, 2014; Sood and Kaur, 2019; Abdel-Fattah *et al*., 2020), lentil (Kumar *et al*., 2016; El haddad *et al*., 2021; Kumar, 2021), cotton (Abro *et al*., 2015; Jamil *et al*., 2020), Faba bean (Abdelmula and Abuanja, 2007), and cowpea (Matoso *et al*., 2018). Heat stress reduced vegetative and reproductive phases by stimulating the rate of plant growth and development. Similar findings were reported in previous studies. Heat stress has been induced by global warming as a result of climate change, reducing agricultural yield, and no country is protected from it, Okra is very sensitive crop to the temperature. Poor fruit setting has been observed below 18°C and above 34°C (Hall, 2001). The result of the current study supports the hypotheses as some okra cultivars i.e., Qena-1, Qena-2, Luxor and Qena-3 were tolerant and less affected by the heat stress than the others. A substantial variation was recorded among the tested okra cultivars on growth, yield, and physiological traits. Dry matter content was significantly affected by heat stress of reason that extreme temperature induced modifications in physiological process or may be alter the pattern of development (Weaich *et al*., 1996). The origin of these cultivars is in the south of Egypt, it can be concluded that the same climate and environmental conditions in this geographical area had similar effects on their reactions to heat stress, as an adaptation strategy over the years. The data of the correlation among studied traits were significant positive or negative for the studied parameters of okra plants under different planting dates. Along with yield characteristics, it might be used as criteria for screening heat-tolerant plants in the field. The protein content begins to accumulate in plants leaves at 40 °C (Burke *et al*., 1985). Our results are in assent with the previous findings were found by (Abdel-Fattah *et al*., 2020; Ahmad *et al*., 2016; Asghar, 2016), they observed a positive correlations between DF and NB, PH and NPP, NPP and FPW and TFY. Furthermore, significantly positive correlation was recoded between FPW and TFY. On the contrary, significantly negative correlations were recorded between DF and NPP, FPW and TFY, when okra seeds planted on 15th March. While, in 15th April they found significant and positive correlations between DF and NB and between PH and NPP. In addition, significantly positive correlations were recorded between NPP and FPW and TFY. Highly significant and negative correlations were recoded between DF and NPP, FPW and TFY, and between NB and NPP, FPW and TFY. Also, (Akinyele *et al*., 2006; Chattopadhyay *et al*., 2011), noticed that there are a positive/negative correlations between growth parameters and yield and its components. Our study indicated that under late planting date, total fruit yield was a highly significant positively correlated with yield attributes characters and relative chlorophyll content. On the other side, Plant height (PH) was negatively correlated among CCI, FPL, NB, and NFP, and RCI% was negatively correlated among all variables except plant height. Heat tolerance in plants has been found to be strongly associated to photosynthesis, the plants with more photosynthesis recovering from heat stress effects rapidly (Xu *et al*., 2020). The photosynthetic system of plants may be damaged as a result of heat stress (Van der Westhuizen *et al*., 2020). The correlation analysis in this study revealed relative chlorophyll was associated with total fruit yield. The cultivars QENA-1, Luxor, Qena-2, Qena-3, and Aswan have a higher content of chlorophyll and have a high yield under the late planting date (Tripathi *et al*., 2011; Ahmad *et al*., 2016; Hayamanesh *et al*., 2016; Brengi, 2018). Reported that high temperatures are the most probable environmental variables to have a negative impact on pollination and fertilization. Okra growth and yield were affected by high temperatures of 40-42°C. Overall, the cultivars grown in the Upper Egypt region were more tolerant under high temperature as compared to the cultivars developed in the other regions with low temperature degrees. High average temperatures in such environment, as well as heat waves, cause flower shedding and decrease plant development. In tomato (Abdul-Baki, 1991), found that extreme temperatures for a short time can reduce respiration, impede photosynthesis, disrupt plant water status owing to high rate of leaf transpiration, and induce bud quality.

The results of the current investigation revealed that when the temperature was constantly raised, flower setting reduced. Cultivar Qena-1 had the least loss in chlorophyll concentration. Reduced fruit-set at higher temperatures was primarily exceptional due to low pollen viability, pollen production is reduced, and pollen tube development is weak, resulting in inadequate flower fertilization (Prasad *et al*., 2003). The result of this study displayed that all parameters were significantly affected by the heat stress, and reduced leaves size, induced CCI, NB, NPP, FPW, and TFY, and drastic decrease in DM%. Qena-1, Qena-2, Luxor, and Qena-3 (Figure 5) were the most heat tolerant cultivars, whereas Alexandria, Damietta, Mansoura, and Matrouh were the least.

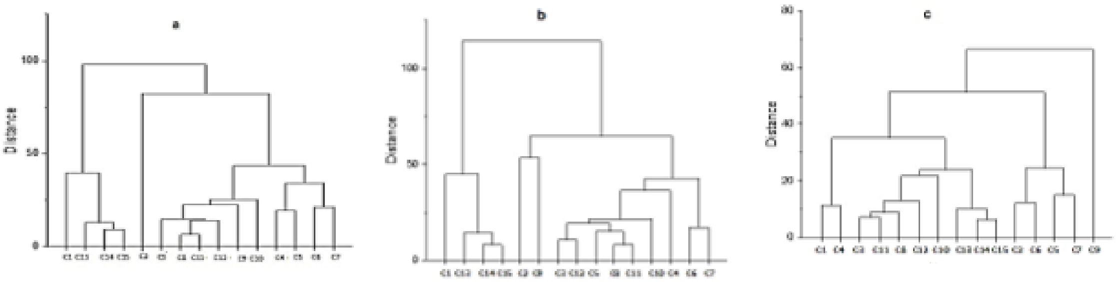


**Fig. 5. Clustering of 15 Okra Cultivars by Upgma Based on Euclidean Distance of 12 Morphological and Physiological Traits Response to Different Planting Dates.**

## CONCLUSION

High temperatures cause damages to the reproductive system of okra, resulting in a substantial reduction in yield and yield attributes. The current study indicates that heat stress has a significant impact on flower development and pod set in okra, resulting in a significant reduction in growth and yield. Under heat stress, the field screening approach has been shown to be a useful way of assessing and choosing promising lines. Adaptation through the selection of resilient genotypes can be a powerful tool for reducing the effects of climate change. Based on its morphological and physiological performance at high temperatures and high production in favorable environments, this study suggested okra cultivars Qena-1, Qena-2, Luxor, Qena-3 and Aswan, would be superior cultivars under unfavorable conditions, and an excellent source of heat stress tolerance and more adapted to climate change, which is a major concern impacting agriculture right now.

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**Conflict of Interest**

"The authors declare no conflict of interest".

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## تأثير مواعيد الزراعة علي النمو، والمحصول والصفات الفسيولوجية للباميا والتقييم الحقلي لتحمل الحرارة

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تعد الباميا من أكثر الخضروات الصيفية شيوعًا في مصر. درجات الحرارة المرتفعة تؤثر بشكل كبير على نمو، محصول وجودة الباميا. أجريت هذه الدراسة لفحص التنوع الوراثي لخمسة عشر صنفاً من الباميا تحت مواعيد زراعة مختلفة. صممت التجربة في تصميم القطاعات الكاملة العشوائية في قطع منشقة مرة واحدة، في ثلاث مكررات. زرعت بذور أصناف الباميا في ثلاث مواعيد هي: ١ مارس (عادي) ، ١ أبريل (متأخر قليلاً) و ١ مايو (متأخر) ، في موسمي ٢٠١٨ و ٢٠١٩. أظهرت النتائج أن مواعيد الزراعة كان لها تأثير معنوي علي صفات النمو والمحصول. أدت الزراعة المتأخرة في الأول من مايو والذي كانت درجة حرارته مرتفعة للغاية (> ٤٦ درجة مئوية) إلى انخفاض معنوي في كل من صفات النمو والمحصول ومكوناته، مثل ارتفاع النبات ، وعدد الأفرع ، وعدد القرون لكل نبات، ووزن القرون الطازج، والمحصول الكلي للقرون، وكذلك الصفات الفسيولوجية، حيث قل المحتوى النسبي للكلوروفيل (CCI)، بينما زادت نسبة الخلايا المتضررة (RCI٪) بشكل ملحوظ. تدعم نتيجة الدراسة النظرية الفرضية حيث أن بعض أصناف الباميا مثل قنا ١ وقنا ٢ والأقصر وقنا ٣ وأسوان تتمتع بأداء عالي في البيئات ذات درجات الحرارة العالية.

***الكلمات الدالة:*** التراكيب الوراثية، الباميا، الاجهاد الحراري، الثبات الحراري.