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RESPONSE OF SOME POTATO VARIETIES TO GROWTH AND PRODUCTION UNDER HIGH TEMPERATURE CONDITIONS: AN APPROACH TO IDENTIFY THE RESISTANT VARIETIES

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ABSTRACT: Potato is a winter crop; the optimal temperature range is 20-25°C for haulm growth and 15–20 °C for tuberization. Recently climatic changes, provoked the importance of adaptability of varieties to high temperatures. For this reason, a study was conducted during 2018 and 2019 seasons at Vegetables Research Farm in Kaha, Qualiobia Governorate, to test the response of some potato varieties (Cara, Spunta, Barcelona and Valor) for cultivation during the summer months (first July, first August, first September and first October). Data were recorded to measure vegetative growth at 75 DAPS while yield parameters were recorded at harvesting time. Concerning differences between planting dates, the results showed that the planting in October gave the best results for vegetative growth and yield in all tested varieties, while September plantation came the second place. Planting during July and August caused dramatic effects on vegetative growth and yield. Furthermore, the cv. Cara gave higher significant growth measurements (stem length, weight of tubers plant, fresh and dry total weight, CGR and RGR). Also, Cara gave also the highest stem number, leaves number, tubers number and close to that obtained from cv. Valor in both seasons. Cara variety produced the highest tuber yield and its components followed by Barcelona, and then Valor and Spunta, in both seasons. Moreover, the interaction between the tested varieties and planting dates showed that the most tolerant cultivars during the high temperature months (July and August) was Cara in the first place, then Valor and Barcelona in the second rank, while Spunta cv. was the most sensitive cultivar. In general, it is recommended for early potato planting in summer months (July and August) under Egyptian conditions the choice of varieties which exhibit tolerance to stresses as Cara, Valor or Barcelona and avoid planting susceptible varieties as Spunta in these months.

Key words: ***Potato, Varieties, High temperature, Cara, Spunta, Barcelona, Valor, RGR, CGR, Planting dates.***

INTRODUCTION

Potato is one of the most important foods and cash crops cultivated worldwide under a wide range of climatic condition. At present, it is the fourth most important food crop in terms of its production in the world, after wheat, rice and maize (FAO, 2018). In Egypt about 432 thousand feddans are cultivated in the three seasons (summer, fall and winter) produce about 5 million tons of potato tubers (E.M.A.S., 2017). Egypt exported 701 thousand tons of fresh potato tubers in 2019 (GAPQR., 2019).

Climate change is a serious threat to global food security, sustainable development and poverty eradication. Furthermore, heat stress due to increased temperature is an agricultural problem in many areas in the world (Birch *et al.,* 2012) especially in the last few years. However, temporary or constant high temperatures cause morpho-anatomical, physiological and

biochemical changes in plants, which affect plant growth and development as well as reduction in yields (Wahid *et al.,* 2007; and Hancock *et al.,* 2014).

Potato (*Solanum tuberosum* L.) is a winter crop and most commercial varieties are adapted for temperate climates; for this reason, potato crop has specific temperature requirements. Paul *et al*. (2016) reported that, high temperature had a deleterious effect on growth and metabolism of all the studied potato cultivars. The crop grows best in cool but frost- free seasons and does not perform well in hot climates (Hijmans, 2003). The limits and optimal values for the growth of the above-ground and under-ground parts are different (Marinus and Bodlaender, 1975; Struik *et al*., 1989 a, b; and Van Dam *et al.,* 1996). The optimal temperature range is 20–25°C for haulm growth and 15–20 °C for tuberization (levy and Veilleux, 2007 and Rykaczewska, 2015). Furthermore, during the bulking stage, potato plants growing under heat stress prefer to translocate assimilates to shoots rather than to storage organs (Menzel 1985; Randeni and Caesar1986; Wolf *et al*., 1990; and Gawronska *et al*., 1992). Moreover, the optimal yield for most commercial potato varieties is produced in average day time temperatures of 14-22 ^{o}C; higher temperatures lead to sharp yield decline. For example, at 27^{o}C, yield of variety Desiree dropped to 0% while for Spunta it reduced to about 15% of maximum yields (Hancock *et al*., 2013). Also, chlorophyll contents are affected by heat stress (Tang *et al.,* 2018). In the tropics and subtropics, heat is a major limiting factor in potato cultivation. However, there are reports of the existence of genetic variability for heat tolerance which could be exploited for cultivation in the tropics (Tai *et al.,* 1999, and Menezes *et al.,* 1999). Transitory or constant high temperatures cause an array of morpho-anatomical, physiological and biochemical changes, which affect plant growth and development and may diminished the yields (Wahid *et al.,* 2007; and Hancock *et al.,* 2014). Although, the adverse effects of heat stress on potato can be mitigated by developing heat tolerant cultivars (Levy *et al.,* 1991; and Veilleux *et al.,* 1997). Nevertheless, some commercial varieties exhibited high temperature tolerance (Rykaczewska, 2015; and Rykaczewska, 2016).

In Egypt, planting date in early autumn (fall) season is restricted by the high temperature in July and August. Furthermore, concerning the global warming in the last few years the recommendation is to delay cultivation of fall seasons to the end of September and beginning of October. For this purpose, this study was intended to examine the response of some potato varieties to growth and production under high temperature conditions and test the possibility of cultivation in early fall season.

MATERIALS AND METHODS

Experimental site

Field experiment was carried out at the Experimental Vegetable Res. Farm of Kaha, Al-Qalyubiyah Governorate, Horticulture Research Institute, Agriculture Research Centre, Egypt, during the two successive seasons of 2018 & 2019. The purpose of this experiment was to study the differential responses of some potato varieties for cultivation under high temperatures. The site of planting is located at an altitude of 21.1 m above sea level, latitude 30°16' N and longitude 31°12' E. with clay loam soil in texture. Chemical and physical properties of the experimental soil are shown in Table 1.

Table 1. The physical and chemical properties of the experimental soil*.

Physical Properties (%)	Seasons 2018	Seasons 2019	Chemical (available) (ppm)	Seasons 2018	Seasons 2019
Clay	61.52	60.28	N	82.80	90.28
Silt	17.73	18.98	P	5.25	4.98
Sand	20.75	20.74	K	200.12	189.46
Texture class	Clay loam		pH (1- 2.5 suspension)	7.50	7.42

*Soil chemical analysis was measured according to the procedures described by Jackson (1973).

Plant material

Four potato varieties were tested to grown under different responses to high temperatures are demonstrated in Table 2.

Climate data

Table (3) show maximum and minimum temperatures for Al-Qalyubiyah Weather Station form July to January for 2018/2019 and 2019/2020, respectively.

The experiment contained:

1. Planting dates *i.e.,* (First July, first August, first September and first October).
2. Four potato varieties (Valor, Cara, Barcelona and Spunta)

The treatments were arranged in a split plot design with three replicates, where time of planting and varieties were arranged as main and subplots, respectively.

The area of the experimental plots was 17.75 m^2 consisting of 5 ridges 5 m in length and 0.71 m in width whereas; one row was left without planting as a guard ridge between plots. The agricultural practices were conducted as recommended by Ministry of Agriculture and land Reclamation, Egypt.

- Vegetative growth data were recorded for main stems number, stem length, tubers number, leave area, leaf area index per plant and canopy fresh mass. Canopy dry mass was determined after oven-drying the samples at 70 ^{O}C until a constant dry weight. Three plants were randomly selected from each sub plot at 60 and 75 days after planting (DAP) for data recording.
- Some parameters of growth analysis were also determined as follows:

1- Crop Growth Rate (CGR).

Crop growth rate can be calculated by the following formula.

$$CGR = \frac{W_2 - W_1}{T_2 - T_1} \quad \text{(gm/week)}$$

(cited after Mahata *et al.,* 2018)

2- Relative growth rate (RGR).

Dry weight accumulated per unit of plant dry weight per unit of time. RGR is given by the formula:

$$RGR = \frac{(\ln w_2 - \ln w_1)}{T_2 - T_1} \quad \text{(gm/week)}$$

(cited after Mahata *et al.,* 2018)

Where: W_1 and W_2 are the total dry weight at times T_1 and T_2 respectively, and T_2-T_1 equals period in unit of time between the two consecutive samples.

- yield characteristics were recorded at harvesting time; yield data included number of produced tubers per plant, average tuber weight (g), tuber yield (kg/plant) and total yield (ton/fed.). As well as, Tuber dry weight was determined by drying the tuber slices at 70 ^{O}C until a constant dry weight according to the method of Dogras *et al.* (1991) and Starch content was determined using the method of AOAC (1990).

Table 2: List of varieties used in this experiment, showing origin and the maturity type*.

Varieties	Imported from	Heat resistance	Maturity
Valor	Scotland	Very high tolerance	Intermediate to late
Cara	Scotland	Tolerant	Late
Barcelona	France	Tolerant	Medium early
Spunta	Netherlands	Sensitive	Medium early

* https://www.europotato.org/

Table 3: Max and min air temperature (°C) during growing seasons in the years of study 2018/2019 and 2019/2020.

	First Season			Second Season		
Months	Max	Min	Average	Max	Min	Average
July	35.90	25.39	30.65	35.9	25.3	30.60
August	35.35	25.65	30.50	35.9	25.7	30.80
September	34.00	24.73	29.37	33.0	23.7	28.35
October	30.23	21.23	25.73	30.8	21.7	26.25
November	25.63	16.97	21.30	27.2	17.7	22.45
December	20.55	13.48	17.02	20.5	12.6	16.55
January	18.19	9.90	14.05	16.9	9.7	13.30

The obtained data were subjected for analyses of variance by Statistix 10 Statistical Software. Means were separated by LSD testing at 5% level.

RESULTS AND DISCUSSION

1.1. Plant growth measurements at 75 days after planting.

Temperature is one of the most important uncontrollable factors affecting growth and yield of potato. Data presented in Table 4 illustrate the difference between different planting dates for the tested varieties in autumn seasons under Egyptian conditions after 75 days of planting; Concerning the effect of planting date on stem length the planting in July resulted in the tallest plants followed by planting in August and then September, in both seasons. This result agreed with those reported by Rykaczewska (2015) who reported that high temperature caused an increase in stem length of potato plants. In addition, Bodlaender (1963), Benoit *et al*. (1983), Struik *et al.* (1989 a), Gawronska *et al.* (1992), Kooman and Haverkort (1995), Van Dam *et al.* (1996) and Rykaczewska (2013b) demonstrated that the increase in stem length was greater in plants exposed earlier to heat stress. It has been suggested that a high temperature and long day lead to increase of Gibberellin acid (GA_3) concentration in plants. Regarding the difference between varieties; Cara recorded the highest significant increases in stem length values comparing with other varieties, in both seasons. In the second place came Barcelona followed by Valor and Spunta in both seasons. These differences among cultivars are attributed to genetical factors.

The interactions between the two tested factors (planting dates and varieties) were significant; in both seasons. In July, Cara produced the tallest plants followed by Spunta compared with other interactions, in both seasons. This increment in stem length

could be resulted from the interactions between varieties and high temperature during the first stages of growth.

Table 4: Vegetative response of tested varieties for different planting dates after 75 days after planting in 2018/2019 seasons.

Planting Dates	Varieties	Stem length (cm)		Stems No./plant		Leaves No./plant		Tubers No./plant	
		2018	2019	2018	2019	2018	2019	2018	2019
First Jul.		59.25	56.67	1.50	1.33	28.42	30.83	2.50	2.92
First Aug.		50.92	48.58	2.08	1.83	40.75	42.33	3.92	4.42
First Sep.		46.83	43.42	2.92	2.50	56.33	60.50	5.75	6.42
First Oct.		39.92	37.17	3.50	3.08	75.42	78.50	7.42	7.92
L.S.D. at 5% level		2.11	0.69	0.34	0.38	1.75	2.69	0.46	0.85
	Cara	56.75	52.92	2.92	2.33	58.33	54.67	5.92	6.08
	Spunta	45.50	41.83	2.00	1.75	43.08	49.08	3.58	4.08
	Barcelona	49.00	46.92	2.33	2.00	48.75	51.25	4.33	5.17
	Valor	45.67	44.17	2.75	2.67	50.75	57.17	5.75	6.33
L.S.D. at 5% level		1.84	1.26	0.31	0.30	1.00	1.32	0.44	0.47
First Jul.	Cara	65.67	61.67	1.67	1.33	37.67	32.67	2.67	2.67
	Spunta	60.00	56.67	1.33	1.00	18.67	20.00	1.67	2.33
	Barcelona	55.33	53.33	1.33	1.33	28.00	32.67	2.00	2.67
	Valor	56.00	55.00	1.67	1.67	29.33	38.00	3.67	4.00
First Aug.	Cara	57.67	56.33	2.67	2.00	52.33	51.00	4.67	5.00
	Spunta	46.67	42.67	1.67	1.33	27.33	30.00	2.67	3.00
	Barcelona	52.67	50.33	1.67	1.67	40.00	43.00	4.00	4.67
	Valor	46.67	45.00	2.33	2.33	43.33	45.33	4.33	5.00
First Sep.	Cara	54.33	52.00	3.33	2.67	66.67	62.67	7.67	8.00
	Spunta	42.67	36.33	2.33	2.00	50.67	66.00	4.00	4.33
	Barcelona	48.00	45.67	3.00	2.33	54.67	52.67	4.67	6.33
	Valor	42.33	39.67	3.00	3.00	53.33	60.67	6.67	7.00
First Oct.	Cara	49.33	41.67	4.00	3.33	76.67	72.33	8.67	8.67
	Spunta	32.67	31.67	2.67	2.67	75.67	80.33	6.00	6.67
	Barcelona	40.00	38.33	3.33	2.67	72.33	76.67	6.67	7.00
	Valor	37.67	37.00	4.00	3.67	77.00	84.67	8.33	9.33

L.S.D. at 5% level	3.81	2.28	0.63	0.64	2.45	3.52	0.90	1.17

Regarding main stems number October planting date resulted in the highest number of main stems per plant followed by September, August and July planting dates came in the last place, in both seasons (Table 4). Furthermore, varietal differences were noted in number of main stems per plant. Potato Cara and Valor varieties produced higher stems number per plant than Barcelona and Spunta, in the both seasons. Also, the interaction between the two tested factors was significant. Cara and Valor varieties planted in October produced the highest number of main stems, in both seasons. However, for both seasons the lowest number of main stems produced by Spunta planted in the earliest planting date in July. The increase in main stems per plant in Cara and Valor varieties possibly due to the increase in the number of eyes on the tubers compared to Barcelona and Spunta. In addition, the length of the storage period may activate the buds on the tubers of some varieties than others (Tawfik, 1984).

Concerning the leaves number and tubers number per plant after 75 days of planting the two tested factors and the interactions between it exhibited significant differences (Table 4).

The differences between planting dates on leaves number and tubers number per plant indicate that the delayed planting date (October) enhanced production of higher leaves number and tubers number per plant, in both seasons. Planting in July resulted in the lowest leaves number and tubers number per plant, in both seasons. Cara variety produced the highest leaves number and tubers number per plant in the first season. However, insignificant differences between the average number of tubers per plant of Cara variety and volar variety were recorded, in this season. Furthermore, the interactions between planting in October and the four tested varieties produced the highest leaves number and tubers number per plant, in both seasons. However, Spunta planted in July recorded the lowest leaves number and tubers number per plant, in both seasons. The reduction in number of leaves and tuber number per Spunta plant might be due to the decrease in number of main stems per plant as well as the sensitivity of one variety to heat stress than other varieties, while, Cara and Valor varieties were less sensitive to heat stress than Spunta and Barcelona.

Data presented in Table 5 indicate that, planting in October resulted in the highest total fresh weight, tubers weight per plant, total dry weight and CGR followed by planting in September and August, in both seasons. However, Planting in July produced the lowest values of the mentioned parameters, in both seasons. This is may be due to the succession of morphological and physiological processes, each with its own optimal temperature.

Concerning planting dates, data tabulated in Table 5 show clearly that, the differences between the tested varieties has a significant effect on total fresh weight, tubers weight per plant, total dry weight and crop growth rate (CGR), in both seasons. The highest values after 75 day after planting were obtained by Cara variety compared with Spunta, Barcelona and Valor except the tuber weight per plant which showed the highest values with Barcelona variety, in the two seasons. The increments in total fresh weight, total dry weight per plant and CGR at 75 DAPS in Cara variety could be related to its tolerant to high temperature stress. These results are in agreement with Levy (1986) who reported variation in potato genotypes in response to high ambient temperatures.

Table 5: Vegetative response FW, DW and crop growth rate (CGR) of the tested varieties for different planting dates after 75 days after planting in 2018/2019 seasons.

Planting Dates	Varieties	Total plant F.W (g)		Tuber Weight/plant (g)		Total plant D.W (g)		CGR (g/week)	
		2018	2019	2018	2019	2018	2019	2018	2019
First Jul.		272.97	276.50	158.83	176.80	55.60	59.90	9.25	10.77
First Aug.		436.24	481.47	272.74	284.13	105.38	120.81	16.57	17.33
First Sep.		525.33	590.55	308.61	338.94	134.80	150.01	25.69	28.33
First Oct.		706.81	758.43	421.11	428.08	192.88	215.11	38.39	43.60
L.S.D. at 5% level		31.27	46.04	33.14	44.75	6.00	11.800	1.96	1.36
	Cara	496.27	545.71	272.85	294.89	127.45	133.92	26.54	27.61
	Spunta	411.21	446.81	251.23	245.17	108.03	117.78	20.55	21.97
	Barcelona	521.96	578.01	347.64	372.60	122.69	146.85	20.20	25.06
	Valor	511.91	536.44	289.55	315.28	130.51	147.28	22.61	25.40
L.S.D. at 5% level		37.87	35.23	18.86	33.98	4.54	5.56	2.12	1.97
First Jul.	Cara	339.23	341.21	170.14	210.15	71.32	69.45	14.08	12.50
	Spunta	186.59	189.75	77.24	51.99	46.24	42.98	5.00	6.34
	Barcelona	273.61	280.81	193.88	243.05	42.69	56.95	6.67	8.92
	Valor	292.44	294.22	194.05	201.99	62.15	70.20	11.25	15.33
First Aug.	Cara	432.29	467.51	279.85	273.26	95.87	101.20	23.25	24.92
	Spunta	255.47	289.79	150.34	143.35	62.98	77.60	12.27	14.79
	Barcelona	543.56	626.00	383.42	390.17	128.28	158.93	15.83	11.58
	Valor	513.64	542.59	277.33	329.74	134.40	145.52	14.92	18.04
First Sep.	Cara	550.43	639.75	260.50	315.83	147.14	155.62	26.42	29.67
	Spunta	493.68	553.87	313.17	320.00	129.38	139.97	23.67	23.75
	Barcelona	543.56	626.00	383.42	390.17	128.28	158.93	28.42	31.08
	Valor	513.64	542.59	277.33	329.74	134.40	145.52	24.25	28.83
First Oct.	Cara	663.12	734.36	380.92	380.33	195.45	209.40	42.42	43.33
	Spunta	709.09	753.81	464.17	465.33	193.50	210.57	41.25	43.00
	Barcelona	727.09	779.21	429.83	467.00	191.49	212.59	29.87	48.67

Valor	727.92	766.34	409.50	399.66	191.09	227.89	40.00	39.38
L.S.D. at 5% level	75.75	76.20	46.37	73.70	9.85	15.18	4.16	3.67

The effect of the interaction between varieties and planting dates on total fresh weight, tubers weight per plant, total dry weight and crop growth rate (CGR) were significant. The four tested varieties gave the highest total fresh weight, tubers weight per plant, total dry weight and CGR when planted in October; whereas, Spunta planted in July gave the lowest values of the previous characters at 75 DAP, in both seasons. These results are in accordance with those obtained by Lafta and Lorenzen (1995) who indicated that, the growth of potato plants was reduced at high temperature and recorded that transpiration rates were increased at the higher temperature.

Concerning relative growth rate (RGR) (Table 6) planting in October resulted in the highest significant RGR while planting in July produced the lowest one. Regarding, the effect of varieties on RGR; the highest RGR produced by Cara variety in both seasons. Cara and Valor potato varieties in the second season did not show any significant differences between their mean values in this character while Spunta gave the lowest RGR values, in both seasons. Furthermore, the interactions between varieties and planting dates gave significant effects on this parameter; Cara variety planted in October showed the most significant increases in this character, in both seasons. Otherwise, Spunta planted in July gave the lowest RGR values, in both seasons tested.

Regarding leaf area (LA), the planting dates caused significant effects on LA in both seasons. Planting in October gave the uppermost LA whereas planting in July resulted in the lowest LA values. However, the three varieties Cara, Valor and Barcelona produced significantly higher LA than Spunta in the first season. Although, insignificant differences were observed between the four tested varieties in (LA) at the second season. Concerning the effect of the interaction between varieties and planting dates on LA, data presented in Table 6 show that the highest LA produced by planting in October for the four tested varieties. However, the lowest values of LA were produced by Spunta planted in July or August, in both seasons.

From the data presented in Tables 4, 5, and 6 on vegetative growths, the effects of planting in early planting dates is related to high temperature. High temperatures are affecting membrane linked processes due to alterations in membrane fluidity and permeability (Alfonso *et al.,* 2001; Sangwan *et al.,* 2002). Also, enzyme function is also sensitive to changes in temperature; heat-induced alterations in enzyme activity which can lead to imbalance in metabolic pathways, or heat can cause complete enzyme inactivation due to protein denaturation (Vierling, 1991). High temperature causes loss of cell water content for which the cell size and ultimately the growth is reduced (Rodríguez *et al*, 2005; and Ashraf and Hafeez, 2004). Nevertheless, heat stress differentially affects the stability of various proteins, membranes, RNA species and cytoskeleton structures, and alters the efficiency of enzymatic reactions in the cell for which the major physiological processes obstacle, creates metabolic imbalance and damage to the photosynthetic apparatus (Ruelland and Zachowski 2010; and Taiz *et al.* 2015). Furthermore, Paul and Gogoi (2013) stated that, high temperature has a significant impact on the morphological and biochemical traits of potato. Also, (Wahid, 2007) on maize and millet and

(Srivastava *et al,* 2012) on sugarcane reported that, high temperature led to reduction in net assimilation rate (NAR) is also another reason for reduced relative growth rate (RGR). In addition to this Rodríguez *et al*, (2005) reported that, the morphological symptoms of heat stress include scorching and sunburns of leaves and twigs, branches and stems, leaf senescence and abscission, shoot and root growth inhibition. In some plant species growth under heat stress cause decrease in elongated stems and extended leaves and diminish in total biomass (Savin *et al*., 1997). In addition, Lafta and Lorenzen (1995) found that the transfer of plants from 19/17 to 31/29 ^{o}C achieved increment in transpiration rates at the higher temperature. Also, Gawronska *et al.,* (1992) reported that heat stress resulted in a significant reduction in total plant dry weight of all tested potato clones. Wolf *et al.,* (1990) indicated that, high temperature associated with a decrease in stomatal resistance, an increase in transpiration, and a larger difference between air and leaf temperatures. Dark respiration rates and compensation points for CO_2 concentration were also greater at the high temperatures. Also, vegetative growth data (Tables 4, 5, and 6) indicated that the four varieties of potatoes differed in their response to planting dates at July, August and September (high temperature) compared to the optimal planting dates (October). These results were in agreement with Levy (1986) who reported varietal differences between potato genotypes in response to high temperature. This could be correlated with the variation in the genetic makeup of the variety and its tolerance to high temperatures. Spunta variety was more sensitive to high temperature leading to significant reduction in vegetative growth at planting in July or August compared to the other tested verities (Cara, Valor and Barcelona). Furthermore, the decrease in the values of growth measurements in July and August triggered by the rise in temperatures, which causes an increase in the rate of transpiration and respiration, as the high temperature leads to the closing of the stomata and a decrease in the net photosynthesis process, which is reflected on the suppressive effects on plants comparing with planting in the optimum conditions in October cultivation.

Yield and its components at harvest time:

The obtained results according to the tubers yield (ton/ feddan) show significant differences between planting dates and the four tested varieties (Table 6). The planting in October resulted in the production of the highest tubers yield per feddan, whereas the least yield produced when planting in July. Furthermore, Cara variety came in the first place with the highest tubers yield followed by Barcelona, then Valor and Spunta tubers yield in both seasons. However, there is insignificant difference between Cara and Barcelona varieties, in this parameter.

Regarding the interactions between the two tested factors, planting Barcelona or Spunta in October produced the heaviest tuber yield per feddan, in both seasons. Although, planting Spunta in July caused the largest significant reduction in tubers yield.

Data of tuber yield per plant presented in Table (6) showed that planting dates caused dramatic effects on tuber yield per plant; planting in October gave the largest tuber yield per plant followed by planting in September and August, whereas planting in July caused the lowest yield per plant. Also, the same table reveal significant differences between the four tested varieties. Barcelona produced the highest tubers yield per plant in both seasons. However,

Spunta variety gave the lowermost yield per plant in both seasons. Significant effects were recorded for the interactions between the two tested factors; the highest significant tubers yield per plant produced when planting the Barcelona variety at October, in both seasons. Although, Barcelona and Spunta in the second season showed quite similar values with insignificant differences between their mean values in this parameter. In the meantime the lowest tuber yield per plant recorded in July planting date for Spunta, in both seasons.

Table 6: Relative growth rate (RGR), leaf area (LA), total yield per feddan and per plant of tested varieties and different planting dates at harvest 2018/2019 seasons.

Planting Dates	Varieties	RGR (g/week)		LA/ plant (cm^2)		Total yield (ton/Fed.)		Yield/plant (g)	
		2018	2019	2018	2018	2018	2019	2018	2019
First Jul.		0.0832	0.0864	3145.02	3150.64	2.853	2.950	327.443	309.658
First Aug.		0.1082	0.1038	3955.03	4618.36	5.140	5.053	408.730	443.475
First Sep.		0.1129	0.1087	6528.97	6807.54	10.692	10.212	646.710	610.950
First Oct.		0.1179	0.1305	8321.61	8442.61	16.737	16.282	824.683	823.093
L.S.D. at 5% level		0.004	0.007	634.56	458.18	0.310	0.442	11.80	27.74
	Cara	0.1188	0.1174	5977.67	6017.21	9.666	9.357	585.475	568.475
	Spunta	0.0931	0.0957	5058.88	5358.80	8.232	7.895	482.480	512.843
	Barcelona	0.1043	0.0999	5497.14	6024.94	9.478	9.270	598.958	575.883
	Valor	0.1061	0.1163	5416.93	5618.20	8.047	7.975	540.653	529.975
L.S.D. at 5% level		0.005	0.008	497.60	544.25	0.387	0.254	23.57	29.31
First Jul.	Cara	0.1033	0.0953	4010.30	3900.23	3.459	3.874	403.370	375.000
	Spunta	0.0513	0.0773	2119.73	2060.23	1.370	1.247	230.030	215.000
	Barcelona	0.0813	0.0810	3006.40	3175.20	3.292	3.340	396.700	378.330
	Valor	0.1033	0.0953	4010.30	3900.23	3.459	3.874	403.370	375.000
First Aug.	Cara	0.1027	0.1100	4692.60	5457.60	5.749	5.567	469.530	475.900
	Spunta	0.1030	0.1010	2912.93	3048.27	4.076	3.505	313.490	375.000
	Barcelona	0.1277	0.0810	3988.63	5043.30	5.367	5.640	430.030	458.330
	Valor	0.0997	0.1233	4225.93	4924.27	5.367	5.500	421.870	464.670
First Sep.	Cara	0.1227	0.1163	6563.60	6621.17	12.621	12.033	686.670	659.500
	Spunta	0.0973	0.0900	6444.33	6892.07	9.953	9.255	557.770	584.970
	Barcelona	0.1273	0.1050	6953.97	7191.80	11.057	10.660	676.200	608.000
	Valor	0.1043	0.1233	6153.97	6525.13	9.138	8.899	666.200	591.330
First Oct.	Cara	0.1467	0.1480	8644.17	8089.83	16.835	15.955	782.330	763.500
	Spunta	0.1207	0.1147	8758.53	9434.63	17.528	17.572	828.630	876.400

	Barcelona	**0.0810**	**0.1327**	**8039.57**	**8689.47**	**18.195**	**17.439**	**892.900**	**858.870**
	Valor	**0.1233**	**0.1267**	**7844.17**	**7556.50**	**14.390**	**14.160**	**794.870**	**793.600**
L.S.D. at 5% level		**0.010**	**0.016**	**1066.90**	**1046.00**	**0.737**	**0.622**	**42.46**	**57.72**

As illustrated in Table 7 significant differences between planting dates obtained. Planting in October gave the highest values of the average number of tubers per plant at harvest. On the other hand, significant varietal differences were observed in average tubers number per plant and average tuber weight. Valor cultivar was superior in tubers number per plant followed by Cara with insignificant differences between their mean values, in both seasons. While the interaction between planting date in October and cv. Valor achieve the highest value in number tubers per plant and followed by Cara, in both seasons as compared with the other tested interactions.

Data presented in Table 7 indicated that planting dates caused a significant difference in average of tuber weight. Planting in October or September resulted in the highest average tuber weight in the first season, while in the second season planting in October, September or August resulted in the highest average of tuber weight. Although, planting in July produced the lowest average of tuber weight, in both seasons. Concerning the difference between potato varieties in average of tuber weight (Table 7), data clear that, Barcelona recorded the heaviest average tuber weight, whereas Valor recorded the lowest one, in both seasons.

Regarding the interaction between planting dates and varieties in the first season; Barcelona planted in September and Spunta planted in October recorded the highest average tuber weight compared with the other interactions. In the second season, Spunta variety planted in October gave the highest value in average tuber weight.

Concerning the effect of planting dates on tubers dry weight and starch content at harvest time (Table 7) planting in July or August resulted in the lowest dry weight and starch content than planting in September or October, in both seasons. Furthermore, varieties showed significant differences in tuber dry weight and starch content at harvest time, in both seasons. Data indicated that, Cara and Barcelona produced the highest dry weight and starch content in tubers at harvest time, whereas Spunta formed the lowest values of both characters, in both seasons. Concerning the interactions effect between planting date and varieties results show that planting in October for all varieties gave significantly higher dry weight and starch content in tubers at harvest time. Nevertheless, the interactions between Spunta and the two earlier planting dates (July or August) produced the lowest dry weight and starch content in tubers at harvest times in the first and the second seasons.

The potato has long been considered as a cool weather crop best suited for the temperate climates although yields decline during the hot and dry seasons even in Europe, America and Australia (Gilbert, 1920). The superiority in the yield of Cara potatoes could be attributed to strength of the variety growth and tolerance for cultivation during the months of July and August; this is obviously shown in the vegetative growth data presented in Tables (5 and 6). Whereas, the reduction in the yield of Spunta variety when planting in July or August could be due to susceptibility of

Spunta variety to high temperature during the vegetative stage. As well as, the reduction in vegetative growth during planting in July or August might be also due to the disturbance in metabolic activities, which might be affected by the increase in evapotranspiration and disturbance of mineral balance. A similar phenomenon was observed by Ahn *et al.* (2004) indicate a lack of high tolerance of cultivar Desirée to high temperature during the growing season compared to Russet Burbank, Atlantic and Norchip varieties. Also, these results are in agreement with those reported by Lafta and Lorenzen (1995) who reported that, tuber growth was reduced under high temperatures in two cultivars.

Table 7: At harvest, yield components, dry weight of tubers and starch content of the tested varieties planted at different dates during 2018 and 2019 seasons.

Planting Date	Variety	Tubers No./plant		Average tuber weight (g)		Tubers D.W (g)		Tubers starch content (g)	
		2018	2019	2018	2019	2018	2019	2018	2019
First Jul.		3.25	3.39	101.85	93.87	67.42	61.46	9.33	8.22
First Aug.		3.64	4.19	114.72	110.61	80.83	85.90	10.93	11.28
First Sep.		5.42	5.72	124.74	108.80	123.88	114.35	16.16	14.47
First Oct.		6.80	7.22	125.62	117.42	149.59	147.97	19.34	18.48
L.S.D. at 5% level		0.28	0.26	11.21	11.76	2.11	5.28	0.53	0.37
	Cara	5.42	5.72	106.46	96.92	117.56	111.32	17.56	16.10
	Spunta	3.61	4.11	127.96	121.72	86.59	91.73	11.16	11.34
	Barcelona	4.42	4.75	138.15	124.64	113.90	106.97	13.99	12.90
	Valor	5.67	5.94	94.35	87.43	103.66	99.67	13.05	12.10
L.S.D. at 5% level		0.31	0.29	7.87	12.78	4.34	5.89	0.63	0.81
First Jul.	Cara	3.78	4.00	105.78	94.58	88.55	80.99	14.07	12.21
	Spunta	2.33	2.67	98.81	81.17	43.77	39.50	5.80	5.14
	Barcelona	3.22	2.89	126.10	130.14	80.07	70.69	9.75	8.56
	Valor	3.67	4.00	76.69	69.58	57.28	54.67	7.68	6.95
First Aug.	Cara	4.00	4.44	110.20	103.41	93.08	96.35	14.47	14.03
	Spunta	2.67	3.00	120.36	135.78	57.86	69.14	7.81	9.20
	Barcelona	3.78	4.33	125.58	110.33	89.50	88.83	10.64	10.54
	Valor	4.11	5.00	102.72	92.93	82.86	89.28	10.79	11.33
First Sep.	Cara	6.67	6.44	101.48	94.24	137.37	122.38	20.47	17.74
	Spunta	4.10	4.66	135.92	126.13	101.13	105.41	13.15	13.00
	Barcelona	4.33	5.44	159.67	121.62	128.21	118.73	14.75	13.76
	Valor	6.56	6.33	101.87	93.21	128.79	110.86	16.28	13.36
First Oct.	Cara	7.22	8.00	108.37	95.44	151.25	145.55	21.25	20.42
	Spunta	5.33	6.10	156.73	143.79	143.59	152.85	17.86	18.01

	Barcelona	6.33	6.33	141.24	136.45	157.81	149.63	20.82	18.72
	Valor	8.33	8.44	96.13	94.01	145.72	143.86	17.44	16.77
L.S.D. at 5% level		0.60	0.57	17.60	25.01	7.80	11.46	1.20	1.45

The higher total yield and its components of all variety tested in planting date September and October were likely due to the more favorable conditions for potato tuber development during the stages of tuber formation. In the contrarily, planting date in July give the lowest total yield and its components at harvest in the two tested seasons. This could be related to the high temperature prevailing during the formation of tubers. These results are similar to those stated by Rykaczewska (2015) who indicated that, the high temperature during the growing season had a negative effect on the final yield. Furthermore, the reduction in tubers number per plant under high temperature in July and August months could be attributed to the reduction in vegetative growth, as well as, number of stolen. These results are in agreement with those obtained by Hasanuzzaman *et al.,* 2013, Mittler and Blumwald 2010, and McClung and Davis 2010. Moreover, heat stress affects all aspects of plant processes like germination, growth, development, reproduction and yield. As well as, high temperature increases the rate of dark respiration in plants Bushnell (1925). Also, at high temperatures (above 17 ^{o}C) tuberization diminishes (Reynolds and Ewing, 1989). High temperatures inhibit tuber initiation (Minhas *et al*., 2006 and Paul *et. al.,* 2016). Nevertheless, potato tuber initiation and development are much more sensitive to high temperature stress than photosynthesis (Reynolds and Ewing, 1989). Although, potato can give good yield even at day temperatures of 30-35 ^{o}C provided night temperatures are below 18 ^{o}C (Minhas & Kumar, 2005). But if night temperature goes beyond 22 ^{o}C tuberization is decline even when the day temperature is 25-27 ^{o}C. So heat tolerance in potatoes is concerned more with the minimum night temperature than the maximum day temperature (Burton, 1996; and Stäubli et al., 2008).

RECOMMENDATIONS

The obtained results demonstrated that Cara potato variety is the most tolerant against high temperature followed by Barcelona and Valor ranked as the second tolerant variety whereas Spunta is the least tolerant variety. As a conclusion, it is recommended for early potato planting in summer months (July and August) under Egyptian conditions the choice of varieties which exhibit tolerance to stresses as Cara, Valor or Barcelona and avoid planting susceptible varieties as Spunta in these months.

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إستجابة بعض أصناف البطاطس للنمو والإنتاج تحت ظروف الحرارة العالية (نهج لتحديد أصناف مقاومة)

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الملخص العربى

البطاطس محصول شتوي حيث ينمو المجموع الخضري بشكل جيد في درجات حرارة بين ٢٠ – ٢٥ درجة مئوية، بينما تحتاج الدرنات لحرارة تتراوح بين ١٥ – ٢٠ درجة مئوية لتنمو بشكل جيد. حديثا أظهرت التغيرات المناخية أهمية تأقلم الأصناف النباتية للحرارة المرتفعة. لذلك أجريت دراسة في ٢٠١٨، ٢٠١٩ بمزرعة بحوث الخضر بقها قليوبية لاختبار قدرة بعض أصناف البطاطس (كارا – سبونتا – برشلونة – فالور) للزراعة خلال أشهر الصيف (أول يوليو – أول أغسطس – أول سبتمبر – أول أكتوبر) وتم أخذ البيانات الخضرية عند ٧٥ يوم بعد الزراعة. كما تم تقدير المحصول ومكوناته وبعض مواصفات الجودة عند الحصاد. أظهرت النتائج أن الزراعة خلال شهر أكتوبر يليه في المرتبة الثانية شهر سبتمبر أعطوا أفضل نتائج للنمو الخضري والمحصول في كل الأصناف المختبرة في حين تأثر النمو الخضري والمحصول عند الزراعة خلال شهري يوليو واغسطس. على الجانب الآخر صنف بطاطس كارا أعطى زيادة معنوية في قياسات النمو (طول الساق، وزن الدرنات للنبات، الوزن الكلي الطازج والجاف، معدل النمو المحصولي، معدل النمو النسبي). بينما أعطى أعلى القيم في عدد السيقان، عدد الاوراق، عدد الدرنات خلال الموسم الأول في حين تفوق صنف بطاطس فالور في الموسم الثاني في هذه الصفات. كما حقق الصنف كارا يليه الصنف برشلونة أفضل النتائج في المحصول ومكوناته مقارنة بالأصناف سبونتا وفالور. كما أن التفاعل بين الأصناف المختبرة ومواعيد الزراعة أظهر أن أكثر الأصناف تحملا للزراعة خلال أشهر الحرارة المرتفعة (يوليو وأغسطس) هو صنف كارا في المرتبة الأولي ثم صنفي فالور وبرشلونة في المرتبة الثانية أما صنف سبونتا فكان أكثر الأصناف حساسية للزراعة خلال أشهر الحرارة المرتفعة.

بشكل عام، فمن المستحسن لزراعة البطاطس في أشهر الصيف (يوليو وأغسطس) في ظل الظروف المصرية اختيار الأصناف التي تظهر تحملا للحرارة كما في صنف كارا و فالور أو برشلونة وتجنب زراعة الأصناف الحساسه للحرارة المرتفعة كما في صنف سبونتا خلال هذه الأشهر.

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