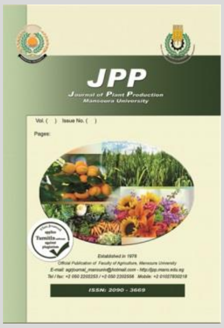
Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Effect of Seed Tuber Piece Size and The Number of Eyes on Growth and Yield of Potato (*Solanum tuberosum* L.)

Heba M. Ibrahim *

Dept. of Agric. Botany, Fac. of Agriculture, Mansoura University, 35516, El-Mansoura, EGYPT.



ABSTRACT

This research was done to evaluate the growth and yield of potato plants raised from seed tuber pieces (STP) containing one, two, three and four eyes, for ascertaining whether seed tuber pieces containing two eyes will sustain potato growth and yield indifferently from those of larger seed tuber pieces containing more eyes. Results indicated that number of stolons and leaves per plant, leaf area, plant fresh and dry weight, relative growth rate, net assimilation rate, crop growth rate, chlorophyll a, b as well as total chlorophylls, Number of tubers and total tuber yield per plant were decreased with decreasing number of eyes in the STP. However, final emergence percentage and total carotenoids content were not significantly affected. Nevertheless, number of tubers and total tuber yield per plant did not differ significantly neither between whole seed tubers and half seed tubers containing four eyes nor half STP containing three eyes and quarter STP containing two eyes. However, all these parameters were significantly lower in response to single-eye STP compared with those containing two eyes or more. From the economic point of view, cultivation of quarter STP containing two eyes instead of half STP containing four eyes represents 50 % conservation in the seed tubers used for only 13.5 % loss in tubers yield. So, it could be concluded that the gain in net income became substantiated by cultivation of quarter STP containing at least two eyes instead of larger seed tuber pieces, even that represents half of the seed tuber.

Keywords *:*Potato, *Solanum tuberosum* L.; Seed tuber piece, size, number of eyes; growth; yield

INTRODUCTION

Globally, potato (*Solanum tuberosum* L.) is the most important vegetable crop and the third-most important food crops in terms of consumption after rice and wheat. The crop is cultivated using seed tubers, the characteristics of which profoundly affect the plant growth and productivity. The cost of seed tubers constitutes 60-70 % of the total crop production cost (Mayakaduwa *et al*., 2017), therefore, seed tubers should be used at the minimum amount that substantiate good crop. So, it is a common practice to cut seed tubers into pieces with variations in the extent and type of cutting (Vanderzaag and Demagante, 1989; Hossain *et al*., 2011; Mayakaduwa *et al*., 2017; Diop *et al*., 2019).

Within seed tubers' features, their physiological age and weight/size have paramount influence on the vegetative and yield potential of the plant. Appropriate seed tuber size has very important implications on potato production. Emergence, seedling vigour, subsequent plant growth, and final yield are affected by seed tuber size. In addition, the physiological status of seed tubers has a great impact on the emergence, number of stems per plant, number of tubers per stem, tuber size distribution and tuber yield of the crop (Struik, 2007). Storage period and conditions, along with some other factors, affect the physiological age of the seed tubers (Caldiz *et al*., 2001) whereas cutting and its extent affect seed tuber size/weight.

Though potato plants could be raised from a piece of a tuber that has been cut into pieces with at least one eye containing three buds (Beattie, 2010), research shows that larger seed pieces result in more total yield than smaller ones (Adhikari, 2005; De Almeida *et al*., 2016, Ibrahim *et al*, 2018, Webster *et al*., 2018). Nevertheless, cultivation of large seed tuber pieces not only increase yield, but also increase production cost, sometimes, to the extent that net income becomes negative. Moreover, the benefit of larger-sized seed pieces diminishes as the size of seed pieces increases above certain limit (Iritani *et al*., 1983). This occurs because the number of eyes on each seed tuber increases only slightly as the tuber size increases. This means that the larger the tuber, the fewer eyes there are on a seed piece of the recommended size. So, there is a need to determine the minimum seed tuber piece size containing the number of eyes that does not compromise yield.

As it is more tedious to denote the seed tuber piece by the number of eyes it contains, it is a common practice to denote the tuber piece by its size/weight, though the first factor is more important than the later. It is true that seed tuber pieces of bigger size/heavier weight contain higher amounts of food reserves that aid the plant in its early establishment, but the vegetative makeup of the plant that determines its tuber production capacity lies within eyes, and originates from the buds it hosts. The number of eyes in the seed tuber piece influences stem number per plant (Nielson *et al*., 1989), which affects plant vegetative vigor, consequently its tuber yield potential. Every eye on a seed piece has the potential to produce at least one stem. In potato commercial plantings, 2.5-3.5 stems per plant is considered optimum for maximum performance (Bohl *et al*., 1994). So, the seed tuber piece containing two eyes hosting six buds is supposed to have the potential to fulfill

*** Corresponding author.**
E-mail address: hebaho@mans.edu.eg
DOI: 10.21608/jpp.2021.187444

the required number of stems per plant that ensures satisfactory commercial yield.

So, the present investigation aimed to assess the growth and yield of potato plants raised from seed tuber pieces containing one, two, three and four eyes. Specifically, the hypothesis to which the study is intended to ascertain whether quarter STP containing two eyes will sustain potato growth and yield indifferently from those of larger STP. In doing so, production cost is minimized and the yield is maintained, consequently, net income is increased.

MATERIALS AND METHODS

Two field experiments were conducted at the Experimental Farm of the Agric. Bot. Dept., Fac. of Agric., Mansoura University, Egypt during the two growing seasons 2017/2018 and 2018/2019. Potato seed tubers, cv. Spunta, were obtained from a local importing company and ascertained by Potato and Vegetatively Propagated Vegetables Department, Horticulture Research Institute, A.R.C., Giza, Egypt , sorted and these between 35 and 45 mm were used as planting materials. Two days before planting, seed tubers were cutted either in halves or quarters longitudinally, from rose to heel, using sharp knife which was dipped sequentially in 10 % sodium hypochlorite solution, followed by distilled water before cutting the next tuber. Cut tuber halves were sorted into two categories, in one category the piece contains four eyes (STP-4e) whereas the other contains three eyes (STP-3e) . Likewise, Cut tuber quarters were sorted into two categories, in one category the piece contains two eyes (STP-2e) whereas the other contains only one eye (STP-1e). Whole seed tubers (WST) were also planted as control. All pieces in each category were weighted, counted, then weight is divided by number to estimate mean weight of cut seed tuber piece in each category, which was 27.8, 21.6, 14.7, 10.6 g/piece in STP-4e , STP-3e , STP-2e , STP-1e, respectively, whereas that of WST was 56.4 g/tuber. Afterwards, cut seed tuber pieces were spread in one layer above jute bags for two days before planting in well-areated store at 20 °C and 85 % RH to ensure the formation of protective suberin layer on cutted surfaces.

Planting of seed tubers/pieces was done at 65 x 25 cm in 4 x 3 m plots , each containg four rows on November 11, 12, during the first and second season, respectively. The main physical and chemical characteristics of the experimental soil were determined according to Hoddinott and Lamb (1990) and presented in Table (1). The experiment was laid out in a randomized complete block design with three replicates. During soil preparation, 150 Kg/ha of phosphorus as calcium super phosphate (15.5% P_2O_5 was added). Nitrogen fertilizer was applied at the rate of 300 Kg of N/ha in the form of ammonium nitrate (33.5% N) in three equal doses during the growing season. Potassium sulphate (48% K_2O) was added at the rate of 150 kg K_2O/ha and applied at 40, 60 days after planting. Pest and disease control, weeding, and irrigation were done according to the recommendations of the Hort. Res. Inst., ARC, Egypt.

Table 1. Mechanical and chemical analysis of the used soil.

	CS %	FS %	S %	C %	$CaCO_3$ %	OM %	TN%	AP ppm	EK ppm	TSS %
2017/2018	10.7	27.8	28.1	33.4	2.6	2.2	0.17	22	218	0.18
2018/2019	10.4	26.7	29.8	33.1	2.8	2.3	0.19	25	223	0.17

***CS, Coarse sand; FS, Fine sand; S, Silt; C, Clay; OM, Organic matter; TN, total N; AP, available P; EK, exchangeable K; TSS, total soluble solutes; determinations were according to Hoddinott and Lamb (1990).**

Recorded parameters and analyses

Growth attributes

Number of emerged tubers was recorded at 30 days after planting (DAP) to determine final emergence (%). At 50 DAP, no. of stolons was recorded in ten emerged seed tubers/pieces per replicate. At 70 DAP, nine plants were randomly selected, three from each replicate to determine growth attributes represented by number of leaves, leaf area/plant (determined by estimating the fresh weight of a known area of leaf discs and estimated according to the formula: Leaf area = Total area of leaf discs X Total fresh weight of leaves per plant/ fresh weight of leaf discs) , and fresh as well as dry weight. Another sample was taken 10 days later to estimate biomass and leaf area. Data of the two samples were used to calculate relative growth rate (RGR), net assimilation rate (NAR), and crop growth rate (CGR) according to Radford (1967)'s formulae as follows:

$$\mathbf{RGR = (\log_e DW_2 - \log_e DW_1) / t_2 - t_1}$$

$$\mathbf{NAR = [(W_2 - W_1)(\log_e A_2 - \log_e A_1)] / [(A_2 - A_1)(t_2 - t_1)]}$$

$$\mathbf{CGR = [(W_2 - W_1) / (t_2 - t_1)] / GA}$$

where W1, A1 and W2, A2 are DWs, leaf areas at time 1 and time 2, respectively; GA = ground area.

Leaf photosynthetic pigments

One hundred mg of leaves, from the 3rd fully expanded leaf from the plant top of three randomly selected plants per replicate, was grounded in acetone, incubated overnight at 4 ◦C and then centrifuged 5 min at 10,000 rpm. Absorbance at 647, 663, and 470 nm was measured on a T60 U UV-VIS Spectrophotometer (PG Instruments, Leicestershire, England) to calculate chlorophyll a, chlorophyll b, and carotenoids using the following formulas of Lichtenthaler (1987):

$$\mathbf{Chl\ a = [(12.25 \times Abs663) - (2.55 \times Abs647)] \times V(mL)/weight\ (g).}$$

$$\mathbf{Chl\ b = [(20.31 \times Abs647) - (4.91 \times Abs663)] \times V(mL)/weight\ (g).}$$

$$\mathbf{Carots = [((1000 \times Abs470) - (1.82 \times Chl\ a) - (85.02 \times Chl\ b))/198] \times V(mL)/weight\ (g).}$$

Tchls content was estimated by adding the value of chl a to that of chl b.

Yield components and tubers quality

Yield and its components as well as tubers quality parameters were estimated 120 DAP. Ten plants, selected randomly from each replicate, were uprooted to estimate tuber number, average tuber weight and yield per plant. In addition, samples were taken from the tubers of three plants per replicate to estimate number of eyes/tuber, tuber specific gravity, dry matter percentage, protein percentage, and starch as well as glycoalkaloids concentrations.

Tuber specific gravity, dry matter percentage and starch concentration were determined according to Kumar *et al*. (2005). The specific gravity was determined using the following formula: Specific gravity = (weight in air) / [(weight in air) - (weight in water)]. For estimation of dry matter, ten tubers were cut longitudinally in two halves from stem end to bud end, then chopped into small pieces. Chopped pieces were put in aluminium boxes. The fresh weight was recorded and boxes were kept at 70 °C in a hot-air oven till constant dry weight. The boxes were again weighed and dry matter content was calculated.

Tuber protein percentage was determined according to the method of Lowry *et al.* (1951) using Folin-Fenol (1:2 v/v) as a reagent and measuring the absorbance at 750 nm. Bovine albumin was used for the establishment of the standard curve, through which protein was determined. Starch estimation was carried out by making the tuber tissues sugar-free by repeated extraction with 80 % isopropanol, hydrolyzing the starch by 60 % perchloric acid, and estimating glucose spectrophotometrically at 620 nm by using anthrone reagent according to Kumar *et al.* (2005).

Total glycoalkaloids (GA) content was determined spectrophotometrically by the method described by Grunenfelder *et al.* (2006). Tuber tissue (500 mg) was extracted with 10 ml of 80 % ethanol at 80 °C for 30 min, filtered, reduced to 5 ml on rotary evaporator at 50 °C, rinsed twice with 3 ml of 10 % (v/v) acetic acid and then centrifuged at 10,000× g for 30 min at 10 °C. The pH of the supernatant was adjusted to 9.0 with NH_4OH, refluxed at 70 °C for 25 min followed by overnight storage at 4 °C and was centrifuged as earlier. After discarding the supernatant, the resulting pellet was dissolved in 0.5 ml of 7 % (v/v) phosphoric acid. The total glycoalkaloids content was estimated by adding 200 µl of extract to 1 ml of 0.03% (w/v) phosphoric acid, allowing the contents to be settled for 20 min, then the absorbance was measured at 600 nm. The content of GA was quantified based on α-solanine (Sigma Chemical Co., St. Louis, MO, USA) standard curve and expressed as mg Kg^{-1} FW.

Statistical analysis:

Data were analyzed by one-way analysis of variance. The statistical analyses were performed using the procedures of SAS software (version 9.1). Duncan's multiple-range test was used for mean separations. Differences at $P < 0.05$ were considered as significant.

RESULTS AND DISCUSSIONS

Results

Growth attributes

All recorded growth parameters except final emergence were decreased in plants raised from seed tuber pieces compared with those in plants raised from whole tubers in both experimental seasons (Table 2). In addition, these growth attributes were progressively decreased with decreasing the size and number of eyes in the seed tuber piece used for cultivation. Final emergence percentage was not significantly affected by treatments, whereas all other estimated growth attributes were significantly affected. Number of stolons, number of leaves, leaf area, fresh weight, dry weight, relative growth rate (RGR), net assimilation rate (NAR), and crop growth rate of plants raised from seed tuber pieces containing either number of eyes (four, STP-4e; three, (STP-3e); two, STP-2e; one (STP-1e) were lower compared with those of plants raised from whole tuber pieces (WT). However, the decrease recorded in STP-4e-raised plants with regard to number of stolons, leaf area, RGR, NAR, and crop growth rate was not significant during both seasons.

Compared with WT-raised plants, number of stolons was decreased by 18.7, 21.8, 26.5 % and 23.8, 28.3, 34.3 % in STP-3e, STP-2e, STP-1e-raised plants during the first and second experimental season, respectively. The corresponding decreases in plant dry weight were 25.1, 27.7, 38.7 % and 28.5, 29.7, 39.7 %, respectively. Likewise crop growth rate was decreased by 14.4, 17.3, 25.0 % and 13.6, 16.2, 22.7 %, respectively. Also the results presented in Table (2) indicate that the recorded growth attributes of plants raised from STP-3e did not differ significantly from those of plants raised from STP-2e. Moreover, growth attributes of plants raised from STP-3e did not differ significantly from those of plants raised from STP-4e.

Table 2. Growth attributes of potato plants raised from whole tubers (WT), seed tuber pieces having four eyes (STP-4e), seed tuber pieces having three eyes (STP-3e), seed tuber pieces having two eyes (STP-2e) and seed tuber pieces having only one eye (STP-1e).

	WT	STP-4e	STP-3e	STP-2e	STP-1e	LSD (5 %)
2017/2018						
Final emergence (%)	99.7	98.7	97.5	97.8	96.4	NS
No. of stolons/tuber	6.4a	5.8ab	5.2bc	5.0bc	4.7c	0.9
No. of leaves/plant	12.7a	11.2b	10.4bc	9.8bc	9.3c	1.4
Leaf area ($cm^2 plant^{-1}$)	3102a	2942ab	2830bc	2785bc	2736c	217
Fresh weight (g $plant^{-1}$)	235.1a	182.4b	178.2b	170.8b	151.6c	19.0
Dry weight (g $plant^{-1}$)	34.6a	25.9b	26.54b	25.7b	21.2c	2.9
RGR (mg g^{-1} d^{-1})	33.4a	31.6ab	29.7b	30.8b	26.7c	2.1
NAR (mg cm^2 d^{-1})	1.61a	1.42a	1.14b	1.17b	0.92c	0.20
Crop growth rate (g m^2 d^{-1})	45.6a	41.8ab	39.0b	37.7bc	34.2c	3.8
2018/2019						
Final emergence (%)	99.5	98.2	97.8	97.5	97.0	NS
No. of stolons/tuber	6.7a	6.0ab	5.1c	4.8cd	Cd	0.8
No. of leaves/plant	13.1a	11.7b	10.2c	10.0cd	9.0d	1.2
Leaf area ($cm^2 plant^{-1}$)	3082a	2886ab	2750bc	2680bc	2625c	226
Fresh weight (g $plant^{-1}$)	241.6a	190.8b	175.3c	161.2cd	150.4d	14.8
Dry weight (g $plant^{-1}$)	35.0a	27.0b	25.0bc	24.6bc	21.1d	2.5
RGR (mg g^{-1} d^{-1})	32.8a	30.7ab	30.0b	29.2b	26.1c	2.4
NAR (mg cm^2 d^{-1})	1.70a	1.53a	1.15b	1.02bc	0.86c	0.25
Crop growth rate (g m^2 d^{-1})	46.1a	42.8ab	39.8bc	38.6c	35.6c	4.0

Different small letters within the same row indicate significant differences between means at $P \leq 0.05$ according to Duncan's multiple-range test.

Photosynthetic pigments

Chlorophyll a (chl a), Chlorophyll b (chl b), and total chlorophylls (tchls) in leaves of plants raised from STP were significantly lower compared with those in leaves of plants raised from whole seed tubers (Table 3). Data also indicated that the lower the number of eyes in the seed tuber piece, the lower the concentration of tchls in the leaves of plants from which they arise. However, the decrease recorded in chl b and tchls in leaves of plants raised from STP-4e during the second season was not significant. Total chlorophylls concentration was decreased by 11.3, 21.9, 26.5, 29.5 % and 12.1, 17.0, 24.3, 27.6 % in leaves of plants raised from STP-4e, STP-3e, STP-2e, STP-1e during the first and second experimental season, respectively. On the other hand, total carotenoids concentration was not significantly affected by treatments.

Table 3. Chlorophyll a (chl a), Chlorophyll b (chl b), total chlorophylls (tchls), and total carotenoids (tcarots) concentrations in the leaves of potato plants raised from whole tubers (WTs), seed tuber pieces having four eyes (STP-4e), seed tuber pieces having three eyes (STP-3e), seed tuber pieces having two eyes (STP-2e) and seed tuber pieces having only one eye (STP-1e).

	WT	STP-4e	STP-3e	STP-2e	STP-1e	LSD (5 %)
2017/2018						
Chl a (mg g^{-1} FW)	0.97[a]	0.89[b]	0.76[c]	0.72[c]	0.70[c]	0.07
Chl b (mg g^{-1} FW)	0.34[a]	0.30[b]	0.26[c]	0.23[d]	0.20[e]	0.03
tchls (mg g^{-1} FW)	1.31[a]	1.19[b]	1.02[c]	0.95[cd]	0.90[d]	0.12
Tcarots (mg g^{-1} FW)	0.32	0.29	0.34	0.32	0.26	NS
2018/2019						
Chl a (mg g^{-1} FW)	0.92[a]	0.83[b]	0.79[c]	0.70[d]	0.67[d]	0.06
Chl b (mg g^{-1} FW)	0.30[a]	0.27[ab]	0.25[b]	0.22[bc]	0.20[c]	0.04
tchls (mg g^{-1} FW)	1.22[a]	1.10[ab]	1.04[b]	0.92[bc]	0.87[c]	0.15
Tcarots (mg g^{-1} FW)	0.28	0.25	0.30	0.32	0.22	NS

Different small letters within the same row indicate significant differences between means at P ≤ 0.05 according to Duncan's multiple-range test.

Yield and its components

Plants raised from seed tuber pieces containing two eyes or less produced significantly lower number of tubers compared with those raised from whole seed tubers (Table 4). This is also true regarding the number of tubers formed from plants raised from STP-3e, but the decrease was significant only during the first season. Though plants raised from STP-4e produced also lower number of tubers compared with those raised from whole seed tubers, the difference did not reach the significance level. There was a converse relationship between number of tubers and tuber weight in plants raised from not only whole tubers, but also STP-4e and STP-3e, i.e. as the number of tubers decreased, tuber weight is increased, reaching a maximum of 242.8 and 264.8 g/tuber in plants raised from STP-3e, during the first and second season, respectively. On the other hand, as the number of tubers is decreased in response to STP-2e and STP-1e, tuber weight is also decreased, reaching a minimum of 166.4 and 175.0 g/tuber in plants raised from STP-1e, during the first and second season, respectively. Nevertheless, tuber yield per plant was progressively decreased as the number of eyes in the seed tuber piece is decreased. However, the decrease recorded in plants raised from STP-4e was not significant during both experimental seasons. Total tuber yield per plant was decreased by 9.7, 17.9, 42.3 % and 16.2, 24.7, 45.5 % in plants raised from STP-3e, STP-2e, STP-1e during the first and second experimental season, respectively, compared with that of plants raised from whole tubers (Table 4).

Plants raised from STP-2e produced 13.2, 16.9 % fewer number of tubers compared with those raised from STP-4e, during the first, second season, respectively. In addition, total tuber yield per plant in STP-2e was decreased by 10.3, 16.7 % compared with that in STP-4e, during the first, second season, respectively.

Table 4.Yield components of potato plants raised from whole tubers (WT), seed tuber pieces having four eyes (STP-4e), seed tuber pieces having three eyes (STP-3e), seed tuber pieces having two eyes (STP-2e) and seed tuber pieces having only one eye (STP-1e).

	WT	STP-4e	STP-3e	STP-2e	STP-1e	LSD (5 %)
2017/2018						
No. of tubers/plant	7.4[a]	6.8[a]	6.6[bc]	5.9[c]	4.6[d]	0.8
Average tuber weight (g)	208.6[b]	231.7[ab]	242.8[a]	214.8[b]	166.4[c]	25.4
Tuber yield (g $plant^{-1}$)	1543[a]	1423[ab]	1392[bc]	1276[c]	889[d]	125
2018/2019						
No. of tubers/plant	6.9[a]	6.5[a]	6.2[ab]	5.4[b]	4.4[c]	0.9
Average tuber weight (g)	232.8[b]	250.7[ab]	264.8[a]	198.4[c]	175.0[d]	22.4
Tuber yield (g $plant^{-1}$)	1514[a]	1392[ab]	1268[b]	1159[bc]	825[d]	128

Different small letters within the same row indicate significant differences between means at P ≤ 0.05 according to Duncan's multiple-range test.

Tuber quality

Tubers formed on plants raised from seed tubers pieces containing either four or three eyes contained significantly higher number of eyes compared with those formed on plants raised from whole seed tubers (Table 5). The number of eyes on tubers formed on plants raised from STP-4e and STP-3e was increased by 14.8, 24.4 % and 16.3, 26.0 % compared with that on tubers formed on plants raised from whole tubers during the first and second season, respectively. On the other hand, the number of eyes on tubers formed on plants raised from either STP-2e or STP-1e did not differ significantly from that on tubers formed on plants raised from whole tubers.

Starch concentration in the tuber was significantly affected by treatments. Tubers formed on plants raised from all types of seed tuber piece contained lower starch concentration compared with those formed on plants raised from whole seed tubers. However, the recorded decrease in response to STP-4e during both seasons as well as due to STP-3e during the first season was not significant. Other tuber quality parameters, i.e., tuber specific gravity, dry matter percentage, protein percentage, and glycoalkaloids concentration did not significantly affected by treatments (Table 5).

Table 5. Quality attributes of potato tubers formed on plants raised from whole tubers (WT), seed tuber pieces having four eyes (STP-4e), seed tuber pieces having three eyes (STP-3e), seed tuber pieces having two eyes (STP-2e) and seed tuber pieces having only one eye (STP-1e).

	WT	STP-4e	STP-3e	STP-2e	STP-1e	LSD (5 %)
2017/2018						
No. of eyes/tuber	9.4^{b}	10.8^{a}	11.7^{a}	9.6^{b}	8.6^{b}	1.1
Tuber specific gravity	1.079	1.072	1.069	1.070	1.072	NS
Dry matter (%)	20.4	19.7	18.6	19.5	19.3	NS
Protein (%)	2.0	2.0	1.9	1.7	1.8	NS
Starch (mg g^{-1} FW)	190.8^{a}	186.4^{a}	182.3^{ab}	173.1^{b}	156.4^{c}	11.6
Glycoalkaloids content (mg Kg-1 FW)	68.2	64.5	60.7	62.3	63.8	NS
2018/2019						
No. of eyes/tuber	9.2^{b}	10.7^{a}	11.6^{a}	9.8^{b}	8.3^{b}	1.2
Tuber specific gravity	1.075	1.070	1.065	1.071	1.074	NS
Dry matter (%)	20.1	19.0	18.5	19.1	19.7	NS
Protein (%)	1.9	1.7	1.6	1.6	1.7	NS
Starch (mg g^{-1} FW)	200.2^{a}	196.4^{a}	180.3b	170.8^{bc}	167.0^{c}	12.7
Glycoalkaloids content (mg Kg^{-1} FW)	65.5	66.0	64.8	64.0	62.7	NS

Different small letters within the same row indicate significant differences between means at P ≤ 0.05 according to Duncan's multiple-range test.

Discussion

The present investigation aimed to ascertain the hypothesis that seed tuber pieces containing two eyes will sustain potato growth and yield indifferently from those of larger seed tuber pieces. Results of the present study indicated that growth (Table 2) and yield (Table 4) parameters were increased as the number of eyes in the seed tuber piece is increased, even within the same size category of the seed tuber. So, growth and yield of potato plants are positively correlated with the number of eyes in the seed tubers from which the plants arise. This positive relationship is in line with the results of Arioglu (2009) and Masarirambi *et al*. (2012). Higher number of eyes containing more buds so, more stems are formed on large seed tubers-raised plants contributing to higher growth vigour and yield. Canopy coverage, main stem number/hill, tuber number/hill, and tuber yield were significantly increased with increasing number of eyes in cut seed tuber pieces. These results are in conformity with those of Cisneros and Herrera (1987) and Mahmood and Gill (1984). Additionally, the higher number of eyes entails a higher size of the seed tuber piece, hence higher amount of reserved food materials that might have helped in early shoot emergence, reducing the period required to produce sprouts, advancing emergence, and sustaining plants developed from larger seed tubers (Shakh *et al*., 2001).

Number of stems per plant as well as per unit area, number of tubers per plant and per unit area, and tuber yield per plant were significantly higher when tuber pieces with double eyes were planted compared with cut tubers with single eye (Mahmud et al., 2010). Conversely, Planting of single eyed-pieces produced tubers of higher weight compared with double-eyed pieces due to the higher number of tubers produced in the later case. The inter-plant competition for nutrition is higher as the number of eyes in the seed tuber pieces is increased due to the higher number of stems produced. Tuber production per plant is directly correlated with the number of main stems per plant and is affected by inter-plant competition (Bushan et al., 2007). Several stems develop from the seed tuber depending on its size and physiological age. Each stem behaves as sparate potato plant since each has its own root and shoot system (Struik, 2007). Mahmud et al. (2010) concluded that cut seed tubers containing two eyes cultivated at 40 X 15 cm spacing was the best for net income according to a cost-benefit analysis.

Data of this study indicated that cultivation of two-eyed seed tuber pieces produced significantly higher tuber yield compared with one-eyed seed tubers, but significantly indifferent yield compared with those of three-eyed pieces. Considering that the two-eyed seed tuber piece is a quarter seed tuber whereas the three-eyed one is a half tuber, and both were exposed to similar cultivation conditions, the indifferent yield between them is supposed to be a certain factor that compensated for the piece size, likely the extent of cutting in this case. According to Allen (1979), reducing the number of dormant buds is one of the major advantages of cutting seed tubers, so it is assumed that increasing the extent of cutting attenuated the degree of bud dormancy, consequently increasing bud sprouting, forming more stems, approaching that was resulted from the three-eyed piece. Similar effect was recorded previously by Vanderzaag and Demagante (1989) who found that the number of stems produced from the seed tuber quarter was equivalent to that produced from the seed tuber half in cultivars Berolina and Perricholi. They also added that there is another important yield-determining factor, which is the canopy duration, leads to better prediction of yield than the number of stems/ m^{2}. In addition, If stem or plant density is low, branching increases, enhancing canopy cover, i.e., low stem density is compensated with vigorous haulm growth (Fleisher *et al*., 2011; Shayanowako *et al*., 2014).

Results of the present study indicated that cultivation of the three-eyed pieces led to a reduced number of tubers per plant, but tubers were of higher weight compared with cultivation of the four-eyed pieces, i.e., within this size range of the seed tuber piece, there is a converse relationship between number of tubers produced and the individual tuber weight. Similar results were reported (Shakh *et al*., 2001; Mahmud *et al*., 2010). This is attributed to the lower number of tubers produced in response to cultivation of pieces having lower eye number, thereby the individual tuber weight is increased. According to Vanderzaag and Demagante (1989), tuber seed cutting is a way to reducing the number of tubers produced, thereby increasing tuber weight.

On the other hand, results indicated that the reduction in the number of tubers as a result of cultivating the one-eye seed tuber pieces was also accompanied with a reduction in the weight of the individual tuber. This may be due to the severe growth reduction, including a reduced number of leaves and a diminished leaf area of plants raised from one-eye seed tuber pieces (Table 2), consequently high competition between tubers on a reduced amount of photosynthates (Li *et al*., 2016).

Results indicated that cultivation of STP-2e led to about 15.0 and 13.5 % decrease in tubers number and total tuber yield/plant, respectively, over the two experimental seasons, compared with STP-4e. Considering that the STP-2e is half size compared with the STP-4e, it is evident that cultivation of STP-2e instead of STP-4e represents 50 % conservation in the seed tubers used at the expense of only 13.5 % loss in tubers yield. If also the fact that the price of seed tubers is higher than that of the tubers sold as food, the gain in net income became evident by cultivation of quarter STP containing two eyes instead of half STP containing four eyes.

CONCLUSION

The number of eyes in the seed tuber piece used for cultivation affected growth and yield of potato plants. Growth and yield of plants were decreased with decreasing the number of eyes in the seed tuber piece. This was also concomitant with a decline in chlorophyll concentration in the leaves. Nevertheless, there was no significant difference in total tuber yield per plant between plants raised from quarter seed tuber pieces containing two eyes and those raised from half seed tuber pieces containing three eyes. Therefore, raising the potato crop from quarter seed tuber pieces containing two eyes is recommended to conserve the cost of seed tubers as this outcome outweighs the yield loss.

ABBRECIATIONS

WT, seed tuber planted as whole; STP, seed tube piece(s); STP-4e, seed tuber piece containing four eyes; STP-3e, seed tuber piece containing three eyes; STP-2e, seed tuber piece containing two eyes; STP-1e, seed tuber piece containing only one eye; chl a, chlorophyll a; chl b, chlorophyll b; tchls, total chlorophylls; tcarots, total carotenoids.

REFERENCES

Adhikari, R.C. (2005). Performance of different size true potato seed seedling tubers at Khumaltar, Nepal. Agric. Res. J., 6: 28-34.

Allen, E. J., J. N. Bean, R. L. Griffith, P. J. 2¶%ULHQ Effects of length of sprouting period on growth and yield of contrasting early potato cultivars. J. Agric. Sci. (Camb.) 92:151±163.

Arioglu H. (2009). Effects of seed size and in row spacing on growth and yield of early potato in a Mediterranean-type environment in Turkey. African J. Agric. Res., 4(5): 535-541. DOI: 10.1007/fs12450-015-9164-21.

Beattie, B.M. 2010. The effects of seed production practices on the productivity of the succeeding ware potato crop. Ph.D. Thesis, University of Tasmania.

Bohl, W.H.; Nolte, P.; Kleinkopf, G.E.; Thornton, M.K. 1993. Potato Seed Management: Seed Size and Age. University of Idaho, College of agriculture. CIS 1031. 4 pp.

Bushan, A.J., Mitchell, P.D., Copas, m.E., Drillias, m.J. 2007. Evaluation of the effect of density on potato yield and tuber size distribution. Crop sci. 47 (6), 2462-2472.

Caldiz , D. O.; Fernandeza, L. V.; Struik, P. C. (2001). Physiological age index: a new, simple and reliable index to assess the physiological age of seed potato tubers based on haulm killing date and length of the incubation period. Field Crops Research 69 (2001) 69-79.

Cisneros, B., Herrera, J. 1987. Planting distance and tuber size in potato (*Solanum tuberosum* L.) seed production in Cartago. Agronomia Costarricense 11, 65-69.

De Almeida, F.M.; Sanchez, J.A.; de la Noval, W.T.; Rodriguez, J.A.C. (2016). Effects of different plant spacings and seed tuber sizes on some morpho-productive characteristics of potato in Huambo, Angola. Cultivas Troicales, 37 (2): 88-95.

Diop P, Sylla, E.S., Diatte, M., Labou, B., Diarra, K. 2019. Effect of cut seed tubers and pre-germination on potato tuber yield. Int. J. Biol. Chem. Sci. 13(7), 3157-3163. DOI: https://dx.doi.org/10.4314/ijbcs.v13i7.15.

Ebrahim, S.; Mohammed, H.; Ayalew, T. (2018). Effect of seed tuber size on growth and yield performance of potato (*solanum tuberosum* L.) varieties under field conditions. African J. Agric. Res., 13 (39): 2077-2086.

Fleisher DH, Timlin DJ, Yang Y, Reddy VR (2011). Potato stem density effects on canopy development and production. Potato Research 54 (2):137–55. http://dx.doi.org/10.1007/s11540-011-9185-2

Grunenfelder, L.A., Knowles, L.O., Hiller, L.K. & Knowles, N.R. (2006). Glycoalkaloid development during Greening of fresh Market Potatoes (*Solanum tuberosum* L.). J. Agric. Food Chem. 54, 5847–5854.

Hoddinott, K.B., Lamb, R.O. 1990. PhysicoChemical Aspects of Soil and Related Materials. ASTM (ASTM special technical publication; 1095) Philadelphia, PA.

Hossain, M.S., Zakaria, M., Hossain, M.M., Rashid, M.H. 2011. Effect of seed size and cutting methods on the yield and profitability of potato. The Agriculturists 9(1,2), 54-62.

Iritani, W.M., Weller, L.D., Knowles, N.R. 1983. Relationships between stem number, tuber set and yield of Russet Burbank potatoes. Am. Potato J. 60, 423-431.

Kumar, D., R. Ezekiel, B. Singh, and I. Ahmed. (2005). Conversion table for specific gravity, dry matter and starch content from under water weight of potatoes grown in north-Indian plains. Potato J., 32 (1–2): 79–84.

Li W, Xiong B, Wang S, Deng X, Yin L, Li H (2016) Regulation Effects of Water and Nitrogen on the Source-Sink Relationship in Potato during the Tuber Bulking Stage. PLoS ONE 11(1): e0146877. doi:10.1371/journal.pone.0146877

Lichtentbaler, H.K. (1987). Chlorophylls and carotenoids: Pigments of photosynthetic biomembranes. Methods Enzymol; 148: 350-382.

Lowry, O.H.; Rosebrough, N.J.; Farr, A.L. and Randall, R.J. (1951). Protein measurement with the Folin-Phenol reagent. J. Biol. Chem., 193: 265-275.

Mahmood, A., Gill, A. 1984. Relationship of stem density with seed size and weight of four potato cultivars (*Solanum tuberosum* L.). J. Agric. Res. Pakistan 22, 309-312.

Mahmud, A.A., Hoque, M.A., Mamun, A.A., Bazzaz, M.M., Hossain, M.A. 2010. Yield and profitability of potato as influenced by intra-row spacing and number of eye in cut tuber in northern region of Bangladesh. Ann. Bangladesh Agric. 14 (1&2), 111-124.

Masarirambi MT, Mandisodza FC, Mashingaidze AB, Bhebhe E. (2012). Influence of plant population and seed tuber size on growth and yield components of potato (*Solanum tuberosum*). Int. J. Agric. Biol., 14(7): 545-549. DOI: 10.1007/BF02854248.

Mayakaduwa, M.A.P., Babu, A.G.C., Nugaliyadde, M.M., Peter, J., Kahawandala, K.R.S.C.B., Nishshanka, N.I.J.H. 2017. Performance of seed tuber pieces of potato as planting material under up country wet zone conditions. Annals of Sri Lanka Department of Agriculture. 19, 129 – 138.

Nielson M., Iritani W.M., Weiler L.D., 1989. Potato seed productivity: factors influencing eye number per seed piece subsequent performance. Am. J. Potato. Res., 66(3): 151-160.

Radford ,P.G. (1967). Growth Analysis Formulae - Their Use and Abuse. Crop Sci; 3: 171-175.

SAS (Statistical Analysis System) Institute (2004) SAS user guides, version 9.1.SAS Inc. Cary. North Carolina, USA.

Shakh, M.N.U., Awal, M.A., Ahmed, S.U., Baten, M.A. 2001. Effect of eyes number in cut seed tuber and different levels of nitrogen on growth, yield and grading of tuber size in potato (*Solanum tuberosum* L.). Pakistan J. Biol. Sci. 4 (10), 1184-1187.

Shayanowako, A. ; Mangani, R.; Taurira Mtaita, T.; Mazarura, U. 2014. Effect of stem density on growth, yield and quality of potato variety amethyst. African Journal of Agricultural Research. Vol. 9(17), pp. 1391-1397, 24 April, DOI: 10.5897/AJAR2014. 8570.

Struik, P.C. 2007. Above-ground and below ground plant development In:Vreugdenhill*et al*. (eds) Potato Biology and Biotechnology, Advances and Perspective, Elsevier, Netherlands, pp. 2L9-236.

Vanderzaag, P., Demagante, A.L. 1989. Potato (*Solanum spp.*) in an isohyperthermic environment, IV. Effects of cutting seed tubers. Field Crops Res. 20, 1-12.

Webster BJ, Chen Y, Gevens AJ. (2018). Impact of seed cutting and seed-borne inoculum on daughter tuber common scab and plant growth. Am. J. Potato Res., 95: 191–198. DOI: 10.1007/s12230-017-9626-9.

تأثير حجم و عدد العيون فى درنات التقاوى على نمو و محصول البطاطس ***Solanum tuberosum* L.**

هبة محمد ابراهيم عبد السلام
قسم النبات الزراعى، كلية الزراعة، جامعة المنصورة، 35517 المنصورة، جمهورية مصر العربية

أجريت تجربتان حقليتان بالمزرعة البحثية لقسم النبات الزراعى، كلية الزراعة، جامعة المنصورة فى موسمى الزراعة 2018/2017 و 2019/2018 لتقييم نمو و محصول نباتات البطاطس التى تنشأ عن درنات تقاوى تحتوى اما على واحدة، اثنتان، ثلاثة أو أربعة من العيون. و لقد أوضحت النتائج أن عدد السيقان الأرضية (Stolons) و كذا عدد الأوراق فى النبات الواحد، المساحة الورقية، الوزن الغض و الجاف للنبات، معدل النمو النسبى، معدل صافى التمثيل، و معدل نمو المحصول قد انخفضت بانخفاض عدد العيون فى قطعة درنة التقاوى المنزرعة، بينما لم تتأثر نسبة الانبات النهائية Final emergence. و بصورة مشابهة، فلقد انخفض تركيز كلوروفيل أ، ب، و كذا الكلوروفيلات الكلية فى أوراق النباتات الناشئة عن قطعة درنة التقاوى المنزرعة كلما قل عدد العيون بها، بينما لم يتأثر تركيز الكاروتنيدات الكلية. و لقد أوضحت النتائج أيضاً حدوث نقص فى عدد الدرنات الناتجة و المحصول الكلى من الدرنات للنبات كلما قل عدد العيون فى قطعة درنة التقاوى التى نشأ منها النبات. و رغم هذا فلم يكن الانخفاض فى صفتى عدد الدرنات الناتجة و المحصول الكلى من الدرنات/ النبات فى النباتات الناشئة عن قطع درنات التقاوى المحتوية على اثنتان من العيون معنوياً بالمقارنة بقيم الصفتبن فى النباتات الناشئة عن قطع درنات التقاوى المحتوية على ثلاثة من العيون. و كذا فلم يكن الانخفاض فى صفتى عدد الدرنات الناتجة و المحصول الكلى من الدرنات/ النبات فى النباتات الناشئة عن قطع درنات التقاوى المحتوية على ثلاث من العيون معنوياً بالمقارنة بقيم الصفتبن فى النباتات الناشئة عن درنات التقاوى التى زرعت كاملة. و على النقيض من ذلك، فلقد نقصت قيم كل صفات المحصول و مكوناته معنوياً فى النباتات الناشئة عن قطع درنات التقاوى المحتوية على عيناً واحدة فقط بالمقارنة بقيم الصفات فى النباتات الناشئة عن قطع درنات التقاوى المحتوية على عدد اثنتان أو أكثر من العيون. و لما كانت زراعة قطع درنات التقاوى المحتوية على عدد اثنتان من العيون قدد أدت الى اتقاص محصول الدرنات بنسبة 13.5 % فقط وفى ذات الوقت تمثل توفير فى كمية التقاوى المستخدمة قيمته 50 % بالمقارنة بزراعة قطع درنات التقاوى المحتوية على عدد أربعة من العيون، فانه يمكن استنتاج، و من ثم التوصية، باستخدام قطع تقاوى تمثل ربع الحجم المعتاد لدرنات التقاوى بحيث تحتوى على اثنتان من العيون على الأقل بدلاً قطع التقاوى التى تمثل نصف الحجم المعتاد لدرنات التقاوى فى زراعة محصول البطاطس لزيادة صافى الربح من الانتاج.