

## Evaluation of some potato cultivars productivity by using seedling

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### ABSTRACT

Two field experiments were carried out at Baloza Station of the Desert Research Center at North Sinai Governorate during two consecutive seasons of 2016/2017 and 2017/2018. The experiment was conducted to study the response of five imported potato cultivars i.e. Spunta, Cara, Diamant, Arizona and Nicola to tubers soaking in different concentrations of gibberellin i.e., 0, 50, 100 and 150 ppm for 1 hour and effect on sprouting; seedling production; growth and yield. The trial was conducted in three stages i.e., Laboratory and green house stages to produce seedlings for planting open field stage. Results revealed that the highest values on No. of buds/tuber; percentage of bud sprouts/tuber; No. of stem/seedling; No. of seedling/100 tubers; plant weight; No. of branches/plant; tubers No. /plant; percentage of tuber dry matter; plant yield; total tuber number/m<sup>2</sup> and total yield/fed., recorded significant increase in Cara Cv. followed by Spunta Cv. in both growing seasons. Moreover, gibberellin concentration treatment at the rate of 100 ppm followed by 150 ppm recorded the highest values and significant increases of all most study parameters in both growing seasons. Economic study revealed that Cara Cv. followed by Spunta Cv. combined with gibberellin concentration at the rate of 100 ppm followed by 150 ppm recorded the highest values and significant increase on output; investment ratio and the lowest values of total tubers weight for producing seedling (TW) in both growing seasons. Moreover, it can be recommend to use seedling method produce tuber seeds for the next season because seedling method need lowest tuber seeds to cultivate equal production unit, showed the highest investment ratio and produced high number of tubers/m<sup>2</sup> when compared with traditional method.

**Keywords:** Potato, Cultivars, Gibberellin, Seedling, Growth, Yield, Economic study.

### Introduction

Potato (*Solanum tuberosum* L.) is a member of the family (Solanaceae). It is the major world food crop and by far the most important food crop in terms of quantities produced and consumed worldwide, ranking fourth (368 million metric tons/year) after maize, rice and wheat, with an estimated production area in Egypt of 158248 hectares with average total yield of 4113441ton (FAOSTAT, 2016).

In general seed potato situation in Egypt characterized by three different growing seasons: 1) summer season planted with full imported potato seed from European countries by 1.5 billion pound each year to produce tuber seeds for all next seasons. 2) Autumn season planted with local tuber seeds from the previous season, its characterized by the meager period to produce tubers for domestic consumption and small quantities for export. 3) Winter season planted with tuber seeds from the previous season, its characterized by the meager period to produce tubers for export. The high production costs in the summer season due to the high costs of imported tuber seeds and the inability to divide the tubers to avoid infection, the result led to increase in the price of the crop, as well as the tuber seeds in the following seasons.

Tuber size profile is an important quality component of a potato seed lot. However, many farmers prefer drop size (25-50 mm in diameter) of potato tubers over large whole tubers or cut tuber pieces. Larger tubers increase the weight of tuber seeds per unit area, which are increases both seeds and transport costs. Additionally, larger tubers are generally unacceptable for seed because when they are cut some seed pieces may not contain a meristem or eye (blind seed pieces) and subsequently plant population may be reduced (Nielson *et al.*, 1989) for that purpose multiplication methods that ensure rapid production of this amount of tubers are always preferred. Rapid multiplication added advantage of ensuring high health status of the resultant crop.

Effect of cultivar and density on growth and dry matter in five cultivars of potato were reported, the differences among the cultivars were recorded in number of days after planting to emergence,

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flowering, number of stems per plant, stem and leaf dry weight and tuber dry weight (Damavandi and Asle- Gorgani, 2005). Similar results were also reported by Luthra *et al.* (2005) and Schittenhelm *et al.* (2006). It is presumed that the differences in growth and yield characters among various genotypes may be due to combined effects of plant genetics, nutrient status of soil and agro-environmental conditions under which were the plants grown. In another study, results showed that all potato cultivars have significant differences in all of growth traits Ranjbar and Mirzakhan (2012). Also, Eaton *et al.* (2017) they reported differences in growth parameters and Stolon, also tuberilisation processes of different potatoes genotypes might be due to plant genetic makeup and environmental effects.

Gibberellins are able to break dormancy of potato tubers by soaking the seed tubers or spraying potato plants (Lorreta *et al.*, 1995 and Vreugdenhil and Sergeeva, 1999). More buds will be generated per unit area by using gibberellic acid (GA<sub>3</sub>) with potatoes because the GA<sub>3</sub> can increase the number of stems or stolon in plant (Mikitzel, 1993). Also, Xu *et al.* (1998) indicated that GA is a dominant regulator in tuber formation and promoted stolon elongation and inhibited tuber formation. Moreover, by treating the tubers using gibberellic acid, the tubers will sprouts faster; also the tubers treated with GA<sub>3</sub> produce more number of seed tubers (Rehman *et al.*, 2001). Foliar application of GA<sub>3</sub> (5 and 10 ppm) increased the length of stems and stolons, and decreased the tuber fertility, but causes elongation of the stolons (Chapman, 2006). Moreover, exogenous gibberellins increased the plant height, stem diameter, leaf area index and the tubers number of potato Atlantic cultivar (Qin 2006). In field studies, foliar applications of GA<sub>3</sub> caused deformation of tubers, while reducing tubers yield and starch content (Sharma *et al.* 1998). As regard, Plant growth regulators (PGR) have considerable effects on tubers fertility and it is highly related to hormonal balance (Vreugdenhil and Struik, 2006).

Plants which were treated with GA, seeds typically show a more upright growth habit with elongated internodes (Knowles *et al.* 2012), but this effect is confined to the early stages of plant establishment. Additionally, GA reduced apical dominance which were resulting with increases stems number of seed tubers (Blauer *et al.* 2013). This effect, in turn, increases tubers number per plant and decreases average tubers size (Blauer *et al.* 2013 and Herman *et al.* 2016). GA can therefore be used to improve manage tuber size distribution to maximize profits in accordance with market demands for smaller tubers (Blauer *et al.* 2013 and Dean *et al.* 2018).

## Materials and Methods

Two field experiments were carried out at Baloza Station of the Desert Research Center at North Sinai Governorate during two consecutive seasons of 2016/2017 and 2017/2018. The experiments were conducted to study the response of five potato cultivars i.e. Spunta, Cara, Diamant, Arizona and Nicola to gibberellin application. Twenty treatments were used, which were the combination of five potato cultivars and four levels of gibberellin concentrations as a soaking solution for tubers, i.e. 0, 50, 100 and 150 ppm. As one of the main targets of this research was to study the possibility of producing seedlings from full tubers in a greenhouse and then transferring them to the field to study the effect of gibberellin concentrations on growth and yield of five potato cultivars grown in sandy soil conditions.

The physical and chemical soil characteristics of the studied site were determined according to Page *et al.* (1982) and Klute (1986) respectively, as recorded in Table (1). The chemical analysis of irrigation water was carried out using the standard method of Page *et al.* (1982) and presented in Table (2).

**Table 1:** Some Physical and chemical properties of the experimental soil site.

Soil depth (cm)	Texture class	Soluble anions (Meg/l)			pH soil paste	E.C dSm <sup>-1</sup>	Soluble cations (Meg/l)			
		HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>=</sup>	Cl <sup>-</sup>			Ca <sup>+2</sup>	Mg <sup>+2</sup>	Na <sup>+</sup>	K <sup>+</sup>
0 – 30	Sandy	3.85	6.5	3.3	8.2	1.37	3.65	4.40	4.78	0.54

**Table 2:** Chemical analysis of the irrigation water.

Soluble anions (me/l)			pH	E.C ppm	Soluble cations (me/l)			
HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>=</sup>	Cl <sup>-</sup>			Ca <sup>+2</sup>	Mg <sup>+2</sup>	Na <sup>+</sup>	K <sup>+</sup>
5.7	2.10	7.5	7.10	1512	2.90	3.20	8.6	0.60

pH: Acidity, E.C.: Electrical conductivity, dSm<sup>-1</sup>: decseime per meter,

### 1. Laboratory stage:

Tubers for all cultivars were received on 20 September on both seasons, all tubers were selected healthy, regular in shape and diameter of the tuber does not exceed 5 cm., tubers from each cultivar were selected and divided to equal tubers number and weighted Table (3) showed average weight for 100 tubers for each gibberellin treatments and the same tubers number were cultivated as traditional methods for economic studies. The gibberellin solution with different concentrations was prepared and water was used as a control treatment. The tubers were soaked for 1 hour in the solution. The tubers were transported on a piece of burlap in a normal laboratory atmosphere with poor lighting left for 10 days. Ten tubers from each replicate were randomly taken for recording number of buds/tuber, buds long and diameter and percentage of sprouted buds/tuber.

**Table 3:** Average weight (kg)/100 tubers from each cultivars

Cultivars	Spunta	Cara	Diamant	Arizona	Nicola
Average weight (kg)	13.45	11.61	13.52	14.23	12.54

### 2. Greenhouse stage

Each bud was cut with part of the tuber (10gm) and dipped in an IBA (Indole butyric acid) solution at a concentration of 100 ppm to stimulate root growth, then treated with fungicide disinfectant then left for 48 hours to curing, seedling media were prepared with a mixture between peat moss, Pearlite and sand (1:1:1), adjusting the pH of the mixture in the range of 6.5 to 7 using calcium carbonate (4 kg / 300 L of peat moss) and adding 750 grams of compound fertilizer NPK (19:19:19) and 75gm of fungicide. The buds were planted in 10 cm plastic seedling bags with holes from the bottom, after that irrigated for 30 days. Ten seedlings were randomly taken from each replicate to record seedling length and diameter, number of stems/seedling and No. of seedling/100 tubers. At the same date full tubers from each cultivar used in the study were cultivated in open field as traditional methods with density 4 plant/m<sup>2</sup> for economic comparison.

### 3. Field stage

Field soil (for seedling and full tubers) was prepared. Organic manure was added at the rate of 30 m<sup>3</sup>/fed, while calcium super-phosphate (15% P<sub>2</sub>O<sub>5</sub>) at the rate of 400 kg/fed. Nitrogen fertilizer was added as ammonium sulphate (20.5% N) at the rate of 300 kg/fed and potassium sulphate (48% K<sub>2</sub>O) at the rate of 200 kg/fed. Nitrogen and potassium quantities were divided and applied all over the season within drip irrigation system starting after 2 days from transplanting. Potato transplant of five cultivars were transplanted 25 cm apart on one side of the ridge in planting pit by cutting seedling bags from bottom and irrigated with drip irrigation system. The ridges were 60 cm width and 1m among drip irrigation lines. Each experimental plot consisted of 5 ridges with a net area of 15 m<sup>2</sup>. Potato seedlings were transplanting with density 4 plant /m<sup>2</sup> (16800 plants/fed.) during the second week of December of both growing seasons. All agricultural practices for potato crop production were followed according to the recommendation of Ministry of Agriculture.

### Sampling for growth parameters:

After 60 days from transplanting, three plants from each experimental unit were randomly taken for recording vegetative growth characteristics, i.e., plant height and weight, also number of branches/plant.

### 4. Sampling for tubers parameters and yield:

At harvesting stage (50% yellowish from foliar growth), a sample of 10 plant tubers were randomly taken from each experimental plot for recording tuber characteristics, i.e., tubers number /plant; average tuber weight and percentage of tuber dry matter were recorded. In addition, 3m<sup>2</sup> randomly taken from each experimental plot for recording plant yield; total tuber yield and total tubers number/ m<sup>2</sup>.

### 5. Investment ratio:

Investment Ratio (IR) = (total revenue, LE / total cost, LE) for seedling and full tubers yield following Rana *et al.* (1996).

### 6. Experimental design and statistical analysis:

The experimental treatments were arranged in split plot design with three replicates, the main plots were assigned for cultivars, whereas, gibberellin treatments were randomly arranged in the sub plots. Statistical analyses of obtained data were analyzed according to Thomas and Hills (1975).

## Results and Discussion

### 1. Laboratory and Greenhouse stage:

Presented data in Table (4 and 5) showed the effect of potato cultivars and gibberellin concentrations on number of buds/tuber; buds length; percentage of sprouted buds; seedling length and diameter; number of stems/seedling and No. of seedling/100 tubers. Obtained results showed significant differences among either cultivars or gibberellin concentrations on all parameters. From the obtained data it could remark the following:

The highest significant values of No. of buds/ tuber and percentage of sprouted buds/tuber were recorded with Cara and Spunta CVs. when compared with other cultivars. While, Spunta Cv followed by Nicola Cv recorded the highest increase of buds length without significant differences between both cultivars in both growing seasons. Moreover, the highest values of seedling length were recorded with Arizona and Nicola CVs. While, Diamant Cv followed by Arizona Cv recorded the highest values of seedling diameter, in addition Cara Cv. followed by Spunta Cv. which were recorded significant increase on number of stems/seedling and No. of seedlings/100 tubers, without significant differences between both cultivars in both growing seasons. Differences among the cultivars may be due to emergence Damavandi and Asle- Gorgani, 2005 and, Eaton *et al.* (2017) reported differences in growth parameters due to the differences of potatoes genotypes and plant genetic makeup.

Gibberellin concentrations showed the highest values on all parameters when compared with control treatment, but the highest values on No. of buds/tuber and percentage of sprouted buds/tuber recorded significant increase with concentration 100 ppm, while concentration 150 ppm followed by gibberellin 100 ppm recorded significant increase in buds length without significant differences between both treatments in both growing seasons. Moreover, the highest values of seedling length and number of stems/seedling recorded significant increase with concentration 150 ppm followed by 100 ppm

While, the highest values of No. of seedlings/100 tubers were obtained with 100 ppm concentration, but control treatment recorded significant increase on seedling stem diameter in both growing seasons. These results gave the same trend with those reported by (Mikitzel, 1993; Lorreta *et al.*, 1995; Vreugdenhil and Sergeeva, 1999 and Rahman *et al.*, 2001) who reported that gibberellins are able to break dormancy of potato tubers by soaking the seed tubers and more buds will be generated per tuber also, tubers will sprouts faster than untreated tubers. Also, Xu *et al.* (1998) indicated that GA is a dominant regulator in tuber formation and promoted stolon elongation and inhibited tuber formation.

The interaction among cultivars and gibberellin concentrations showed that Spunta Cv combined with 100 ppm gibberellin concentration recorded the highest values of No. of buds/tuber and bud length in the first season only and Spunta Cv with 150 ppm gibberellin concentration gave the highest buds length in the second growing season only. While, Cara Cv with 100 ppm gibberellin recorded the highest values in percentage of sprouted buds/tuber in the second season only. Moreover, the interaction among cultivars and gibberellin concentrations showed that Spunta Cv with 100 ppm gibberellin treatment recorded the highest values of No. of buds/tuber in the first season only and buds length surpassed in both growing seasons. While, Cara Cv with 150 ppm gibberellin recorded the highest values of percentage of sprouted buds/tuber in the second season only.

**Table 4:** Effect of cultivars and gibberellin concentrations on No. of buds/ tuber, buds length and percentage of sprouted buds/tuber of potato during 2016/2017 and 2017/2018 growing seasons.

Characters		No. of buds/ tuber					Buds length (cm)					Sprouted buds/tuber (%)				
Treatments	Gibberellin	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>
<b>Cultivars</b>																
<b>1<sup>st</sup> season</b>																
Spunta		1.3	5.0	8.0	6.0	5.1	2.6	3.6	3.7	3.5	3.3	12.6	57.4	84.3	85.0	59.8
Cara		2.0	6.0	7.7	6.0	5.4	2.3	2.7	2.6	2.8	2.6	11.4	71.7	89.3	83.3	63.9
Diamant		1.3	3.7	5.7	4.0	3.7	1.7	2.9	3.3	3.3	2.8	13.3	45.0	70.0	65.0	48.3
Arizona		1.3	3.0	4.3	4.7	3.3	2.1	2.7	3.2	2.9	2.8	12.3	53.3	64.2	67.5	49.3
Nicola		1.7	4.3	5.0	4.0	3.8	2.2	3.4	3.2	3.4	3.1	16.1	52.0	69.0	63.6	50.2
X <sup>-</sup>		1.5	4.4	6.1	4.9		2.2	3.1	3.2	3.2		13.1	55.9	75.4	72.9	
<b>2<sup>nd</sup> season</b>																
Spunta		1.7	5.0	7.0	6.0	4.9	2.5	3.8	3.5	4.4	3.5	13.2	50.0	87.6	84.9	58.9
Cara		1.7	4.7	7.0	7.0	5.1	2.0	2.6	2.9	3.1	2.7	14.6	55.8	88.7	86.0	61.3
Diamant		1.3	3.3	5.7	5.0	3.8	1.9	2.5	2.8	2.6	2.5	13.3	41.3	66.9	66.7	47.0
Arizona		1.3	3.0	4.3	4.3	3.3	1.7	2.5	2.8	2.8	2.5	13.7	38.7	58.9	58.9	42.6
Nicola		1.3	3.3	5.0	4.7	3.6	2.3	2.6	3.6	4.1	3.2	13.0	48.3	76.7	65.0	50.8
X <sup>-</sup>		1.5	3.9	5.8	5.4		2.1	2.8	3.1	3.4		13.6	46.8	75.7	72.3	
<b>L. S. D. (0.05) for:</b>			<b>Sea. 1</b>		<b>Sea. 2</b>		<b>Sea. 1</b>		<b>Sea. 2</b>		<b>Sea. 1</b>		<b>Sea. 2</b>			
<b>Cultivars</b>			1.26		0.71		0.39		0.35		8.46		5.12			
<b>Gibberellin</b>			0.60		0.65		0.22		0.29		8.49		5.35			
<b>Interaction</b>			1.34		NS		0.49		0.65		NS		11.97			

**Table 5:** Effect of cultivars and gibberellin concentrations on seedling length and diameter; number of stems/seedling and No. of seedling/100 tubers of potato tuber during 2016/2017 and 2017/2018 growing seasons.

Characters Treatments	Seedling length (cm)					Seedling stem diameter (mm)					No. of stems/seedling					No. of seedlings/100 tubers					
	Gibberellin	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>
<b>Cultivars</b>																					
<b>1<sup>st</sup> season</b>																					
Spunta	13.5	12.5	17.7	14.5	14.5	10.7	7.3	7.1	7.5	8.2	3.1	4.2	4.2	3.9	3.9	133.3	490.7	782.3	628.3	508.7	
Cara	12.8	13.8	15.0	15.2	14.2	10.7	8.6	7.4	8.2	8.7	3.3	4.4	4.5	4.5	4.2	196.0	581.0	729.3	616.3	530.7	
Diamant	13.7	12.5	14.4	15.5	14.0	11.7	8.4	8.5	8.4	9.2	1.8	2.6	3.1	3.3	2.7	129.0	320.7	551.7	445.0	361.6	
Arizona	14.2	15.3	16.5	18.6	16.1	9.1	8.8	9.5	9.0	9.1	2.9	2.6	4.2	4.4	3.5	128.0	287.3	392.3	424.3	308.0	
Nicola	13.3	16.0	16.0	17.5	15.7	9.3	7.5	8.7	8.1	8.4	1.9	2.5	3.3	3.2	2.7	145.0	419.0	477.3	403.0	361.1	
X <sup>-</sup>	13.5	14.0	15.9	16.3		10.3	8.1	8.3	8.2		2.6	3.2	3.8	3.9		146.3	419.7	586.6	503.4		
<b>2<sup>nd</sup> season</b>																					
Spunta	12.8	16.2	15.6	16.2	15.2	10.6	9.8	8.9	8.4	9.4	2.5	3.5	4.1	4.4	3.6	142.0	428.3	629.0	490.3	422.4	
Cara	12.8	14.2	16.0	14.5	14.4	10.7	8.7	8.8	9.4	9.4	2.5	3.5	4.9	4.6	3.9	158.3	428.0	703.7	442.0	433.0	
Diamant	11.9	13.4	14.9	14.8	13.7	11.5	8.9	10.3	9.0	9.9	2.0	2.4	2.8	3.1	2.6	116.0	299.7	518.3	408.3	335.6	
Arizona	12.2	14.8	18.5	19.6	16.3	9.8	10.2	9.0	10.3	9.8	2.5	2.6	4.5	4.3	3.4	112.3	274.0	391.3	404.7	295.6	
Nicola	12.2	16.0	17.1	18.9	16.1	9.8	10.2	9.0	10.3	9.8	2.4	2.5	3.9	4.2	3.2	135.7	306.7	469.7	403.0	328.8	
X <sup>-</sup>	12.4	14.9	16.4	16.8		10.5	9.6	9.2	9.5		2.4	2.9	4.0	4.1		132.9	347.3	542.4	429.7		
<b>L. S. D. (0.05) for:</b>			<b>Sea. 1</b>	<b>Sea. 2</b>				<b>Sea. 1</b>	<b>Sea. 2</b>			<b>Sea. 1</b>	<b>Sea. 2</b>				<b>Sea. 1</b>	<b>Sea. 2</b>			
<b>Cultivars</b>			0.87	1.25				0.61	0.29			0.30	0.39				121.5	84.96			
<b>Gibberellin</b>			1.25	1.12				0.60	0.60			0.40	0.29				67.55	76.22			
<b>Interaction</b>			NS	NS				1.35	1.34			NS	0.64				NS	NS			

## 2. Field stage:

The presented data in Tables (6-8) showed the effect of potato cultivars and gibberellin treatments on plant height and weight, number of branches/plant, tubers number /plant, average tuber weight, percentage of tuber dry matter, plant yield, total tuber number / m<sup>2</sup> and total yield/fed. Obtained results showed significant differences either among cultivars or gibberellin treatments on all parameters. From the data obtained it could remark the following:

The highest values of plant weight, number of branches/plant, tubers number /plant, percentage of tuber dry matter, plant yield, total tuber number / m<sup>2</sup> and total yield/fed. recorded the highest significant increase with Cara Cv. followed by Spunta Cv. in both growing seasons. While, Arizona Cv followed by Spunta Cv recorded the highest significant increase of plant height but Diamant Cv followed by Arizona Cv recorded the highest significant increase of average tuber weight in both growing seasons. The differences among various genotypes affected on growth and yield characters may be due to combined effects of plant genetics, nutrient status of soil and agro-environmental conditions which were the plants grown (Luthra *et al.* 2005 and Schittenhelm *et al.* 2006). These results were agreement with those reported by Ranjbar and Mirzakhani (2012) and Eaton *et al.* (2017) they showed that all potato cultivars have significant differences in all of growth parameters, stolon and tuberisation processes of different potatoes genotypes and might be due to plant genetic makeup and environmental effects.

Gibberellin concentrations showed the highest values of all parameters as compared with control treatment except the highest values of tubers dry matter percentage were recorded with control treatment in both growing seasons. But, the highest significant values of plant height, weight, number of branches/plant, tubers number /plant, average tuber weight, plant yield, total tuber number / m<sup>2</sup> and total yield/fed., were obtained with concentration 100 ppm in both growing seasons. While gibberellin concentration treatment of 150 ppm showed the highest values of number of branches/plant and average tuber weight on the first season only and no significant differences were found between 100 ppm and 150 ppm concentration regarding plant weight, number of branches/plant, average tuber weight and plant yield in both growing seasons. Gibberellins were a dominant regulator in tuber formation and promoted stolon elongation and inhibited tuber formation. Application GA to tubers produced more number of seed tubers also increased the tuber height, stem diameter, leaf area index and the tuber number per plant but decreases average tuber size ( Xu *et al.* 1998; Rehman *et al.* 2001; Qin 2006; Blauer *et al.* 2013 and Herman *et al.* 2016).

The interaction between cultivars and gibberellin concentrations showed that Cara Cv with 100 ppm gibberellin treatment recorded the highest values of number of branches/plant, tubers number /plant, plant yield and total yield/fed., in both growing seasons, also total tubers number / m<sup>2</sup> in the second season only. While, Arizona Cv with 100 ppm gibberellin treatment recorded the highest values of plant height in the first season only.

## 3. Investment ratio:

The final goal of any agricultural application is to get profitable yield as gain from the invested cost. The agricultural process is mainly economic especially if we decrease production cost, so the net gain of each pound from the input is important to get the highest rate of revenue. Table (9) showed the calculation of fixed input and variable cost for traditional production which were planted on open field for both full tubers or seedling method and the total cost of one ton of potato tubers preparation to produce seedling. Also, output for one ton of tubers production. We must note that when calculate investment ratio for seedling production method for each cultivars use the following equation:

$$TW = \{(16800 \div N) * X\} = \text{kg/fed.}$$

$$\text{Investment ratio} = Y \div (((C + A)*TW) + Z)$$

TW = Tubers weight for producing seedlings for planting one fed., Table (10).

N = Number of seedling from 100 tubers for each treatment. Table (5).

X = Average weight for 100 tubers (kg). Table (3).

Y = Total output /Fed., (total yield ton \* season price of one ton). Table (8).

C = Cost of preparation one Kg of tubers to produce seedling. Table (9).

**Table 6:** Effect of cultivars and gibberellin concentrations on plant height, weight and number of branches /plant of potato during 2016/2017 and 2017/2018 growing seasons.

Characters Treatments	Plant height (cm)					Plant weight (gm.)					No. of branches/plant					
	Gibberellin	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>
<b>Cultivars</b>																
<b>1<sup>st</sup> season</b>																
Spunta		48.7	56.2	54.5	54.3	53.4	306.8	332.2	402.6	398.3	360.0	17.3	17.7	19.1	19.0	18.3
Cara		44.1	48.6	58.1	57.1	52.0	276.2	347.0	437.3	409.7	367.5	19.2	19.7	20.6	19.5	19.8
Diamant		50.9	50.4	53.3	54.4	52.3	174.5	269.3	326.2	343.7	278.4	14.2	17.2	18.5	18.2	17.0
Arizona		50.0	50.6	62.1	53.8	54.1	331.2	324.6	353.2	353.7	340.7	16.2	16.4	19.7	19.7	18.0
Nicola		44.7	43.8	53.9	49.1	47.9	237.8	290.9	348.8	314.7	298.0	9.3	15.0	17.7	19.7	15.4
X <sup>-</sup>		47.7	49.9	56.4	53.7		265.3	312.8	373.6	364.0		15.2	17.2	19.1	19.2	
<b>2<sup>nd</sup> season</b>																
Spunta		44.1	48.1	59.2	55.7	51.8	264.5	332.3	451.7	442.3	372.7	18.7	19.3	20.3	20.0	19.6
Cara		41.1	51.0	56.8	46.8	49.0	348.2	411.2	459.4	445.7	416.1	19.3	20.4	22.1	21.2	20.7
Diamant		44.7	50.4	55.0	52.7	50.7	247.6	294.6	331.2	312.8	296.6	16.7	16.5	18.1	19.0	17.6
Arizona		53.0	56.2	62.4	59.0	57.7	303.8	295.5	403.1	394.2	349.1	18.5	19.5	19.3	20.7	19.5
Nicola		45.2	46.4	51.4	51.8	48.7	260.5	315.6	353.4	332.0	315.4	18.5	17.0	19.1	17.0	17.9
X <sup>-</sup>		45.6	50.4	57.0	53.2		284.9	329.9	399.7	385.4		18.3	18.5	19.8	19.6	
<b>L. S. D. (0.05) for:</b>					<b>Sea. 1</b>	<b>Sea. 2</b>			<b>Sea. 1</b>	<b>Sea. 2</b>			<b>Sea. 1</b>	<b>Sea. 2</b>		
<b>Cultivars</b>					1.73	2.50			62.38	28.90			1.42	0.94		
<b>Gibberellin</b>					2.51	2.31			29.80	26.04			1.47	0.63		
<b>Interaction</b>					5.62	NS			NS	NS			3.29	1.41		



**Table 7:** Effect of cultivars and gibberellin concentrations on number of tubers/plant, average tubers weight and tuber dry matter (%) of potato plant during 2016/2017 and 2017/2018 growing seasons.

Characters		No. of tubers/plant				Average tubers weight (gm.)				Tuber dry matter (%)						
Treatments	Gibberellin	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>
<b>Cultivars</b>																
<b>1<sup>st</sup> season</b>																
Spunta		6.7	8.0	11.0	10.7	9.1	40.6	55.8	44.7	52.8	48.5	18.5	18.7	18.6	15.5	17.9
Cara		5.0	8.0	12.0	10.3	8.8	46.1	57.8	58.8	57.7	55.1	18.3	16.9	18.4	17.2	17.7
Diamant		6.7	7.7	8.0	8.3	7.7	49.5	62.8	65.7	63.9	60.5	15.4	15.5	14.6	14.5	15.0
Arizona		6.0	7.3	8.7	7.7	7.4	52.4	52.0	60.9	62.3	56.9	18.8	14.8	14.7	14.6	15.7
Nicola		6.0	7.0	8.3	7.7	7.3	35.8	57.8	58.8	59.2	52.9	14.6	16.3	16.6	14.3	15.5
X <sup>-</sup>		6.1	7.6	9.6	8.9		44.9	57.2	57.8	59.2		17.1	16.5	16.6	15.2	
<b>2<sup>nd</sup> season</b>																
Spunta		6.3	8.3	11.7	10.3	9.2	44.9	58.5	60.5	54.1	54.5	18.8	16.1	16.1	17.3	17.1
Cara		5.7	8.3	10.7	10.0	8.7	50.2	54.3	58.9	58.8	55.6	16.3	17.7	17.8	18.5	17.6
Diamant		6.3	8.0	8.0	8.7	7.8	54.9	58.8	66.1	61.9	60.4	15.9	14.3	12.9	13.7	14.2
Arizona		5.7	6.7	9.3	8.3	7.5	48.8	59.9	63.6	62.5	58.7	15.9	14.7	15.4	13.8	15.0
Nicola		6.0	8.0	8.0	7.0	7.3	44.8	54.0	63.1	58.0	55.0	15.8	15.5	14.8	15.0	15.3
X <sup>-</sup>		6.0	7.9	9.5	8.9		48.7	57.1	62.4	59.1		16.5	15.7	15.4	15.7	
<b>L. S. D. (0.05) for:</b>				<b>Sea. 1</b>	<b>Sea. 2</b>		<b>Sea. 1</b>	<b>Sea. 2</b>				<b>Sea. 1</b>	<b>Sea. 2</b>			
<b>Cultivars</b>				0.62	0.87		7.29	3.86				0.86	1.71			
<b>Gibberellin</b>				0.68	0.65		6.96	3.42				0.87	0.81			
<b>Interaction</b>				1.53	1.45		NS	NS				1.95	1.81			

**Table 8:** Effect of cultivars and gibberellin concentrations on plant yield, No. of tubers/ m<sup>2</sup> and total yield of potato plant during 2016/2017 and 2017/2018 growing seasons.

Treatments	Characters		Plant yield (gm.)				No. of tubers/ m <sup>2</sup>				Total yield ton/fed.					
	Gibberellin	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>
<b>Cultivars</b>																
<b>1<sup>st</sup> season</b>																
Spunta		267.2	335.9	513.1	403.5	379.9	45.0	64.0	96.0	82.7	71.9	5.21	6.38	9.44	7.89	7.23
Cara		280.3	381.7	525.6	438.4	406.5	55.0	64.0	88.0	85.3	73.1	5.48	7.21	10.17	8.65	7.88
Diamant		236.9	297.2	345.6	387.6	316.8	49.3	57.3	60.3	63.7	57.7	4.23	5.68	6.29	6.63	5.71
Arizona		233.4	354.9	445.9	442.7	369.2	45.3	56.0	65.7	57.3	56.1	4.25	6.28	8.29	8.57	6.85
Nicola		250.7	270.9	480.4	415.7	354.4	45.3	52.3	64.7	57.3	54.9	4.32	5.24	8.92	7.31	6.45
X <sup>-</sup>		253.7	328.1	462.1	417.6		48.0	58.7	74.9	69.3		4.70	6.16	8.62	7.81	
<b>2<sup>nd</sup> season</b>																
Spunta		249.5	412.6	455.7	475.0	398.2	42.7	62.3	80.0	76.3	65.3	4.63	7.42	8.84	8.53	7.36
Cara		250.6	432.0	594.8	541.4	454.7	48.0	63.0	90.3	79.3	70.2	4.28	7.80	11.84	8.99	8.23
Diamant		212.8	441.4	399.7	422.9	369.2	46.3	61.0	61.3	65.0	58.4	3.90	5.88	7.53	8.04	6.34
Arizona		258.3	310.7	442.3	348.3	339.9	42.3	49.0	71.3	62.7	56.3	4.02	6.01	8.25	6.69	6.24
Nicola		231.8	358.3	430.0	337.5	339.4	48.0	64.0	64.0	56.0	58.0	4.69	6.49	8.19	6.03	6.35
X <sup>-</sup>		240.6	391.0	464.5	425.0		45.5	59.9	73.4	67.9		4.31	6.72	8.93	7.66	
<b>L. S. D. (0.05) for:</b>					<b>Sea. 1</b>	<b>Sea. 2</b>			<b>Sea. 1</b>	<b>Sea. 2</b>			<b>Sea. 1</b>	<b>Sea. 2</b>		
<b>Cultivars</b>					29.50	78.28			9.47	7.80			0.65	1.35		
<b>Gibberellin</b>					31.36	40.29			5.40	5.33			0.60	0.60		
<b>Interaction</b>					70.13	90.09			12.07	11.91			1.34	1.34		

A = Cost of on kg of tuber seeds. Table (9).

Z = Fixed cost of preparation and seasonal practices for one fed., Table (9).

Table (10) showed the total tubers weight to producing seedlings for plant one fed. (TW); output for all treatments and investment ratio. Obtained results in Table (10) indicated significant positive effect for both studied factors, i.e., potato cultivars and gibberellin application on total tubers weight to producing seedlings for plant one fed. and output for all treatments and investment ratio. Data could remark the following:

- 1- The highest values of output and investment ratio recorded significant increase of Cara Cv. followed by Spunta Cv. and the lowest values of total tubers weight to producing seedlings (TW) recorded significant decrease on both growing seasons.
- 2- The highest values of output and investment ratio and the lowest values of total tubers weight to producing seedling (TW) were recorded significant improvement with concentration 100 ppm GA followed by 150 ppm in both growing seasons.

The interaction between cultivars and gibberellin concentrations showed that Cara Cv with 100 ppm gibberellin treatment recorded the highest values of output and investment ratio in both growing seasons

**Table 9:** Fixed input cost for traditional production and seedling production cost for 1 ton (L.E.) of potato tubers.

Traditional production cost					seedling production cost for 1 ton				
Items	Unit	Counts	Unit cost L.E.	Total L.E.	Items	Unit	Counts	Unit cost L.E.	Total L.E.
<b>Fixed cost/fed.</b>					<b>Preparation cost/ton.</b>				
Land preparation	Hour	10	100	1000	Tubers soaking	Worker/day	2	100	200
Organic fertilizer	M <sup>3</sup>	30	100	3000	Uniqueness of tubers		2	100	200
Chemical fertilizer				3500	chopping		4	100	400
					Bud planting		3	100	300
<b>Labor cost</b>					Agriculture bags	KG	1	10	100
1- Fertilizer addition	Worker/day	4	100	400	Peat moss				
2- Planting seeds tuber		5	100	500	perlite				
3- Seasonal labor		10	100	1000	fertilizers				3000
4- Harvesting labor		5	100	500	Pesticides				
Pesticides	Liter	7	100	700	Labor cost	W/d	5	100	<b>500</b>
Foliar fertilizer	Liter	3	100	300	gibberellin				<b>200</b>
<b>Total</b>	<b>Z = 10900 L. E</b>				<b>Total</b>	<b>4900 L. E</b>			
<b>Variable cost price of one ton for each cultivars</b>						<b>C = 4.9 L.E for Kg</b>			
	<b>Full tubers</b>								
Spunta	24000 L.E.			A1 = 2.4 L.E.	<b>Total output</b>				
Cara	27000 L.E.			A2 = 2.7 L.E.	<b>First season</b>				
Diamant	23000 L.E.			A3 = 2.3 L.E.	<b>Y = 4000 L.E /ton</b>				
Arizona	25000 L.E.			A4 = 2.5 L.E.	<b>Second season</b>				
Nicola	20000 L.E.			A5 = 2.0 L.E.	<b>Y = 4000 L.E /ton</b>				

**Economic comparison between the traditional and seedlings method:**

Table (11) gave the total yield/fed., total number of tubers/m<sup>2</sup>, total output and investment ratio for all cultivars planted by traditional method one ton of tuber seed were used for each cultivars. Obtained results in Table (11) indicated that traditional method gave high total yield, total output but gave lowest tubers number than seedling method. On the other hand, seedling method gave the highest number of tuber/m<sup>2</sup> and investment ratio Table (10).

**Table 10:** Effect of cultivars and gibberellin concentrations on average tubers weight for seedling and total output and investment ratio of potato seedling methods during 2016/2017 and 2017/2018 growing seasons.

Treatments	Characters					Total output					Investment ratio					
	Gibberellin	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>	Cont.	50	100	150	X <sup>-</sup>
<b>Cultivars</b>																
<b>1<sup>st</sup> season</b>																
Spunta		1.50	0.48	0.29	0.37	0.66	20859	25523	37749	31571	28925	0.87	1.79	2.89	2.32	1.97
Cara		1.21	0.36	0.27	0.32	0.54	21921	28837	40696	34586	31510	1.13	2.13	3.15	2.59	2.25
Diamant		2.01	0.76	0.43	0.51	0.93	16934	22727	25141	26531	22833	0.70	1.41	1.81	1.82	1.43
Arizona		2.14	0.91	0.61	0.57	1.06	17010	25109	33159	34264	27385	0.68	1.44	2.15	2.27	1.64
Nicola		1.57	0.51	0.46	0.54	0.77	17269	20942	35664	29259	25783	0.81	1.45	2.53	2.01	1.70
X <sup>-</sup>		1.69	0.60	0.41	0.46		18798	24627	34482	31242		0.84	1.64	2.51	2.20	
<b>2<sup>nd</sup> season</b>																
Spunta		1.79	0.55	0.36	0.46	0.79	18533	29662	35361	34124	29420	0.80	2.01	2.61	2.39	1.95
Cara		1.41	0.47	0.28	0.34	0.62	17136	31216	47371	35973	32924	0.84	2.18	3.64	2.21	2.22
Diamant		2.20	0.77	0.45	0.57	1.00	15617	23520	30119	32168	25356	0.60	1.43	2.13	2.16	1.58
Arizona		2.68	0.95	0.62	0.59	1.21	16075	24044	32995	26759	24968	0.60	1.37	2.14	1.76	1.47
Nicola		1.62	0.78	0.47	0.54	0.85	18760	25941	32752	24118	25393	0.88	1.61	2.32	1.65	1.62
X <sup>-</sup>		1.94	0.70	0.43	0.50		17224	26877	35720	30628		0.75	1.72	2.57	2.03	
<b>L. S. D. (0.05) for:</b>				<b>Sea. 1</b>	<b>Sea. 2</b>		<b>Sea. 1</b>	<b>Sea. 2</b>				<b>Sea. 1</b>	<b>Sea. 2</b>			
Cultivars				0.33	0.35		<b>2616.5</b>	<b>5385.4</b>				0.24	0.43			
Gibberellin				0.27	0.26		<b>2402.0</b>	<b>2400.8</b>				0.20	0.27			
Interaction				NS	NS		<b>5371.1</b>	<b>5368.5</b>				0.46	0.60			

**Table 11:** Effect of cultivars on traditional method on total yield (ton/fed.), total number of tubers/m<sup>2</sup>, total output (L.E.) and investment ratio on both growing seasons.

Characters	Total yield ton/fed		No. of tubers /m <sup>2</sup>		Total output L.E.		Investment ratio	
	1 <sup>st</sup> Sea.	2 <sup>nd</sup> Sea.	1 <sup>st</sup> Sea.	2 <sup>nd</sup> Sea.	1 <sup>st</sup> Sea.	2 <sup>nd</sup> Sea.	1 <sup>st</sup> Sea.	2 <sup>nd</sup> Sea.
<b>Cultivars</b>								
<b>Spunta</b>	12.5	12.9	36	39	50000	51600	1.43	1.48
<b>Cara</b>	13.5	13.4	42	43	54000	53600	1.42	1.41
<b>Diamant</b>	12.5	11.9	30	31	50000	47600	1.47	1.40
<b>Arizona</b>	10.5	10.9	29	27	42000	43600	1.17	1.21
<b>Nicola</b>	11.6	12.5	28	29	46400	50000	1.50	1.62

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