

Effect of Treatment with Gibberellic Acid on the Dormancy and Sprouting of Tubers of Some Potato Varieties

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Abstract - The dormancy of potato tubers after harvest is one of the most important factors affecting the yield of the subsequent potato crop. The genetic factor is one of the most important factors affecting the sprouting and the length of the dormant period. Therefore, we conducted this research with the aim of studying the behavior of the tubers of some potato varieties cultivated in northern Syria towards the dormancy and the sprouting. The research was carried out in the 2019 agricultural season in the Al-Rouj Plain, which is considered one of the most important potato production areas in northern Syria. The test was carried out on three varieties: Spunta, Synergy, and Panela. The tubers were treated with gibberellic acid at four concentrations (0, 5, 10, and 20 ppm) during four soaking periods (0, 10, 20, and 30 minutes). The design was used completely randomly in the experiment with three replicates per treatment and each replicate was one kg tubers. The results showed the superiority of all treatments on the control and in all the studied characteristics. Spunta exceeded the other studied varieties in sprouting speed by 24.75 days, and the number of sprouts on the sample by 8.78. While the variety Panela outperformed the average weight of one sprout by 6.85 g. In addition, the highest concentration (20 ppm) exceeded the other concentrations in all the studied traits. The longer soaking period (30 minutes) outperformed the other soaking periods in all the studied traits. In general, the interaction of Spunta with gibberellin was superior to the higher concentration and the longer soaking period in the overall studied traits.

Keywords: Potato, Dormancy, Sprouting, Gibberellic Acid, Concentration, Soaking Period.

I. INTRODUCTION

Potato (*Solanum tuberosum* L.), belonging to the Solanaceae family, is one of the most economically important vegetable crops, as it occupies an area of more than 20 million hectares distributed around the world, mainly in Europe, Asia, and in the Americas (FAO, 2019). Potato is one of the main crops in Syria, and the cultivated area is estimated at 24 thousand hectares distributed over three seasons, the autumn season constitutes more than 50% of the cultivated area (A.A.S.G, 2019).

Potato is propagated by growing whole or segmented tubers. When the tubers mature and reach their final size, they enter a deep internal dormancy stage during which the tubers are not able to sprout even if the appropriate conditions are provided for them (Lang et al., 1987; Van-Ittersum, 1992; Struik and Wiersema, 1999). The dormancy period practically begins from the moment the shoots of the potato plant are mowed to the time when 80% of the tubers show sprouts of at least 2 mm in length (Van-Ittersum and Scholte, 1992). The dormancy period usually ranges between 6-10 weeks, and the length of the period depends to a large extent on genetic factors (species or variety), and to a small extent on the conditions accompanying the growth stage of the tubers (Davidson, 1958; Wurr and Allen, 1976; Burton, 1978). The temperature, humidity, and photoperiod during growth and storage are important environmental factors that regulate the behavior of sprouts (Uwe, 2001; Ezekiel and Singh, 2003). The degree of maturity of the tubers upon harvesting, injuries caused by harvesting or diseases and pests, and exposure to internal and applied dormancy fractures play a role on the length of the dormant period (Aksenova et al., 2013; Muthoni et al., 2014). The analysis of quantitative trait locus (QTL) showed that tuber dormancy is a quantitative genetic trait (Kotch et al., 1992) and is controlled by nine distinct chromosomal sites either independently or through overlapping interactions between them (Freyre et al., 1994; Ewing, 1995; Van-Den-Berg et al., 1996).

Gibberellins (often GA3) are used in seed certification programs where rapid replanting of seed tubers is required for pathogen testing (Rentzsch et al., 2012). The treatment of dormant tubers with gibberellins was used even in practical applications and was a commercial method for early potato cultivation (Claassens and Vreugdenhil, 2000). It was found that gibberellins (GAs) stimulate the growth of active sprouts after breaking the dormant phase in the tuber. According to Hemberg (1985), gibberellins encourage dormancy-breaking and initiation of sprouts growth, as it was found that the activity of endogenous compounds similar to gibberellins was low during dormancy and increased before sprouts growth. The dormancy of the stored tubers can be broken by treating them with gibberellins (Rappaport et al., 1958). Studies indicate that endogenous gibberellins are not closely involved

in controlling tuber dormancy (Suttle, 2004), but play a major role in later sprouts elongation (Suttle, 2007). The artificial reduction in the content of endogenous gibberellins (GA1 and its direct progenitor GA20) by reverse expression of the gibberellin biosynthesis gene *GA20ox1* did not significantly affect the dormancy of the tuber but subsequently delayed sprouts growth (Carrera et al., 2000). Similar results were obtained on transgenic potato plants with enhanced expression of the *GA20ox1* gene associated with GA1 inhibition (Kloosterman et al., 2007). However, other reports indicate the possibility of breaking the dormancy phase associated with gibberellins and stimulating sprouting and encouraging later sprouts growth (Viola et al., 2001; Hartmann et al., 2011; Draie and Al-Absi, 2019).

Breaking the dormancy is of great importance when planting potato tubers in consecutive seasons, as well as when importing newly uprooted tubers and planting them directly and when germinating the tubers to test that they are free of diseases before proving their suitability for seeds. 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 the farmers use of spring season tubers as seeds before the dormant phase ends in planting the autumn season, the importance of research is evident in finding an easy, effective and economical way to end the dormant state in tubers intended for planting in the autumn season. Accordingly, in this research, we will test the effect of treatment with several concentrations and soaking periods of gibberellin acid solution on 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 (Al-Rouj Plain region), where tubers were transferred after treatment to special rooms with low lighting and high humidity, with temperatures of about 25 ° C.

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 varieties, which are Spunta, Synergy, and Panela. The tubers were treated with gibberellic acid at four concentrations (0, 5, 10, and 20 ppm) during four soaking periods (0, 10, 20, and 30 minutes). The complete randomized design (CRD) was used in the experiment with five replicates per treatment and each replicate was one kg tubers. Consequently, the total number of treatments used in the experimentation = 3 varieties x 4 concentrations x 4 soaking periods x 3 replicates = 144 treatments (144 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 variety

Table (1): Effect of the variety on the studied traits

Traits	Spunta	Synergy	Panela	LSD _{0.05}
Days until sprouting	24.75 ^a	28.33 ^c	26.56 ^b	1.56
Number of sprouts per tuber	1.65 ^a	1.06 ^c	1.29 ^b	0.23

Number of sprouts per sample	8.78 ^a	8.13 ^a	5.99 ^b	1.08
Number of apical sprouts	7.91 ^a	7.49 ^a	5.51 ^b	0.91
Number of basal sprouts	0.87 ^a	0.63 ^a	0.48 ^a	0.43
Daily growth rate of sprout (cm)	0.19 ^a	0.13 ^a	0.15 ^a	0.06
Average weight of one sprout (g)	5.03 ^b	4.28 ^c	6.85 ^a	0.62
Weight of sprouts per tuber (g)	8.33 ^a	4.67 ^b	8.94 ^a	1.09
Weight of total sprouts per sample	45.44 ^a	35.04 ^b	39.70 ^{a,b}	7.67

Table (1) 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 (1) 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 (1) 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 (1) 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 (1), 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.

3.1.2 Effect of the treatment with gibberellin

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

Traits	Control	Gibberellin	LSD _{0.05}
Days until sprouting	42.83 ^b	17.74 ^a	1.48

Number of sprouts per tuber	0.63 ^b	1.67 ^a	0.24
Number of sprouts per sample	3.34 ^b	10.06 ^a	1.04
Number of apical sprouts	3.38 ^b	8.95 ^a	0.91
Number of basal sprouts	0.08 ^b	1.11 ^a	0.42
Daily growth rate of sprout (cm)	0.08 ^b	0.18 ^a	0.06
Average weight of one sprout (g)	0.88 ^b	5.71 ^a	0.60
Weight of sprouts per tuber (g)	1.46 ^b	9.45 ^a	1.13
Weight of total sprouts per sample	4.32 ^b	52.19 ^a	7.50

The results of the statistical analysis in Table (2) showed the significant superiority of treatment with gibberellin over the control in all the studied characteristics, as the sprouts began to emerge 25 days earlier than the control (42.83 days in the control and 17.74 days in the treatment of gibberellin). The average number of sprouts per tuber increased by 265%, the number of sprouts per sample by 317%, the number of apical sprouts by 265%, and the number of basal sprouts by 138% compared to the control. Similarly, the daily growth rate increased by 225%, the weight of one sprout increased by 649%, the weight of the sprouts per tuber increased by 647%, and the weight of the sprouts per sample increased by 1208%.

Our results coincide with those of previous studies that demonstrated the importance of gibberellin in breaking the dormancy phase in potato tubers. Where Burton (1989) and Xu et al. (1998) showed that gibberellin accelerates breaking dormant phase and sprouting of many varieties of potato. Also, Chindi and Tsegaw (2020) showed that soaking potato tubers in gibberellin solution reduced the dormancy of potato tubers by 20 days. Similarly, Lippert et al. (1958) and Vreugdenhil and Sergeeva (1999) stated that soaking potato tubers in gibberellin solution breaks the tubers dormancy. Matar et al. (2012) also indicated that gibberellin was significantly superior over the control in sprouting rate of potato tubers when treated with gibberellin acid.

3.1.3 Effect of the treatment concentration

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

Traits	Concentration (ppm)				LSD _{0.05}
	0	5	10	20	
Days until sprouting	42.83 ^c	27.56 ^b	26.44 ^a	25.64 ^a	0.87
Number of sprouts per tuber	0.63 ^d	1.20 ^c	1.33 ^b	1.47 ^a	0.086
Number of sprouts per sample	3.34 ^d	7.04 ^c	7.72 ^b	8.15 ^a	0.42
Number of apical sprouts	3.38 ^c	6.50 ^b	7.05 ^a	7.36 ^a	0.44
Number of basal sprouts	0.083 ^b	0.54 ^a	0.67 ^a	0.77 ^a	0.36
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	0.29
Weight of sprouts per tuber (g)	1.46 ^d	5.73 ^c	7.20 ^b	9.02 ^a	0.57
Weight of total sprouts per sample	4.32 ^d	33.63 ^c	39.30 ^b	47.25 ^a	3.94

It appears from Table (3) that all the treatments of the concentrations (5, 10, and 20 ppm) were significantly superior to the control (0 ppm) in all the studied traits. The concentration of 20 ppm significantly exceeded the other concentrations 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 concentration of 20 ppm and the concentration 10 ppm significantly exceeded the concentration of 5 ppm 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 concentrations 20, 10 and 5 ppm in the number of basal sprouts (average of 0.66 sprouts) and in the daily growth rate of sprout (0.15 cm average).

The previous results showed the positive effect of increasing the concentration 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 20 ppm, 16 days at 10 ppm, and 15 days at 5 ppm. These results are consistent with previous studies. Alam et al. (1994) showed that increasing the concentration 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 concentrations were more effective and led to breaking-dormancy faster than lower concentrations. In a study conducted by Chindi and Tsegaw (2020), using a concentration of 40 and 50 ppm of gibberellin, it was found that a higher concentration reduced the dormancy period by 27 days, while a lower concentration reduced the dormancy period by only 24 days. As indicated Al-Bebili et al. (2015) when using different concentrations of gibberellin (50 and 100 mg/L), that the higher concentrations were more effective on the studied traits.

3.1.3 Effect of the soaking period length

Table (4): Effect of soaking period length on the studied traits

Soaking period length (minutes)	0	10	20	30	LSD _{0.05}
Days until sprouting	42.83 ^c	27.11 ^b	26.31 ^a	26.22 ^a	0.70
Number of sprouts per tuber	0.63 ^c	1.15 ^b	1.38 ^a	1.47 ^a	0.10
Number of sprouts per sample	3.34 ^c	6.66 ^b	7.91 ^a	8.33 ^a	0.53
Number of apical sprouts	3.38 ^d	6.09 ^c	7.14 ^b	7.68 ^a	0.52
Number of basal sprouts	0.08 ^b	0.56 ^a	0.76 ^a	0.65 ^a	0.19
Daily growth rate of sprout (cm)	0.08 ^b	0.15 ^a	0.15 ^a	0.17 ^a	0.04
Average weight of one sprout (g)	0.88 ^d	4.90 ^c	5.39 ^b	5.86 ^a	0.28
Weight of sprouts per tuber (g)	1.46 ^d	5.74 ^c	7.50 ^b	8.71 ^a	0.60
Weight of total sprouts per sample	4.32 ^d	32.10 ^c	40.66 ^b	47.42 ^a	3.75

The results shown in Table (4) indicate that all treatment periods (10, 20 and 30 minutes) were significantly superior to the control (0 minutes) in all the studied traits. The 30-minute soaking period outperformed the other soaking periods in the number of apical sprouts with 7.68g, 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 30-minute soaking period and the 20-minute soaking period significantly exceeded the 10-minute soaking 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 soaking periods of 30, 20 and 10 minutes in the number of basal sprouts (average of 0.66 buds) and the daily growth rate of sprout (an average of 0.16 cm).

The previous results demonstrate the importance of all soaking periods in accelerating sprouting and breaking the dormancy phase. They reduced the dormant period by 17 days in the 30-minute period and the 20-minute period, and 16 days in the 10-minute 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 17 or 16 days 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. 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.

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 x Concentration x Period		Variety	Panela	Spunta	Synergy
Gibberellin	5 ppm	10 min	21.00	15.00	23.00
		20 min	21.00	14.00	22.00
		30 min	21.00	14.00	22.00
	10 ppm	10 min	18.00	13.00	23.00
		20 min	18.00	13.00	22.00
		30 min	17.00	13.00	22.00
	20 ppm	10 min	16.00	13.00	21.00
		20 min	16.00	12.00	21.00
		30 min	16.00	12.00	20.00
LSD (5%)			0.16		
C.V. (%)			16.8		

The results of the statistical analysis of the interaction between the experimental factors outweigh the interaction of the Spunta variety with the concentration of 20 ppm of the gibberellin solution within the periods of soaking 20 and 30 minutes (there were no significant differences between the interaction of the periods of soaking 20 and 30 minutes) in the breaking of dormant phase and sprouting, with an average 12 days after treatment, and the differences were significant from the other interactions, (Table 5).

3.2.2 Number of sprouts per tuber

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

Treatment x Concentration x Period		Variety	Panela	Spunta	Synergy
		Period			
Gibberellin	5 ppm	10 min	1.20	2.10	1.20
		20 min	1.30	2.20	1.20
		30 min	1.40	2.30	1.20
	10 ppm	10 min	1.10	2.20	1.20
		20 min	1.30	2.30	1.20
		30 min	1.40	2.50	1.50
	20 ppm	10 min	1.40	2.20	1.50
		20 min	1.70	2.30	1.50
		30 min	1.68	2.50	1.60
LSD (5%)			0.027		
C.V. (%)			12.5		

Table (6) shows the superiority of the interaction of the Spunta variety with the third (20 ppm) and second (10 ppm) concentrations of gibberellin solution within the third soaking period (30 min) in the number of sprouts per tuber with an average of 2.50 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 sprouts per sample

Treatment x Concentration x Period		Variety	Panela	Spunta	Synergy
		Period			
Gibberellin	5 ppm	10 min	5.70	10.48	9.00
		20 min	6.20	11.00	10.50
		30 min	6.70	12.68	11.28
	10 ppm	10 min	5.20	10.45	9.78
		20 min	7.60	12.68	11.28
		30 min	8.60	13.78	12.00
	20 ppm	10 min	7.20	12.10	11.28
		20 min	8.10	12.68	11.28
		30 min	8.60	13.78	12.00
LSD (5%)			0.058		
C.V. (%)			4.7		

Table (7) shows the superiority of the interaction of the Spunta variety with the second (10 ppm) and third (20 ppm) concentrations of gibberellin solution within the third soaking period (30 min) in the number of sprouts per unit weight (sample of one kg) with an average of 13.78 sprouts, wherever 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 apical sprouts

Treatment x Concentration x Period		Variety	Panela	Spunta	Synergy
		Period			
Gibberellin	5 ppm	10 min	4.59	10.29	8.18
		20 min	5.29	9.40	9.28
		30 min	5.71	11.11	10.19
	10 ppm	10 min	5.20	8.71	9.11
		20 min	7.19	10.31	10.49
		30 min	8.60	13.50	10.90

	20 ppm	10 min	6.50	9.08	9.92
		20 min	8.10	9.48	10.31
		30 min	7.81	11.28	11.10
LSD (5%)			0.035		
C.V. (%)			3.1		

Table (8) shows the superiority of the interaction of the variety Spunta with the second concentration (10 ppm) of the solution of gibberellin within the third soaking period (30 min) in the number of apical sprouts, with an average of 13.50 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 basal sprouts

Treatment x Concentration x Period		Variety	Panela	Spunta	Synergy
Gibberellin	5 ppm	10 min	1.14	0.19	0.85
		20 min	0.94	1.59	1.22
		30 min	0.99	1.51	1.08
	10 ppm	10 min	0.00	1.70	0.61
		20 min	0.41	2.31	0.79
		30 min	0.00	0.22	1.10
	20 ppm	10 min	0.70	3.08	1.31
		20 min	0.00	3.19	0.91
		30 min	0.79	2.50	0.90
LSD (5%)			0.035		
C.V. (%)			3.1		

Table (9) shows the superiority of the interaction of Spunta variety with the third concentration (20 ppm) of gibberellin solution within the second soaking period (20 min) in the number of basal sprouts with an average of 3.19 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 x Concentration x Period		Variety	Panela	Spunta	Synergy
Gibberellin	5 ppm	10 min	0.08	0.20	0.10
		20 min	0.10	0.20	0.20
		30 min	0.10	0.20	0.20
	10 ppm	10 min	0.11	0.20	0.20
		20 min	0.18	0.20	0.20
		30 min	0.28	0.20	0.20
	20 ppm	10 min	0.11	0.20	0.10
		20 min	0.11	0.30	0.20
		30 min	0.18	0.30	0.20
LSD (5%)			0.046		
C.V. (%)			29.8		

Table 10 shows the superiority of the interaction of the Spunta variety with the third concentration (20 ppm) of gibberellin solution in the second (20 min) and third (30 min) soaking periods (there were no significant differences between the interaction of the second and third soaking periods) in the daily growth rate of sprout with an average of 0.30 cm, anywhere 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 x Concentration x Period		Variety	Panela	Spunta	Synergy
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Gibberellin	5 ppm	10 min	6.35	3.87	2.99
		20 min	7.12	4.21	3.48
		30 min	7.11	4.30	3.50
	10 ppm	10 min	7.48	4.79	3.70
		20 min	7.64	4.79	3.80
		30 min	7.71	5.21	5.28
	20 ppm	10 min	7.89	5.42	5.41
		20 min	7.99	5.59	6.27
		30 min	8.01	5.61	8.25
LSD (5%)		0.043			
C.V. (%)		5			

Table (11) indicates the significant superiority of the interaction of Synergy variety with the third concentration (20 ppm) of gibberellin solution within the third soaking period (30 min), in the average weight of sprout by 8.25 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 x Concentration x Period		Variety	Panela	Spunta	Synergy
Gibberellin	5 ppm	10 min	7.62	8.13	3.59
		20 min	9.26	9.31	4.18
		30 min	9.98	9.89	4.20
	10 ppm	10 min	8.21	10.51	4.41
		20 min	9.91	11.01	4.59
		30 min	10.81	13.08	7.92
	20 ppm	10 min	11.02	11.92	8.19
		20 min	13.09	12.79	9.92
		30 min	14.42	14.00	13.20
LSD (5%)		0.027			
C.V. (%)		12.6			

Table (12) indicates the superiority of the interaction of the Panela variety with the third concentration (20 ppm) of gibberellin solution within the third soaking period (30 min) in the weight of sprouts per tuber with an average of 14.42 g. The superiority over the other interactions was significant.

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 x Concentration x Period		Variety	Panela	Spunta	Synergy
Gibberellin	5 ppm	10 min	38.10	47.97	27.28
		20 min	45.39	53.99	31.77
		30 min	46.79	54.39	31.50
	10 ppm	10 min	38.68	56.92	33.30
		20 min	45.68	59.48	34.20
		30 min	47.69	68.02	59.40
	20 ppm	10 min	47.39	61.98	61.20
		20 min	54.19	63.98	74.70
		30 min	57.68	68.68	99.00
LSD (5%)		0.296			
C.V. (%)		1.5			

Table (13) indicates the significant superiority of the interaction of the Synergy variety with the third concentration (30 ppm) of gibberellin solution within the third soaking period (30 min), in the weight of sprouts per weight unit (sample of one kg) with an average of 99.00 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 concentration treatments (20 ppm), and the longer soaking period (30 minutes) were superior in

all the studied traits. We find that the interaction of the variety Spunta with a concentration of 20 ppm of gibberellin, the soaking period 20 minutes and the soaking period 30 minutes (without significant differences between them) outperformed the other interactions in the sprouting velocity and in the daily growth rate. Likewise, we find that the interaction of the variety Spunta with a period of 30 minutes soaking in gibberellin solution and the concentration of 20 ppm and 10 ppm (without significant differences between them) outperformed the other interactions in the number of sprouts per tuber and the number of sprouts per unit weight (sample of one kg). While the interaction of Spunta variety with the concentration of 10 ppm of gibberellin and the period of soaking of 30 minutes exceeded the other interactions in the number of apical sprouts. Similarly, we find that the interaction of Synergy with a concentration of 20 ppm of gibberellin and the soaking period of 30 minutes was the superior in the weight of a single sprout and the weight of the sprouts per sample. While the interaction of the Panela variety with a concentration of 20 ppm of gibberellin and the soaking period of 30 minutes outperformed the other interactions in the weight of the sprouts per tuber.

Our results coincide with many previous studies that showed the importance of the interaction of experimental factors in the studied traits, dormancy and sprouting of potato tuber. Chindi and Tsegaw (2020) showed that the interaction of gibberellin (foliar spray) at the higher concentration (1000 ppm) led to shortening the dormancy period in the potato tubers by 27 days, while the interaction of gibberellin (soaking the tubers) with the higher concentration (50 ppm) shortened the dormancy period by 20 days. Thus, the interaction of gibberellin treatments with higher concentrations achieved a faster dormancy and sprout germination. Also, Al-Babili et al. (2015) showed that the interaction between gibberellin at the highest concentration (100 mg/L) outperformed the control in all the studied traits. Matar et al. (2012) showed that the gibberellin interaction at a concentration of 5 mg/L was superior to the control in all the studied traits (field sprouting speed, sprouting percentage, plant height, number of main stems on the plant and the percentage of potassium in leaves). Also, Xu et al. (1998) showed that the interaction between gibberellin solution during the longer period (30 minutes) achieved a significant superiority over the other treatments in accelerating the sprouting of potato tubers.

IV. CONCLUSION

- 1) All treatments of soaking with gibberellin outperformed the control in all the studied characteristics, and led to breaking the dormant phase during a period of 17.74 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 (24 days), followed by the Panela variety (26 days), then the Synergy variety (28 days).
- 3) The concentration of 20 ppm exceeded the other concentrations and led to breaking the dormancy phase within 25.64 days. Also, the soaking period of 30 minutes exceeded the other periods and led to breaking the dormancy phase within 26.22 days.
- 4) The soaking of the Spunta variety with gibberellin at 20 ppm and the period of 30 minutes gave the fastest break of the dormancy phase (12 days), the number of sprouts was the highest (2.5 sprouts/tuber, 13.78 sprouts/sample), and the highest daily growth rate (0.30 cm/day). While soaking the tubers of the Synergy variety with gibberellin at the concentration of 20 ppm and the period of 30 minutes achieved the largest vegetative growth, as the weight of one sprout reached 8.25 g and the weight of the sprouts per the weight unit (sample of one kg) reached 99 g.

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