

Full Length Research Paper

The effect of gibberellic acid (GA₃) on seed size and sprouting of potato tubers (*Solanum tuberosum* L.)

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An experiment was performed to evaluate the effect of gibberellic acid (GA₃) on seed size and sprouting of potato (*Solanum tuberosum* L.). The experiment was laid done in factorial design (3 × 3) using Agria, Marfona and Draga cultivars and three concentrations of GA₃ (0, 5 and 10 mg/lit). Results showed that application of gibberellic acid at low concentrations (5 and 10 mg/lit) was able to increase general performance and productivity of seed tubers of potatoes. Seed tuber production was increased by application of using gibberellic acid in all cultivars. Total weight of seed tubers produced by application of 5 mg/lit GA₃ was statistically different compared to control ($p \leq 0.05$). Also, results showed that after one week from application of GA₃, starch content decreased and total content of sugar increased in potato tuber. The tubers treated with GA₃ sprouted earlier while in control sprouting was very late and slow. Furthermore, we indicated that sugar content is one of the important parameters determining the sprouting of seed potatoes. Thus the sequence of events can be summarized as: Application of GA₃ → Starch hydrolysis → Decrease of starch content of tubers → Production and increase of total sugar content → Dormancy breaking → Tuber sprouting.

Key words: Potato (*Solanum tuberosum* L.), gibberellic acid (GA₃), tuber size, tuber sprouting.

INTRODUCTION

Potato is considered one of the important food crops in the world. This product contains high amounts of carbohydrate and it is very important in starch production. The most suitable size for seed tubers are 50 to 60 g weight which gives the best quality seed potato. Since potato tubers are not equal in size, in many cases seed tubers are cut into small pieces, but this technique is not desirable because it decreases the growth of main stems and increases disease incidence (Burton, 1989; Nielson et al., 1989). Tuber productivity of good seed tubers in potatoes relies on factors like; day length, temperature, physiological age of seed tubers, plant density, nitrogen, water supplying, and finally growth regulating materials or plant growth regulators (PGR) (Gregory, 1965). Plant growth regulators (PGR) have considerable effects on tuber fertility and it is highly related to hormonal balance

(Stuart and Cathey, 1961; Vreugdenhil and Struik, 2006). By treating the tubers using gibberellic acid, the tubers will sprout faster and the tubers treated with GA₃ produce more number of seed tubers (Rehman et al., 2001; Burton, 1989). Gibberellins (Figure 1) are able to break dormancy of potato tubers by sinking (pre-soaking) the seed tubers or spraying the potato plants (Garcia-Torres and Gomez-Campo, 1973; Lorreta et al., 1995; Rappaport et al., 1957; Vreugdenhil and Sergeeva, 1999). More buds will be generated per unit area by using gibberellic acid (GA₃) (Figure 2) in potatoes because the GA₃ can increase the number of stems or stolons in plant (Mikitzel, 1993). Xu et al. (1998) indicated that GA is a dominant regulator in tuber formation and promoted stolon elongation and inhibited tuber formation. Timm et al. (1962) treated dormant or sprouted seed

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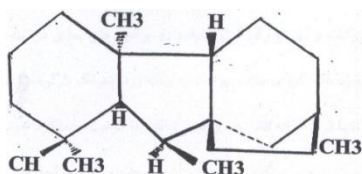


Figure 1. Structural formula for general gibberellins

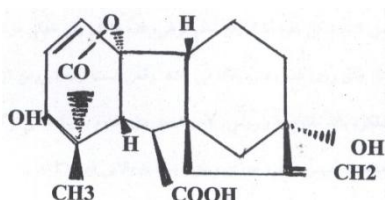


Figure 2. Gibberellic acid (GA_3) formula.

potatoes with various concentrations of gibberellic acid and indicated that emergence of plants from treated seed was more rapid than from untreated seed. Wareing and Jennings (1980) proved that the growth of secondary buds in potato stolons, has been intrigued and this phenomenon should predominate final dominance. Racca and Tizio (1968) found that before tuberization the shoots contained large quantities of gibberellin-like substances which decreased after tuberization and it is suggested that these substances are of importance in the control of tuberization. Also, GA_3 leads to smaller tubers resulting in increased bud numbers and stolons by removing of apical dominance. Foliar application of GA_3 (5 and 10 ppm) increased the length of stems and stolons, and decreased the tuber fertility, but causes elongation of the stolons (Burton 1989; Chapman, 2006).

MATERIALS AND METHODS

An experiment was conducted to evaluate the effect of gibberellic acid (GA_3) on seed size and sprouting of potato (*Solanum tuberosum* L.). The experiment was performed in Agricultural Research Station of Tajark related to Agricultural Research Center and Natural Resources of Hamedan province in spring and summer seasons of 2006 to 2007. The experiment was laid done in a Completely Randomized Block (RCB) factorial design (3×3) having Agria, Marfona and Draga cultivars and application of three concentrations of gibberellic acid (GA_3) (0, 5 and 10 mg/lit) with four replication. The potato's seeds (cultivars) were obtained from Agricultural Research Center, Esfahan, Iran. Tubers were planted with 75 cm inter row and 25 cm intra row spacing. Fertilizer requirement was estimated by soil testing and 200 kg/ha of ammonium phosphate were given to the soil equally for all the treatments. At the first step, seed tubers of three cultivars (Marfona, Draga and Agria) simultaneously were stored in the temperature conditions of 2 to 4°C for one month and then transferred to temperature range of 7 to 10°C (Two weeks before planting), then tubers were sterilized and soaked in gibberellic acid solution with

two concentration of 5 and 10 ppm for 72 h. Finally tubers were planted simultaneously.

The operations of soil preparation, weeding, irrigation and disease control were performed on time equally for all the treatments. Recording for final tuber yield and its characters were done at harvesting (160 day after planting). After harvesting, the number and weight of tubers bigger than 55 mm, average tubers 35 to 55 mm (seed size tubers) and tubers smaller than 35 mm were counted and weighed separately. Starch was extracted one week after treatment with GA_3 by filtering the samples (10 g of each fresh tuber sample) in 95% methanol. For sugar analysis, the samples were homogenized using a blender and filtered through a micro filter paper with 0.45 mm pore size and then the supernatants were used for analysis of sucrose, glucose and fructose using HPLC (Waters model 590, flow rate 0.5 ml/min, column temperature 78 to 79°C, injection volume 100 ml). The total soluble sugar was measured by sum of these. Number of sprouts in a tuber (mean of 10 tuber) were calculated after two week from treatment with GA_3 . The data were statistically analyzed by MSTATC software (Version 1.42, Michigan State University, USA) and Duncan's New Multiple Range Test was used for comparing the means of treatments at 0.01 and 0.05 probability.

RESULTS

Table 1 showed the highest number of seed tubers that were produced by Marfona (32.79), followed by Agria (29.64) and Draga (25.32) respectively. Marfona produced the significantly higher total weight of seed tubers (TWST) (1.95 kg/m²), compared other two cultivars. Results also showed that Marfona cultivar produced more number of tubers and produced higher tuber yield in comparison to other cultivars. The production of seed tubers (35 to 55 mm size) increased in all three cultivars by the application of gibberellic acid. Furthermore, higher TWST was produced by the application of 5 and 10 mg/lit GA_3 with 2.05 kg/m² and 1.96 kg/m² respectively, which was statistically significant compared to 0 mg/L GA_3 ($p \leq 0.05$). Table 2 showed that there was a strong positive correlation between final tuber yield with total weight and number of small tubers (TWSMT) ($P \leq 0.01$). This result showed that final tuber yield was increased by increasing the TWSMT and NSMT under the application of low concentration of GA_3 . There was significant negative correlation between number and total weight of seed tubers with number and total weight of big tubers ($P \leq 0.05$). These indicating that the number and total weight of seed tubers decreased with increasing the number and total weight of big tubers. There was no significant correlation between final tuber yield with TWST and number of seed tubers whereas non-significant negative correlation was observed between TWSMT and NSMT with TWBT and number of big tubers.

Figure 3 and 4 showed that after one week of application of GA_3 starch content started to decrease and total content of sugar increased. This shows that the application of GA_3 causes starch hydrolysis and increased the soluble sugar (sucrose, glucose, and fructose), which in turn break the dormancy and sprouting

Table 1. The effects of treatments on various characters.

Treatments	Number of main stems	TWBT	Number of big tubers	TWST	Number of seed tubers	TWSMT	NSMT	Final tuber yield
Cultivars								
Marfona	11.02 ^a	1.11 ^a	8.25 ^a	1.95 ^a	32.79 ^a	0.58 ^a	27.88 ^a	3.64 ^a
Agria	10.81 ^a	0.77 ^c	6.68 ^b	1.86 ^b	29.64 ^b	0.32 ^b	22.19 ^b	2.95 ^b
Draga	10.08 ^a	1.07 ^b	7.94 ^a	1.55 ^c	25.32 ^c	0.27 ^c	15.53 ^c	2.88 ^b
Levels of GA ₃								
0 mg/L	7.6 ^b	1.33 ^a	9.25 ^a	1.35 ^c	20.81 ^b	0.33 ^b	19.43 ^b	3.02 ^b
5 mg/L	12.6 ^a	0.80 ^b	6.64 ^b	2.05 ^a	33.96 ^a	0.41 ^a	22.76 ^a	3.26 ^a
10 mg/L	12.44 ^a	0.81 ^b	7.15 ^b	1.96 ^b	32.98 ^a	0.42 ^a	23.36 ^a	3.19 ^a

Means not sharing at letter in common in a column differ significantly ($P \leq 0.05$). TWBT, Total weight of big tubers (kg/m^2); TWST, total weight of seed tubers (kg/m^2); TWSMT, total weight of small tubers (less than seed size) (kg/m^2); NSMT, number of small tubers (less than seed size) (kg/m^2).

Table 2. Correlations between various characters.

Characters	Number of main stem	TWBT	Number of big tubers	TWST	Number of seed tubers	TWSMT	NSMT	Final tuber yield
Number of main stem	1							
TWBT	-0.727*	1						
Number of big tubers	-0.788*	0.949**	1					
TWST	0.774*	-0.783*	-0.728*	1				
Number of seed tubers	0.767*	-0.726*	-0.661 ^{ns}	0.975**	1			
TWSMT	0.182 ^{ns}	-0.022 ^{ns}	0.117 ^{ns}	0.585 ^{ns}	0.645 ^{ns}	1		
NSMT	0.161 ^{ns}	-0.272 ^{ns}	-0.102 ^{ns}	0.700*	0.701*	0.912**	1	
Final tuber yield	0.642*	0.05 ^{ns}	0.117 ^{ns}	0.573 ^{ns}	0.622 ^{ns}	0.966**	0.835**	1

** $P \leq 0.01$, * $P \leq 0.05$, ^{ns} Non-significant. TWBT, Total weight of big tubers (kg/m^2); TWST, total weight of seed tubers (kg/m^2); TWSMT, total weight of small tubers (less than seed size) (kg/m^2); NSMT, number of small tubers (less than seed size) (kg/m^2).

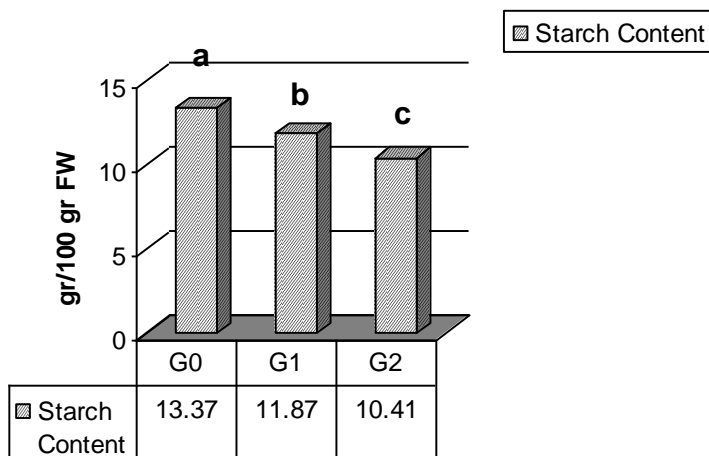


Figure 3. The effect of GA₃ on starch content of tubers. G0= 0 mg/L GA₃; G1= 5 mg/L GA₃; G2= 10 mg/L GA₃.

of the seed tubers commenced. The minimum content of starch was observed from application of 10 mg/L GA₃ (10.41 g/100 g fresh weight) followed by the application

of 5 mg/L GA₃ (11.87 g/100 g Fresh Weight) and untreated tubers had the maximum content of starch (13.37 g/100 g fresh weight) (for the starch analysis,

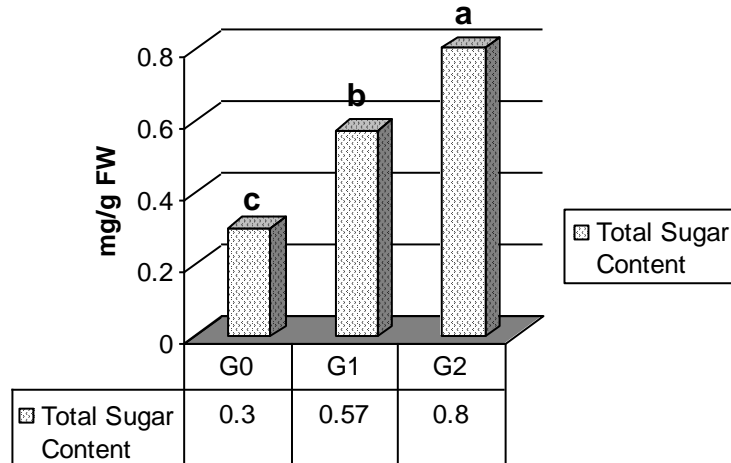


Figure 4. The effect of GA₃ on total sugar content of tubers. G0= 0 mg/lit GA₃, G1= 5 mg/lit GA₃, G2= 10 mg/lit GA₃.

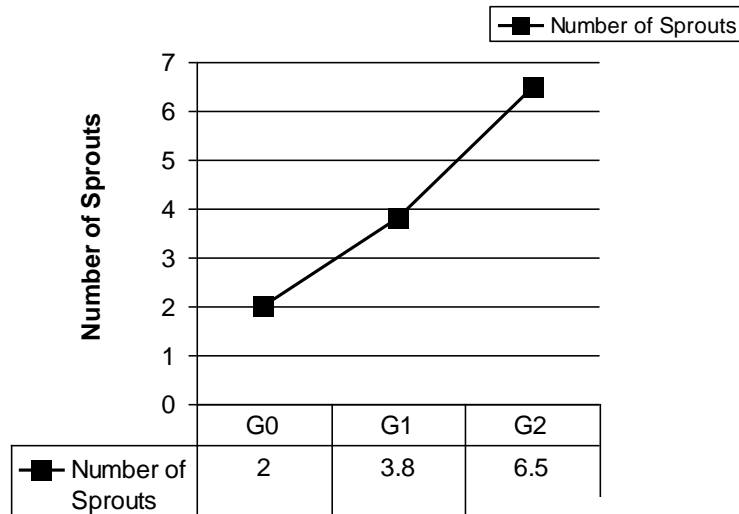


Figure 5. The effect of GA₃ on number of sprouts. G0= 0 mg/lit GA₃, G1= 5 mg/lit GA₃, G2= 10 mg/lit GA₃.

measuring of starch should be on fresh weight (FW), for this reason first water content of samples reach to equal amount for all the treatments then analysis will be done). The maximum content of total sugar content was significantly and recoded for the tubers treated with 10 mg/lit GA₃ (0.8 mg/g Fresh Weight) and was different to the application of 5 mg/lit GA₃ (0.57 mg/g Fresh Weight) and 0.0 mg/lit GA₃ (0.3 mg/g Fresh Weight). With increasing the concentration of gibberellic acid (GA₃) (0, 5, 10 mg/lit, respectively) more and more number of sprouts were observed. The highest number of sprouts was observed from 10 mg/lit GA₃ (6.5) application, which was significantly different to the application of 5 mg/lit GA₃ (3.8) and 0 mg/lit GA₃ (Figure 5).

DISCUSSION

Performance of potato crop is complex and is influenced by a large number of changeable factors including; disease, nutrition, leaf surface, environment, mother tubers and genetics. Environmental factors especially day length and temperature play a major role in tuber initiation. Although some other factors are effective on tuber productivity, it was proved that these factors influence by the growth regulatory materials or plant growth regulators (PGR) and especially changing the levels of "endogenous Gibberellins" (Bielek, 1974). Alexopoulos et al. (1979) showed that when GA₃ was applied to potato it induces dormancy breaking, a

reduction in specific weight, a higher rate of respiration and increased weight loss during storage.

Hormonal treatments led to the reduction weight of big tubers, but increased the number of smaller tubers. Stuart and Cathey (1961) and Wareing and Jennings (1980) obtained similar results through their experiments. Also, gibberellic acid had the ability to increase the number of seed tubers. This is explained by the fact that the effect of this hormone on the removal of apical dominance in potato tubers. This has been also proved previously by Timm et al. (1962) and Racca and Tizio (1968).

Gibberellins show different actions at different concentrations, for example gibberellic acid (GA₃) avoid tuber fertility at high concentration (Chapman 2006; Wareing and Jennings 1980). The pre-soaking application of gibberellic acid at low concentrations (5 and 10 mg/lit) is able to increase the general performance of seed tubers (Wareing and Jennings, 1980). This achievement is very valuable because of two reasons; at first, in seed production programs, any increment of percentage of seed tubers is very important and second, it creates favorable conditions in vogue of tubers in industries by reduction of big tubers and making tubers of equal size. This positive effect of gibberellic acid in increasing seed tuber in potato also has been observed by Alexopoulos et al. (1979). Non-significant differences observed in the most parameters between applications of 5 and 10 mg/lit GA₃, and increasing the concentration from 5 to 10 mg/lit didn't caused any increase in number and weight of seed tubers and total yield in three potato cultivars (Tables 1 and 2). Therefore, there is no need to use high concentration of GA₃. These results are in conformity with the findings of Lorreta et al. (1995). Further, Biemelt et al. (2004) indicated that using high level of concentration of gibberellic acid had negative effects on plant production.

The sprouting of tubers treated with GA₃ was earlier compared to no application of GA₃ where the sprouting was very late and slow. Timm et al. (1962) showed that when seed potatoes were treated either dormant or sprouted, with various concentrations of gibberellic acid, emergence of plants from treated seed was more rapid than from untreated seed tubers. Wareing and Jennings (1980) proved that the growth of secondary buds in potato stolons, has been intrigued and this phenomenon should be predominant to final dominancy. The sugar content is one of the important parameters determining the sprouting vigor of seed potato, because sucrose, glucose and fructose are known to play a primary role in the metabolism and also during potato growth sugars are required for polysaccharide synthesis and tuberization (Rees and Morrell, 1990).

The foregoing discussions lead to prove a new relationship as follows:

Application of GA₃ → Starch hydrolysis → Decrease in starch content of tubers → Production and increase of

total soluble sugar content → Dormancy breaking → Tuber sprouting

Thus, it can be concluded that the application of gibberellic acid increases the productivity of tubers of potato (*Solanum tuberosum* L.). The tubers treated with GA₃ sprouted earlier while non application of GA₃ sprouted very late and slow. Further, it can also be concluded that one week after application of GA₃ the starch fraction started to hydrolyse and increased total sugar content causing the tubers to sprout by breaking dormancy.

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