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Influence of Treatment with Different Levels and Periods of Temperature on Dormancy and Sprouting of Tubers of Some Potato Varieties

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***Abstract* - This research was carried out in order to study the effect of heat treatment on the dormancy of the tubers of potato varieties Spunta, Synergy, and Panela. Potato tubers were stored at 4°C for two weeks. Tubers were exposed to temperatures (15, 20, and 25°C) during four periods (0, 1, 2, 3 weeks). The completely randomized design (CRD) was used in the experiment, with three replicates for each treatment, and each replicate consisted of one kg of tubers.The results showed that all treatments were superior to the control in all the studied traits. Spunta variety outperformed the other studied varieties in the speed of dormancy breaking by 30 days, in the number of sprouts on the tuber by 2.50, in the number of sproutsper the sample by 12.99, in the number of apical sprouts by 11.28, in the average daily growth of 0.30 cm per day, in the total weight of the sprouts/tuber by 11.50 g, as well as in the total weight of the sprouts per sample by 57.50 g / kg.While the variety Synergy was superior in the number of basal sprouts by 2.30. On the other side, the highest temperature (25° C) was superior to the rest of the temperatures in all studied traits, also the longest storage period (3 weeks) outperformed the other periods of storage in all studied traits. In general, the interaction of the Spunta variety with the highest temperature (25°C) and the longest storage period (3 weeks) was superior to the overall studied traits.**

Keywords: Spunta, Synergy, Panela, Potato, Sprouting, Tuber Dormancy, Temperature Treatment.

I. INTRODUCTION

The potato is one of the most economically important and most widely spread vegetable crops, as it is the third food crop grown globally after wheat and rice, and comes first in the volume of production among root and tuber crops. Potatoes are grown in more than 150 countries around the world from the latitude 65° north to 50° south latitude, and from sea level to 4000 m above sea level. There have been great developments in the potato sector all over the world, as global production increased from 38.5 million tons at the beginning of the sixties of the last century to about 10 times in 2019, with the global area planted with potatoes doubling by up to 3 times during the same period. The annual global production reached of the potato crop, 370 million tons (in 2019) were planted on an area of 17.34 million hectares, with an average yield per unit area of 21.36 tons/ha. The average annual per capita consumption of potatoes was 31.3 kg/person/year. China topped the world with a production of about 91.88 million tons in an area of 4.91 million hectares. As for the average productivity per unit area, the USA topped the list with a value of 50.31 tons/ha (FAO, 2019). In Syria, the potato crop is cultivated on an area of an estimated 24000 hectares distributed over three seasons, the autumn season constitutes more than 50% of the cultivated area (AASG, 2019).

When potato tubers mature and reach their final sizes, they enter a deep inner dormancy phase, during which tuber sprouts are not able to germinate even under the right conditions (Lang et al., 1987; Van-Ittersum, 1992; Struik and Wiersema, 1999). The duration of dormancy is usually 6-15 weeks, the length of the period depends largely on genetic factors (species or variety), and to a small extent on the conditions accompanying the stage of growth of the tubers (Davidson, 1958; Wurr and Allen, 1976; Burton, 1978). Temperature, humidity, photoperiod during growth and storage are important environmental factors that regulate sprout behavior (Uwe, 2001; Ezekiel and Singh, 2003). Tuber maturity at harvest, harvest injuries or diseases and pests, and treatment with dormancy compounds also play a role in the length of dormancy (Aksenova et al., 2013; Muthoni et al., 2014; Draie and Al-Absi 2019).

Temperature treatment is one of the treatments used to break the dormancy phase of potato tubers, and the known temperature treatments are high temperature and cold shock with heat. In the high temperature treatment, the tubers are kept in a dark room at a temperature of 18-25° C until sprouting begins. In the cold shock treatment with heat, the tubers are placed at 4 °C for two weeks or more, and then at

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18-25 °C until bud sprouting occurs (CIP, 1989; Deligios et al., 2020).In a study conducted by Nasiruddin et al. (2016) with the aim of determining the importance of heat treatments in breaking the dormancy phase in potato tubers, the tubers were washed and then placed at 4° C for two weeks and then at 18-25° C until sprouting is complete. The results showed that the temperature treatments were superior in the number of days until the start of sprouting (22.75 days in the heat treatment and 28.75 days in the control), the number of total sprouts (4.75 in the heat treatment and 0.5 in the control), average length of sprout (3.1 cm in the heat treatment and 0.18 cm in the control), and the number of days for sprouting of 80% of the tubers (38.5 days in the heat treatment and 64.25 days in the control). The effect of heat treatment also differed according to the variety to which the treatment was applied, where the Diamond variety outperformed the other varieties (Cardinal, Granula, Asterix) in all the studied traits with significant differences.

In view of the importance of planting potatoes in the autumn season, which constitutes more than 50% of the total cultivated area in Syria, and farmers' use of spring season tubers as seeds before the end of their dormancy phase in planting the autumn season, the importance of the research is reflected in finding an easy, effective and economic way to end the dormancy in the tubers intended for planting in the autumn season. Accordingly, in this research, we will test the effect of heat treatment (15, 20 and 25° C) and the length of storage period (0, 1, 2, and 3 weeks) in breaking the dormancy of tubers of some locally grown potato varieties.

II. MATERIALS AND METHODS

2.1 Experimental Location

The study was carried out in the agricultural season 2019, in Idlib countryside, where tubers were transferred after treatment to special rooms with low lighting and high humidity, with temperatures that vary according to the treatment.

2.2 Plant Materials

Three varieties are used in this research:

- Spunta: a medium early-ripening Danish variety, with elongated tubers, large size, smooth surface, short dormancy period and very shallow eyes.
- Panela: a fast-growing and ripening Dutch variety, the tubers are large elongated spherical.
- Synergy: a variety imported from a French company. Its tubers are elongated, medium to large size, with a medium dormancy period.

2.3 Experimental Design and treatments

The research was carried out on three potato varieties, which are Spunta, Synergy, and Panela. Where the tubers were stored at temperatures of 4 °C for a period of two weeks, and then they were transferred to special rooms and exposed to temperatures (15, 20, 25 °C) and during periods (0, 1, 2, 3 weeks), with low lighting and high humidity. The complete randomized design (CRD) was used in the experiment with 3 replicates per treatment and each replicate was one kg tubers. Consequently, the total number of treatments used in the experimentation = 3 varieties x 3temperature levels x 4 treatment periods x 3 replicates = 108 treatments (108 kg potato tubers).

2.4 Measured Parameters

The following measurements were taken:

- The number of days until sprouting on tubers (length of dormancy).
- The number of sprouts on the tuber (sprouts per tuber).
- The number of sprouts on the sample (sprouts/1 kg tubers).
- The number of apical sprouts.
- The number of basal sprouts.
- The daily growth rate of sprout (cm).
- Average weight of one sprout (g).
- Total weight of sprouts per tuber (g).
- Weight of total sprouts per sample (g/1 kg tubers).

2.5 Statistical analysis

The results were analyzed by the statistical program (GenStat-12). The averages were compared by testing the least significant difference (LSD) at 5% significance level.

III. RESULTS AND DISCUSSION

3.1 Effect of one independent factor on the studied traits

3.1.1 Effect of the temperature treatments

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Table (1): Effect of temperature treatments on the studied traits

Traits \ Treatment	Control	Temperature	$LSD_{0.05}$
Days until sprouting	42.83[b]	33.30[c]	1.35
Number of sprouts per tuber	0.63[b]	1.31[b]	0.26
Number of sprouts per sample	3.34[b]	7.40[b]	1.02
Number of apical sprouts	3.38[b]	6.38[b]	0.76
Number of basal sprouts	0.08[b]	1.01[a]	0.41
Daily growth rate of sprout (cm)	0.08[b]	0.15[a]	0.04
Average weight of one sprout (g)	0.88[b]	4.86[b]	0.61
Weight of sprouts per tuber (g)	1.46[b]	6.32[b]	1.06
Weight of total sprouts per sample	4.32[b]	35.49[b]	2.31

The results of the statistical analysis in Table (2) showed that the heat treatment was significantly superior to the control in all the studied traits, where the buds began to sprout 9.53 days earlier than the control (42.83 days in the control and 33.30 days in the temperature treatment), Where the buds began to sprout 9.53 days earlier than the control (42.83 days in the control and 33.30 days in the heat treatment), which is equivalent to a decrease in tuber dormancy by 22.25% than the control. It also increased: the number of sprouts on the tuber by 107.9%, the number of sprouts on the sample by 121.6%, the number of apical sprouts by 88.8%, the number of basal sprouts by 1162.5%, the daily growth rate by 87.5%, the weight of one sprout by 452.3% the weight of the sprouts on the tuber by 332.9%, and the weight of the sprouts on the sample by 721.5%.

Our results are in agreement with the results of previous studies that showed the importance of temperature in breaking the dormancy phase of potato tubers prepared for sowing. Where Burton (1989) and Xu et al. (1998) showed that temperature accelerates the breaking of the dormancy phase and sprouting of many potato varieties. It was also shown that storing potato tubers at different temperatures (15, 20, and 25 °C) for (1, 2, and 3 weeks) reduced the dormancy period of potato tubers by 9.53 days (Chindi and Tsegaw, 2020). It was also mentioned that storing potato tubers at temperatures (15, 20, and 25°C) leads to breaking the dormancy of the tubers (Lippert et al., 1958; Vreugdenhil and Sergeeva, 1999). Also, Matar et al. (2012) indicated that the temperature was significantly superior in the speed of potato tubers sprouting when treated at (15, 20, and 25 °C) for a period of (1, 2, and 3 weeks) over the control.

3.1.2 Effect of the treatment level

Table (2): Effect of treatment level on the studied traits

Traits \ Temperature level (°C)	Ctrl	15	20	25	$LSD_{0.05}$
Days until sprouting	42.83[c]	27.56[b]	26.44[a]	25.64[a]	0.85
Number of sprouts per tuber	0.63[d]	1.20[c]	1.33[b]	1.47[a]	0.08
Number of sprouts per sample	3.34[d]	7.04[c]	7.72[b]	8.15[a]	0.41
Number of apical sprouts	3.38[c]	6.50[b]	7.05[a]	7.36[a]	0.42
Number of basal sprouts	0.083[b]	0.54[a]	0.67[a]	0.77[a]	0.31
Daily growth rate of sprout (cm)	0.081[b]	0.15[a]	0.15[a]	0.16[a]	0.04
Average weight of one sprout (g)	0.88[d]	4.74[c]	5.38[b]	6.04[a]	0.31
Weight of sprouts per tuber (g)	1.46[d]	5.73[c]	7.20[b]	9.02[a]	0.55
Weight of total sprouts per sample	4.32[d]	33.63[c]	39.30[b]	47.25[a]	3.91

It appears from Table (2) that all the temperature levels (15, 20, and 25 °C) were significantly superior to the control in all the studied traits. The level of 25 °C significantly exceeded the other levels in the number of sprouts per tuber with 1.47 sprouts, in the number of sprouts per sample with 8.15 sprouts, in the weight of one sprout with 6.04 g, in the weight of the sprouts per tuber with 9.02 g, and in the weight of the sprouts per sample with 47.25 g. The level of 25 °C and the level 20°C significantly exceeded the level of 15 °C in the number of days until sprouting with values of 25.64 days, 26.44 days and 27.56 days, respectively, and in the number of apical sprouts with 7.36, 7.05 and 6.50 sprouts, respectively. While there were no significant differences between the levels 25, 20 and 15 °C in the number of basal sprouts (average of 0.66 sprouts) and in the daily growth rate of sprout (0.15 cm average).

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The previous results showed the positive effect of increasing the temperature level in breaking the dormancy phase and accelerating the sprouting of tubers, as it led to a reduction of the dormant period by 17 days at 25 °C, 16 days at 20 °C, and 15 days at 15 °C. These results are consistent with previous studies. Alam et al. (1994) showed that increasing the level of the treatment material leads to acceleration of sprouting and breaking the dormancy phase of the potato tubers without exceeding the critical level (which is the limit at which the negative effects of the treatment begin to appear). Also, Coleman and McIcerney (1997) and Coleman (1998) showed that higher levels were more effective and led to breaking-dormancy faster than lower levels. In a study conducted by Chindi and Tsegaw (2020), they showed that the higher levels were more influential on the studied traits. Draie and Al-Ali (2021a;b;c) also showed that increasing the level of the treatment leads to faster tubers sprouting and early breakage of the dormancy phase, and that the higher level was more effective.

3.1.3 Effect of the treatment period length

Table (3): Effect of treatment period length on the studied traits

Treatment period length (week) / Traits	0	1	2	3	$LSD_{0.05}$
Days until sprouting	42.83^{c}	27.11^{b}	26.31^{a}	26.22^{a}	0.72
Number of sprouts per tuber	0.63^{c}	1.15^{b}	1.38^{a}	1.47^{a}	0.11
Number of sprouts per sample	3.34^{c}	6.66^{b}	7.91^{a}	8.33^{a}	0.51
Number of apical sprouts	3.38^{d}	6.09^{c}	7.14^{b}	7.68^{a}	0.48
Number of basal sprouts	0.08^{b}	0.56^{a}	0.76^{a}	0.65^{a}	0.17
Daily growth rate of sprout (cm)	0.08^{b}	0.15^{a}	0.15^{a}	0.17^{a}	0.03
Average weight of one sprout (g)	0.88^{d}	4.90^{c}	5.39^{b}	5.86^{a}	0.25
Weight of sprouts per tuber (g)	1.46^{d}	5.74^{c}	7.50^{b}	8.71^{a}	0.61
Weight of total sprouts per sample	4.32^{d}	32.10^{c}	40.66^{b}	47.42^{a}	2.92

The results shown in Table (3) indicate that all treatment periods (1, 2, and 3 weeks) were significantly superior to the control (0 week) in all the studied traits. The 3-weektreatment period outperformed the other treatment periods in the number of apical sprouts with 7.68 g, in the weight of one sprout with 5.86 g, in the weight of the sprouts per tuber with 8.71 g, and in the weight of the sprouts per sample with 47.42 g. The 3-weektreatment period and the 2-weektreatment period (without significant differences between them) significantly exceeded the 1-weektreatment period in the number of days until sprouting with values of 26.22 days, 26.31 days, and 27.11 days respectively, in the number of sprouts per tuber with 1.47, 1.38, and 1.15 sprouts, respectively, in the number of sprouts per sample with values of 8.33, 7.91, and 6.66 sprouts, respectively. While there were no significant differences between the treatment periods of 3, 2 and 1 weeks in the number of basal sprouts (average of 0.66 sprouts) and the daily growth rate of sprout (an average of 0.16 cm).

The previous results demonstrate the importance of all treatment periods in accelerating sprouting and breaking the dormancy phase. They reduced the dormant period by 17 days in the 3-week period and the 2-week period, and 16 days in the 1-week period. Thus, the effect of the length of the treatment period was similar with respect to the dormancy of the tubers, but all the periods reduced the dormant period by a large time compared with control (43 days). These results are consistent with a number of studies that indicated an increase in the percentage of sprouting by increasing the length of treatment.

Draie and Al-Ali (2021a;b;c) indicated that increasing the length of the treatment period led to faster sprouting of tubers and early breakage of the dormancy phase, and an increase in the number of sprouted shoots, and their daily growth rate and weight. Also, the longer soaking period gave the best results. Similarly, Radi et al. (2013) indicated that the percentage of sprouting increased with the length of the treatment period, and the longer period was the higher of the sprouting percentage. Al-Imam et al. (2016) also showed that increasing the length of the treatment period gave better results and led to an increase in sprouting percentage compared to the other treatments (shorter) and the treatment of the control. While, Al-Saadi (2013) stated that the increase in the length of the treatment period was counterproductive and caused a decrease in the sprouting percentage. These results can be explained by the fact that increasing the length of the treatment period leads to an increase in the sprouting percentage and improvement of the studied traits as long as this period falls below the critical limit, and in the event that the length of the treatment period exceeds the critical limit, it will lead to negative results on the studied traits.

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3.1.4 Effect of the variety

Table (4): Effect of the variety on the studied traits

Traits \ Variety	Spunta	Synergy	Panela	$LSD_{0.05}$
Days until sprouting	24.75[a]	28.33[c]	26.56[b]	1.54
Number of sprouts per tuber	1.65[a]	1.06[c]	1.29[b]	0.22
Number of sprouts per sample	8.78[a]	8.13[a]	5.99[b]	1.06
Number of apical sprouts	7.91[a]	7.49[a]	5.51[b]	0.89
Number of basal sprouts	0.87[a]	0.63[a]	0.48[a]	0.41
Daily growth rate of sprout (cm)	0.19[a]	0.13[a]	0.15[a]	0.07
Average weight of one sprout (g)	5.03[b]	4.28[c]	6.85[a]	0.61
Weight of sprouts per tuber (g)	8.33[a]	4.67[b]	8.94[a]	1.07
Weight of total sprouts per sample	45.44[a]	35.04[b]	39.70[a,b]	3.44

Table (4) shows the superiority of the Spunta variety in the number of days until sprouting, significantly over the Panela variety, which was significantly superior to the Synergy variety, as the sprouts appeared after 24.75, 26.56 and 28.33 days, respectively. Also, the Spunta variety was significantly superior in the number of sprouts per tuber, over the Panela variety, which was significantly superior on the Synergy variety. The number of sprouts per tuber was 1.65, 1.29 and 1.06, respectively. Table (2) shows the superiority of each of the two varieties, Spunta and Synergy, in the number of sprouts per sample, significantly over the variety Panela, with no significant differences between them, as the number of sprouts per sample was 8.78, 8.13 and 5.99 for the variety Spunta, Synergy, and Panela, respectively. Also, there were no differences between the two varieties, Spunta and Synergy, in the number of apical sprouts, and it was superior to the variety Panela, where the number of sprouts reached 7.91, 7.49 and 5.51 for the varieties Spunta, Synergy, and Panela respectively. There were no significant differences between the studied varieties in the number of basal sprouts per tuber, as the number of basal sprouts was 0.87, 0.63 and 0.48 for the varieties Spunta, Synergy, and Panela, respectively. Also, there were no significant differences between the studied varieties in the daily growth rate of sprouts, as the rate was 0.19, 0.15 and 0.13 cm/day for the varieties Spunta, Panela and Synergy, respectively. Table (2) indicates the superiority of the variety Panela over the two varieties, Spunta and Synergy, as well as the superiority of the variety Spunta over the variety Synergy in the characteristic of sprout weight, as the sprout weight reached 5.03, 4.28 and 6.85 g for the varieties Spunta, Synergy and Panela respectively. The results of the statistical analysis according to Table (2) showed that the two varieties Spunta and Panela were significantly superior in the weight of sprouts per tuber over the variety Synergy (there were no significant differences between the two varieties Spunta and Panela), and the weights were 8.33, 4.67 and 8.94 g in the varieties Spunta, Synergy, and Panela respectively. Through Table (2), we notice the superiority of the Spunta variety over the Synergy variety the weight of the sprouts per sample, while there were no significant differences between the Spunta variety and the Panela variety on the one hand, and the Panela variety and Synergy on the other hand, and the weight of the sprouts per sample was 45.44, 35.04 and 39.70 g for the varieties Spunta, Synergy, and Panela, respectively.

Through the previous results, the effect of the genetic factor on the studied traits and parameters is evident, as the Spunta variety surpassed the other varieties, Synergy, and Panela, especially in the characteristic of dormancy-breaking and sprouting, as the dormancy in the Spunta variety ended two days before the Synergy variety and four days before the Panela variety despite applying the same treatments to all varieties. These results confirm the effect of the genetic factor on the dormancy of potato tubers and are consistent with previous studies that talked about the role of the genetic factor as one of the most important dormancy factors in tubers (Suttle, 2007; Muthoni et al., 2014). It also agrees with the findings of Nasiruddin et al. (2016) who showed the difference of the studied potato varieties among themselves in the dormancy period of the tubers and in the degree of the effect of the treatments in breaking the dormancy phase and in all the studied traits depending on the variety on which the treatment was applied. As for the size and weight of the tubers, and inversely proportional to the length of the dormant period (Krijthe, 1958; Suttle, 2007), our results were contrary to what was discussed in the aforementioned studies. Where the variety Spunta surpassed the two varieties Synergy and Panela despite the fact that the tubers are smaller and less weight. This can be explained and linked to the genetic factor, as the size of the tubers affects the length of the dormancy period when the tubers belong to the same variety and thus the degree of maturity (which is less in the young tubers) plays a role in the dormancy period, while in our case the smaller tubers belong to another variety that is characterized by a less dormant period (with the fact that these tubers have reached the stage of biological maturity), and therefore the differences in the dormancy period between the studied varieties are mainly due to the influence of the genetic factor.

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3.2 Effect of the interaction between the experimental factors on the studied traits

3.2.1 Number of days until sprouting

Table (5): Effect of the interaction between the experimental factors on the number of days until sprouting

Treatment × level × Period		Variety	Panela	Spunta	Synergy
Temperature	15 °C	1 w	35.00	35.00	37.00
		2 w	33.00	33.00	35.00
		3 w	32.00	32.00	34.00
	20 °C	1 w	34.00	34.00	36.00
		2 w	33.00	32.00	34.00
		3 w	32.00	31.00	33.00
	25 °C	1 w	34.00	34.00	36.00
		2 w	32.00	31.00	34.00
		3 w	31.00	**30.00**	32.00
LSD (5%)				**0.16**	
C.V. (%)				**16.7**	

The results of the statistical analysis of the interaction between the experimental factors outweigh the interaction of the Spunta variety with the temperature level of 25 °C within the 3-weektreatment period in the breaking of dormant phase and sprouting, with an average 30 days after treatment, where the differences were significant, (Table 5).

3.2.2 Number of sprouts per tuber

Table (6): Effect of the interaction between the experimental factors on the number of sprouts per tuber

Treatment × level × Period		Variety	Panela	Spunta	Synergy
Temperature	15 °C	1 w	0.70	1.00	0.80
		2 w	1.00	2.00	1.00
		3 w	1.00	2.10	1.00
	20 °C	1 w	0.80	1.10	0.90
		2 w	1.20	2.40	1.10
		3 w	1.20	**2.50**	1.20
	25 °C	1 w	0.80	1.20	0.90
		2 w	1.20	2.40	1.10
		3 w	1.20	2.40	1.20
LSD (5%)				**0.027**	
C.V. (%)				**12.5**	

Table (6) shows the superiority of the interaction of the Spunta variety with the temperature level of 20 °C within the 3-weektreatment period in the number of sprouts per tuber with an average of 2.5 sprouts, where the differences were significant from the other interactions.

3.2.3 Number of sprouts per sample

Table (7): Effect of the interaction between the experimental factors on the number of sprouts per sample

Treatment × level × Period		Variety	Panela	Spunta	Synergy
Temperature	15 °C	1 w	3.50	5.90	6.08
		2 w	4.70	10.80	7.50
		3 w	4.30	10.92	7.40
	20 °C	1 w	3.92	6.38	6.81
		2 w	5.52	12.50	8.28
		3 w	4.80	**12.99**	8.88
	25 °C	1 w	3.79	6.60	6.78

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		2 w	5.28	12.48	8.28
		3 w	4.80	11.79	8.88
LSD (5%)					
C.V. (%)					

Table (7) shows the superiority of the interaction of the Spunta variety with the temperature level of 20 °C within the 3-week treatment period in the number of sprouts per weight unit (sample of one kg) with an average of 12.99 sprouts, anywhere the differences were significant from the other interactions.

3.2.4 Number of apical sprouts

Table (8): Effect of the interaction between the experimental factors on the number of apical sprouts

Treatment × level × Period / Variety			Panela	Spunta	Synergy
Temperature	15 °C	1 w	3.50	5.90	4.48
		2 w	4.70	9.00	6.00
		3 w	4.30	9.62	6.31
	20 °C	1 w	3.32	5.18	4.51
		2 w	5.01	10.88	6.11
		3 w	4.39	**11.28**	7.28
	25 °C	1 w	3.19	5.10	5.59
		2 w	4.78	11.10	7.38
		3 w	4.80	10.91	7.62
LSD (5%)				**0.035**	
C.V. (%)				**3.1**	

The results in the Table (8) show the superiority of the interaction of the variety Spunta with the temperature level of 20 °C within the 3-week treatment period in the number of apical sprouts, with an average of 11.28 sprouts, as the differences were significant from the other interactions.

3.2.5 Number of basal sprouts

Table (9): Effect of the interaction between the experimental factors on the number of basal sprouts

Treatment × level × Period / Variety			Panela	Spunta	Synergy
Temperature	15 °C	1 w	0.00	0.00	1.60
		2 w	0.00	1.80	1.50
		3 w	0.00	1.30	1.09
	20 °C	1 w	0.60	1.20	1.61
		2 w	0.50	1.71	2.11
		3 w	0.41	1.68	**2.30**
	25 °C	1 w	0.60	1.50	0.80
		2 w	0.51	1.38	0.90
		3 w	0.00	0.82	1.29
LSD (5%)				**0.035**	
C.V. (%)				**3.1**	

The results in the Table (9) show the superiority of the interaction of Synergy variety with the temperature level of 20 °C within the 3-week treatment period in the number of basal sprouts, with an average of 2.30 sprouts. The differences were significant from the other interactions.

3.2.6 Daily growth rate of sprout (cm)

Table (10): Effect of the interaction between the experimental factors on the daily growth rate of sprout

Treatment × level × Period / Variety			Panela	Spunta	Synergy
Tempera	15 °C	1 w	0.09	0.10	0.09

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		2 w	0.10	0.10	0.10
		3 w	0.10	0.10	0.10
	20 °C	1 w	0.10	0.10	0.09
		2 w	0.10	0.10	0.10
		3 w	0.20	0.20	0.10
	25 °C	1 w	0.10	0.10	0.10
		2 w	0.20	0.10	0.10
		3 w	0.20	**0.25**	0.10
LSD (5%)				**0.046**	
C.V. (%)				**29.8**	

Table 10 shows the superiority of the interaction of the Spunta variety with the temperature level of 20 °C in the 3-week treatment period in the daily growth rate of sprout, with an average of 0.25 cm, wherever the differences were significant from the other interactions.

3.2.7 Weight of one sprout (g)

Table (11): Effect of the interaction between the experimental factors on the weight of one sprout (g)

Treatment × level × Period / Variety			Panela	Spunta	Synergy
Temperature	15 °C	1 w	5.70	3.70	2.60
		2 w	6.38	4.20	2.70
		3 w	7.41	4.30	2.99
	20 °C	1 w	6.10	4.21	3.29
		2 w	6.88	4.39	3.20
		3 w	8.00	4.60	3.38
	25 °C	1 w	6.60	4.21	3.50
		2 w	7.59	4.40	3.60
		3 w	**8.11**	4.70	3.91
LSD (5%)				**0.043**	
C.V. (%)				**5**	

The results in the Table (11) indicate the significant superiority of the interaction of Panela variety with the temperature level of 25 °C within the 3-week treatment period in the average weight of sprout by 8.11 g, on all other interactions.

3.2.8 Weight of sprouts per tuber

Table (12): Effect of the interaction between the experimental factors on the weight of sprouts per tuber

Treatment × level × Period / Variety			Panela	Spunta	Synergy
Temperature	15 °C	1 w	3.99	3.70	2.10
		2 w	6.38	8.40	2.70
		3 w	7.41	9.01	2.99
	20 °C	1 w	4.88	4.68	2.70
		2 w	8.29	10.51	3.52
		3 w	9.79	11.50	4.09
	25 °C	1 w	5.28	5.09	3.20
		2 w	9.08	10.59	4.29
		3 w	10.50	**11.50**	4.78
LSD (5%)				**0.027**	
C.V. (%)				**12.6**	

The results in the Table (12) show the superiority of the interaction of the Spunta variety the temperature level of 25 °C within the 3-week treatment period in the weight of sprouts per tuber with an average of 11.50 g. The superiority over the other interactions was significant.

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3.2.9 Weight of sprouts per sample

Table (13): Effect of the interaction between the experimental factors on the weight of sprouts per sample

Treatment × level × Period		Variety	Panela	Spunta	Synergy
Temperature	15 °C	1 w	19.98	21.81	15.99
		2 w	29.98	45.39	20.28
		3 w	31.99	49.99	21.98
	20 °C	1 w	23.90	26.99	20.52
		2 w	37.99	56.92	26.40
		3 w	39.01	55.50	30.40
	25 °C	1 w	24.81	27.99	24.00
		2 w	39.98	54.90	32.18
		3 w	42.00	**57.50**	35.00
LSD (5%)				**0.296**	
C.V. (%)				**1.5**	

Table (13) displays the significant superiority of the interaction of the Spunta variety with the temperature level of 25 °C within the 3-week treatment period, in the weight of sprouts per weight unit (sample of one kg) with an average of 57.50 g.

The previous results show the importance of the interaction between the experimental factors in influencing the studied traits, whereas the Spunta variety treatments outperformed most of the studied traits (the effect of the genetic factor), the higher temperature treatments (25 °C), and the longer treatment period (3 weeks) were superior in all the studied traits.

We find that the interaction of the variety Spunta with the temperature level of 25 °C within the 3-week treatment period exceeded the other interactions in the number of days until sprouting, in the daily growth rate of sprout, in the weight of sprouts per tuber, and in the weight of sprouts per sample. Whereas, the interaction of the variety Spunta with the temperature level of 20°C within the 3-week treatment period surpassed the other interactions in the number of sprouts per tuber, in the number of sprouts per sample, and in the number of apical sprouts. While, the interaction of the variety Synergy with the temperature level of 20 °C within the 3-week treatment period outperformed the other interactions in the number of basal sprouts. Also, the interaction of the variety Synergy with the temperature level of 20 °C within the 3-week treatment period surpassed the other interactions in weight of one sprout.

The previous results show the importance of the interaction between the studied factors to obtain the best results. Our results are consistent with studies that showed the difference in the effect of heat treatments on sprouting and breaking dormancy of potato tuber buds, whether the length of the treatment period or the level of temperature used in the treatment, according to the studied varieties (Nasiruddin et al., 2016). Similarly, Matar et al. (2012) and Chindi and Tsegaw (2020)indicated the superiority of the interaction between the higher temperature treatments 25°C and the longest treatment period 3 weeks in all studied traits.

IV. CONCLUSION

1) All temperature treatments outperformed the control in all the studied characteristics, and led to breaking the dormant phase during a period of 30 days, while in the control it was 42.83 days.
2) The treatments of the Spunta variety exceeded the other treatments in the speed of breaking the dormancy phase (30 days), followed by the Panela variety (31 days), then the Synergy variety (32 days).
3) The temperature level of 25 °C exceeded the other levels and led to breaking the dormancy phase within 30 days. Also, the 3-weektreatment period exceeded the other periods and led to breaking the dormancy phase within 30 days.

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