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Certified Potato (*Solanum tuberosum* L.) G1 Tubers Production at Different Weight and Planting Distances of G0 Tubers in Lebanon

M. Dalleh [a], J. Borjac [a], G. Younes [b], E. Choueiri [c], A. Chehade [d] and A. Elbitar [d*]

[a] Department of Biological Sciences, Faculty of Science, Beirut Arab University, Debbieh, Lebanon.
[b] Department of Chemistry, Faculty of Science, Beirut Arab University, Debbieh, Lebanon.
[c] Department of Plant Protection, Lebanese Agricultural Research Institute, Tal Amara Station, Ahleh, Lebanon.
[d] Department of Plant Biotechnology, Lebanese Agricultural Research Institute, Tal Amara Station, Plant Tissue Culture Unit, Zahleh, Lebanon.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Plant spacing and seed tuber size are important agronomic management practices in the production of potato. Three weights of G0 potato tubers (W1 < 10g; 10g< W2< 20g; 20g< W3< 30g) and two planting distances (D1: 10 cm and D2: 20 cm) with a potato variety Spunta were taken in a study from March to June during the 2022 planting season at the Lebanese Agricultural Research Institute (LARI, Tal Amara), Bekaa, Lebanon. The objective was to observe the effect of G0 tuber

**Corresponding author: E-mail: abitar@lari.gov.lb;*

weights and planting distance on average weight (AWe), average number (AN), average length (AL), average width (AW) and production/m2 of G1 potato tubers cultivar Spunta in Lebanon. The largest G0 tubers (20g< W3< 30g) planted at widest distance (D2: 20 cm) yielded the maximum significant weight, length, width and yield of 41.75 g 6.63, 3.57 cm and 11.52 Kg/m2 respectively of G1 tubers produced whereas the lowest average in these traits (4.19g, 2.89 cm, 1.49 cm and 3.49 Kg/m2) were obtained in smallest G0 tuber weight (W1 < 10g) and closest planting distance (D1: 10 cm). The highest number of G1 tubers (24) was obtained with smallest G0 tubers (W1< 10 g) planted at the closest plant spacing 10 cm, while the lowest number (12) was obtained in the largest size G0 tuber (20g< W3< 30g) with the closest distance 10cm. To conclude, we outline a protocol to produce potato seeds cultivar Spunta in Lebanon by evaluating the field performance of different size potato tuber and planting distances. Our findings suggest planting G0 tuber of W< 10 g at spacing distance of 10 cm. This will increase the number of G1 tubers obtained and provide access to broader international markets.

Keywords: Solanum tuberosum L*; G0 tuber; spunta; G1 tuber.*

1. INTRODUCTION

The potato (*Solanum tuberosum* L.) originated from the Andean regions in Peru and Bolivia is one of the main agricultural products in the world with 325.3 million tones production and stands in the fourth place after wheat, rice and corn [1]. Potato crop is considered as a high potential food security and profitable crop. It yields high-quality and quantity product per unit input with a shorter crop cycle (mostly <120 days) compared to major cereal crops like maize [2,3]. The production of seeds of high quality (genetic purity, hygiene, proper physiological age) is among the most important activities in potato cultivation throughout the world [4]. So, special attention has been given to tissue culture for potato breeding programs, due to the high number of explants produced from a single mother plant and the adaptation of micro-plants to conditions that favor slow development in order to conserve virus free genetic material for prolonged time periods [5].

In Lebanon, potato is considered the most important field crop. It is a very important source of food and revenue in rural areas. In 2017, the harvested area estimated at 18,900 ha produced around 425,000 tons [6]. Cultivation is mainly concentrated in the Bekaa valley at 900–1000 m above sea level (~70% of total potato cultivated area), and in Akkar plain (~30% of total potato cultivated area) [7]. Potato is cultivated for fresh consumption and processed products, with a certain percentage (~37%) kept for export [8]. In Lebanon, *Spunta* is still the preferred variety for consumers over the years [9]. It can be planted in three different seasons. Despite its importance, potato quality and yield can be affected by many factors such as cultivar, plant population, soil type, weather conditions, water management, seed piece size, pests and diseases and many others [10]. Even with the wide range of microclimates suitable for high quality potato seed production, Lebanese farmers faces difficulties finding suitable and available ones. They import around 18000 tons of high-cost tubers every year [6]. Some farmers purchase uncertified tuber from local markets or by selection of seeds from yield of previous year causing spread of fungal and viral diseases [11]. Optimizing plant density and G0 tuber size during planting are among the most important agronomic practices of potato seed production as it affects seed cost, plant development, yield, and quality of the crop [12]. Many researches tackled the evaluation of the performance of potato seed tubers [13-16] but little information exists on the field performance of tubers for the breeder's potato seed production.

In this context, the present study aims at evaluating the field performance of different sizes of G0 potato tubers and the effect of planting distance to produce high-quality and homogeneous certified G1 tubers at acceptable price in the central region of the Bekaa plain in Lebanon.

2. MATERIALS AND METHODS

2.1 Site Characteristics

The experiment was carried out at the Lebanese Agricultural Research Institute (LARI, Tal Amara station, Bekaa, Lebanon). The site located at 905 m altitude, 33º51.685´ N latitude and 35º59.454´ E longitude.

This region is characterized by typical Mediterranean weather where it is hot and dry

from May till October and cold during the remaining period of the year. It has an average rainfall of 592 mm/year.

The soil of the experimental field is a mixture of clay (41%), sand (23%) and silt (36%) with 4% of active calcareous. It is rich in available sodium (130 ppm), exchangeable magnesium (301 ppm), calcium (6975 ppm), available nitrogen (34 Kg/ha) and available iron (1.1 ppm) but poor in organic matter (1.4%).

2.2 Plant Material and Experimental Treatments

Certified tuber (basic seeds G0) of *Spunta* variety produced using *in vitro* techniques at the department of Plant Biotechnology in LARI, were cultivated in Tal Amara station (LARI) at the end of February 2022 [17]. Three weights (W1<10g; 10g< W2< 20g; 20g< W3< 30g) with two different planting distances (D1: 10 cm and D2: 20 cm) were chosen (Fig. 1).

The experiment was laid out as a Randomized Complete Block Design (RCBD) in a factorial arrangement and replicated three times per treatment combinations (D1W1, D1W2, D1W3, D2W1, D2W2, and D2W3) (Fig. 2). The experimental field was divided into three blocks, representing three replications. Each block is subdivided into six plot units. In each plot, 50 G0 tubers were planted in 5 rows of 10 tubers each. The tubers were covered immediately after planting with 2 inches of soil.

W1: < 10g *10g< W2< 20g* *20g< W3< 30g*

Fig. 1. Different weight potato tubers: W1, W2 and W3

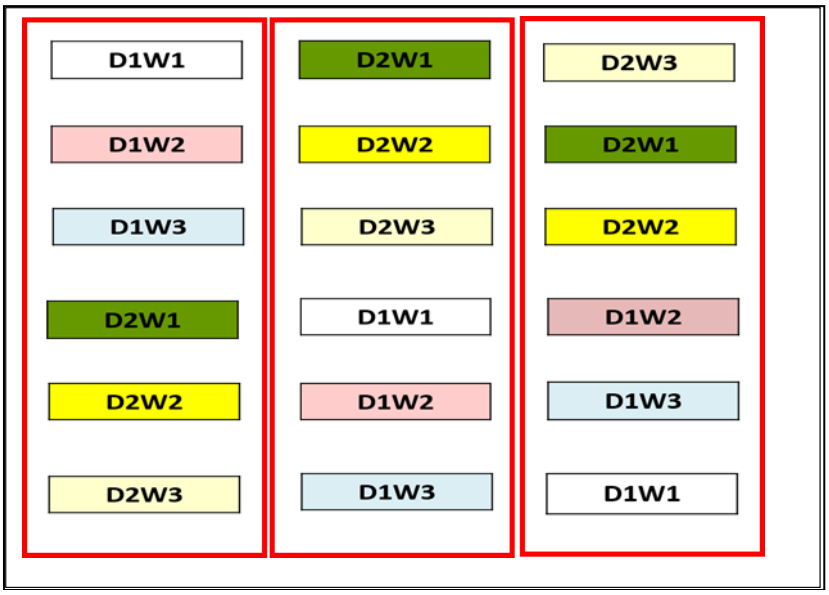

Fig. 2. Scheme of the experimental field divided into three randomized complete block design (RCBD)

2.3 Crop Management

The field was ploughed 3-4 times to a depth of 25 cm. A combination of nitrogen, phosphorus and potassium were applied before planting using the fertilizer 15-15-15 at a ratio of 225 Kg/1000 m^2. After 30 days of planting, nitrogen (17.5%) and P_2O_5 (44%) at a ratio of 50 Kg/1000 m^2 were applied, followed by earthing-up when the plant attained a height of about 15-20 cm from the base. A second earthing-up was done after 20 days of the first earthing up. Water was pumped at a rate of 600 mm/ cultivation season from a reservoir into micro-sprinkler**s** that spray water on a part of the soil surface above the potato crop.

2.4 Pest Management

Protecting the crops from pests and diseases is a crucial step in high-quality potato seeds production. The field was netted during the entire growing period to protect the plants from any infestations, especially the aphids that are considered the main viral vectors. Pesticides were applied to crops every 15 days starting from the date of emergence. A rotation of the two insecticides, i.e. chlorpyrophos and deltamethrin, were applied along with the fungicides mefenoxam and mancozeb for early and late blight.

2.5 Harvesting Potato Seeds Crop

The soil was carefully dug at a distance of ~30 cm deep from the plant to locate and pick all G1 tubers using a fork, in order not to bruise or damage the skins. Any injured tubers were eliminated. Then, the produced potatoes were put in plastic bags and stored at 4°C in order to keep them dormant during the normal storage season.

2.6 Statistical Analysis

Samples of three plants were randomly taken from the middle of each plot (replicate) to reduce the border effect. The mean ± standard deviation of five parameters of G1 tubers was calculated for each treatment:

- Average number of tubers per plant (AN) was recorded.
- Average weight of tubers (AWe): the weight of G1 tuber was measured by analytical balance (g) of mass to the nearest 0.0001 g.
- Average length of tubers (AL): the length of G1 tuber was measured from the tip to the base of the tuber (cm) by using caliper.
- Average width of tubers (AW): the width was recorded as the widest part of the tuber (cm) by using caliper.
- Average production of tubers/m2 was calculated.

Duncan test was performed to determine the significant difference between the calculated means (SAS).

3. RESULTS

After harvesting, samples were cleaned and the two-way Anova was calculated to find out if the weights of G0 tubers and planting distance have effect on the five studied parameters of G1 tubers (average number of tubers per plant, average weight, average length, average width and production (AN, AWe, Al, AW and production respectively). In addition, the effect of G0 tuber weights with combined planting density and vice versa was determined (Duplicate information).

Table 1. Effect of treatments on the AN (average number of tubers/plant), AWe (average weight of tuber), AL (average length of tuber), AW (average width of tuber) and production of G1tubers

Treatments	AN	Awe (g)	AL (cm)	AW (cm)	Production of tubers (Kg/m^2)
T1(D1W1)	24 ± 9.56a*	4.19 ± 1.47e	2.89 ± 0.23e	1.49 ± 0.21e	3.49 ± 1.35e
T2(D1W2)	14 ± 2.45c	11.26 ± 3.07d	3.93 ± 0.37d	2.20 ± 0.26d	5.48 ± 1.52cd
T3(D1W3)	12 ± 3.67c	15.99 ± 2.95c	4.74 ± 0.55c	2.58 ± 0.25c	6.65 ± 1.22c
T4(D2W1)	20.22 ± 1.78ab	29.49 ± 4.83b	5.89 ± 0.37b	3.29 ± 0.27b	10.35 ± 1.86b
T5(D2W2)	15.56 ± 3.16c	32.51 ± 5.99b	6.03 ± 0.71b	3.32 ± 0.35b	8.77 ± 1.31b
T6(D2W3)	15.90 ± 1.96bc	41.76 ± 4.13a	6.63 ± 0.33a	3.57 ± 0.19a	11.52 ± 1.37a

Distance: D1 = 10 cm. D2 = 20 cm.
Weight: W1<10 g. 10g< W2< 20g; 20g< W3< 30g
Treatment: T
**, Means followed by the same letter are not significantly different according to Duncan's multiple range test*

Table 2. Effect of G0 tuber weights with cumulated distance on the AN (average number of tubers/plant), AWe (average weight of tuber), AL (average length of tuber), AW (average width of tuber) and production of G1tubers

	G1 Tuber Characteristics				
G0 Weight	**AN**	**AWe (g)**	**AL (cm)**	**AW (cm)**	**Production of tubers (Kg/m^2)**
W1	22.111 ± 6.95a*	16.84 ± 13.47c	4.39 ± 1.57c	2.39 ± 0.95c	8.62 ± 6.47b
W2	14.78 ± 2.86b	21.89 ± 11.87b	4.98± 1.21b	2.76 ± 0.65b	7.49 ± 3.56c
W3	13.94 ± 3.48b	28.88 ± 13.70a	5.69 ± 1.06a	3.08 ± 0.55a	9.32 ± 4.58a

Weight: W1<10g; 10g< W2 < 20g; 20g <W3 <30g

**, Means followed by the same letter are not significantly different according to Duncan's multiple range test*

Table 3. Effect of distance with cumulated weights on the AN (average number of tubers/plant), AWe (average weight of tuber), AL (average length of tuber), AW (average width of tuber) and production of G1tubers

Distance	**AN**	**AWe (g)**	**AL (cm)**	**AW (cm)**	**Production of tubers (Kg/m^2)**
D1	16.66 ± 7.92a*	10.48 ± 5.53b	3.85 ± 0.86b	2.09 ± 0.51b	6.06 ± 3.02b
D2	17.22 ± 3.15a	34.59 ± 7.19a	6.18 ± 0.58a	3.39 ± 0.30a	10.34 ± 2.38a

Distance: D1: 10 cm, D2: 20 cm

**, Means followed by the same letter are not significantly different according to Duncan's multiple range test*

3.1 Effect of Distance and G0 Weights on G1 Traits

The highest G1 tubers number (24) was obtained for the planting distance D1 and the G0 tubers weight W1 (D1=10 cm and W1< 10 g) while the lowest number of G1 tubers (12) was obtained for the Planting distance D1 and W3 (20<W3<30g).

On the other hand, planting at distance D2 (20 cm) and weight W3 was the most remarkable compared to the other combinations (distance and weight) with the highest significant weight, length, width and production of G1 tubers of 41.75 g 6.63 cm, 3.57 cm and 11.52 Kg/m^2 respectively. The combination D1W1 indicated the lowest average in these traits (4.19g, 2.89 cm, 1.49 cm and 3.49 Kg/m^2) as shown in Table 1.

3.2 Effect of G0 Tuber Weights with Combined Planting Distance on G1 Tuber Formation

The effect of G0 tuber weight on the G1 tuber production is presented in Table 2. A significant ($p<0.0001$) effect of G0 weight tubers was observed on the average number (AN), average length (AL), average width (AW), average weight (Awe) and production of G1 tubers produced. G0 tubers weight W1 (<10g) presented the highest AN of G1 tubers produced per plant (22.11) and the lowest AWe, AL, and AW, while W3 G0 tubers (20g<W3<30g) yielded the lowest number of G1 tubers (13.94) with highest AWe, AL, AW and production of tubers 28.88g, 5.69cm, 3.08cm and 9.32 Kg/m^2 respectively.

3.3 Effect of Planting Distance of Combined G0 Tuber Weights on G1 Tuber Characteristics

The planting distances used in this study did not induce a significant difference in the number of G1 tubers per plant ($p=0.66$). The average number of tubers varied between 16.66 and 17.22 for D1 (10 cm) and D2 (20 cm) respectively. On the other hand, the planting distance D2 induced a significant difference on the other studied traits. The highest average of tubers weight (34.59 g), tuber length (6.18 cm), tuber width (3.39 cm) and production (10.34 Kg/m^2) of G1 tubers were obtained with the planting distance D2 whereas the planting distance D1 yielded smallest average traits as shown in Table 3.

4. DISCUSSION

Potato is well known for its nutritional importance in Lebanon, but one of its main problems is the high prices of imported seeds. Applying the best agricultural practices (planting density and G0 tuber weights) to produce G1 tubers locally with an acceptable price for farmers can reduce the cost of potato seed.

Generally, average G1 tuber weight, length, width, number and production responded differently to different G0 tuber weights and

variable plant spacing. In this context, the present study showed that G1 tuber number increased with decreased G0 seed tuber size where small tuber size yielded the highest G1 tuber number. These results are in accordance with those reported by Roy et al. [18] who reported that the maximum tubers number per plant was obtained with the smallest seed tuber size, but contradicting those of Rojoni et al. [19], and Zkaynak & Samanci [20] where they reported that tubers number per plant was increased with increasing seed tuber weight.

In addition, contrary to the present study, Gulluogl & Arıoglu [21] also indicated that small seeds gave the lowest tubers number per plant, whereas large tubers gave the highest tubers number per plant, the significant difference in tubers number might be due to large seed tuber size attributed high amount of food reserves that produce highest tubers yields. The same information was reported by Rykbost and Charlton et al. [22]

On the other hand, concerning the effect of G0 tuber weight on G1 tuber weight and production of G1 tubers/m^2, the obtained results showed that large G0 seed tuber size resulted in an increase in the average G1 potatoes tuber weight and yield implying that large G0 seed tuber size can provide sufficient nutrients required for growth and development at the initial growth phase as seen by Harnet et al. [23] and Regasa et al. [24] where they showed that the average tuber weight of potatoes increased with the increase in mother tuber size, but opposing those of Berga et al. [2] that an increase in seed tuber size resulted in decreasing the average tuber weight of potatoes.

In addition, our results indicated that large G0 seed tuber yielded G1 tuber with highest length and width. This might be due to the fact that large-size seed tuber had few sinks available per unit area that resulted in less competition between the individuals at low plant densities. Our results are in line with the findings of Kumar et al. [25] and Regasa et al. [24], who reported that large seed tubers had the potential to produce large tuber yield due to its high content of carbohydrate to feed plants, on the other hand, small seed tubers had no capability of equal competition with other plants for resources and had also little amount of carbohydrate source to support the plant at an earlier growth period.

Moreover, our study showed that wider spacing resulted in an increase in the average tubers weight and their yield. The increase in plant population and decrease in spacing probably increased the competition between plants, hence, leading to a decrease in the availability of nutrients to each plant and, consequently, resulted in a decline of mean tuber weight. Wider plant spacing permits free growth without any competition for minerals and other requirements [25]. Similar results were obtained by many researchers [12,21,26,27] where higher average weights were observed at wider spacings compared to closer ones.

Concerning the effect of spacing on the average number of G1 tuber, our results showed that spacing had no significant effect on the number as seen by others [10,28,29]. For instance, Tesfa [27] and Khalafalla [10] found that tubers grown at closer plant spacing efficiently use the soil nutrients and other resources which lead to the production of high marketable tuber number compared to wider spacing.

On the other hand, despite the fact that spacing had no significant effect on the number of tubers, large spacing has a significant one on the average length, width and yield of G1 tubers obtained. This may be explained by the fact that more resources where channeled to each individual tuber at low density plantings resulting in a high number of large sized tubers. This is in agreement with many others who concluded that tuber bulking at close spacing results in the formation of small G1 tubers [20,30-32] because of availability of growth nutrients. It is important to note that presence of nutrient is a main element that control growth; thus, increase in plant density decreases mean tuber size and increase the competition leading to a high number of G1 tubers produced with high stem's numbers.

When relating the effect of distance and weight on G1 trait, we notice that the number of tubers per plant was the highest in smallest tuber size with closest planting distance (D1W1); whereas the highest average tuber weight, length, width and production were recorded for plants grown on D2W3 treatment combinations. This could be related to the fact that large seed tuber sizes and wider plant spacing had less resource competitions and received more nutrient resources compared to other treatments. Our results are in accordance with those of Hossain et al. [32] and Dagne et al. [31] who reported that the G1 tuber weight was the highest in the larger size tuber planted at wider distances due to the

presence of more reserve food which caused increase in mean tuber weight [33,34].

5. CONCLUSION

Lebanon does not produce certified potatoes' seeds; they are imported mainly from the European Union (EU) Member States. In the early years of the 21st century, Lebanon imported between 15,000 and 20,000 tons of potato seeds each year and relied heavily on this import with prices ranging between $750 and $1,000 per ton. The potential implementation of a potato seeds production program in Lebanon should be a priority; especially that Lebanon is characterized by a wide range of microclimates favorable to produce them. In general, potato seeds production was affected by tuber size and planting distance. This study indicated that larger size of tuber produced tubers with highest weight, length, width and production when it was planted in greater distance. But, the higher number of tubers/plant was found in smaller sized tuber with closer planting distance. So, it can be concluded based on the yield, that small weight tuber with 10 cm planting distance may be used for cost effective production of breeders' seeds of potato.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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