Effect of Planting Depth on Vegetative Growth, Yield and uality of Potatoes

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ABSTRACT

Two field experiments were conducted on a private farm in Kafr El-Zayat, Gharbia Governorate, Egypt (latitude 30.867344' N and longitude 30.802303' E), during two successive summer seasons of 2020 and 2021 to investigate the effect of planting depth (10, 15, 20 and 25 cm) on vegetative growth, productivity and quality of potato tubers (*Solanum tuberosum* L.) cv. "Kingsman". The soil texture of the experiment site was clay loam. Generally, there were significant differences among the various treatments of planting depth, in both seasons. The highest significant were obtained at 10 cm planting depth for earliness of potato sprouts emergency, plant height, leaf area, number of leaves per plant, number of tubers per plant, weight of green tubers per fed and cracks of tuber per fed. Moreover, planting depth at 20 cm showed the highest significant value for the number of stems per plant, fresh weight of tubers per plant, size of tubers per plant, total yield and marketable yield per fed. While the lowest values for the same traits were revealed from planting depth at 25cm except marketable yield at 10 cm and tuber cracking at 20 cm in both seasons. However, there was no significant difference among treatments on length of stolons per plant and number of stolons per plant in both seasons. This study recommended that planting depth at 20 cm recorded the best values for most of treatments including lowest tuber greening and cracks.

***Keywords*:** Potatoes, tubers quality, yield, planting depth, cracks, greening.

INTRODUCTION

Potato (Solanum *tuberosum* L.) is a major food crop throughout the worldwide. Potato productions were around 388 million tons in 2017 and have a rank the fourth in the world after rice, wheat and maize. It is estimated that less than 50% of potatoes grown worldwide are consumed cooked. The rest are processed to obtain food ingredients, alcohol, starch and animal feed or re-used as seed tuber of potato (Anonymous, 2017). In Egypt, potato occupies about 408 thousand feddans produced about 4.96 million tons according to FAOSTAT, (2018).

The relationship between tubers-greening and tubers-cracks with planting depth and tuber position inside the hill have been studied (Bohl and Love 2005 and Pavek and Thornton 2009). The effects of planting depth on vegetative growth and productivity of potato have been reported (Selman *et al.,* 2008; Arab *et al.,* 2011; Laei *et al.,* 2012; Nebiyu, 2015; Joshi *et al.,* 2019 and Singh *et al.,* 2020). Presence of green tubers reduces total marketable yield and farm profits (Nebiyu, 2015). On potato tuber showed that the earliness of potato sprouts emergency was found at 10 cm planting depth as compared to 15 and 20 cm (Kumar *et al.,* 2015). On the other hand, it was found that the highest number of stems per plant resulted from 18 cm depth of planting as compared to others treatments (Singh *et al.,* 2020). Arab *et al.* (2011) found that the tallest plants were at 20 cm depth of planting as compare to 10 and 30 cm planting depth. Chehaibi *et al.* (2013 b) showed that the mechanical cultivation increase depths were given significantly increasing in the leaf area of potato. On potato, the maximum number of leaves per plant was found with planting depth at 13 cm, followed by 8 cm, while the minimum number of leaves was recorded at 18 cm planting depth (Singh *et al.,* 2020). In another study, it was reported that the stolon length decreases for Russet Burbank and Umatilla Russet varieties planted at 20 cm compared with a 10 cm depth (Pavek and Thornton, 2009). However, the maximum number of tubers per plant was obtained at 10 cm planting depth but the lowest number of green tuber recorded at 20 cm depth of planting (Kumar *et al.,* 2015). On potato, results showed that significant increment in potato tuber fresh weight at 10 cm and 15 cm depth of Agria variety in compared with the other variety (Draga) which did not have any response (Laei *et al.,* 2012). Also, a research paper showed that the diameter of tuber was influenced by planting depth and potato variety (Tanyaradzwa *et al.,* 2015). In another study bout the effect of planting depth, it was found that planting depth at 20 cm produce high significance in total yield and marketable yield than other treatments (Kumar *et al.,* 2015). Several studies have shown that the quantities of green tubers can be reduced by

increasing planting depth (Stalham *et al.,* 2001 and Bohl and Love 2005; Arab *et al.,* 2011; Laei *et al.,* 2012; Joshi *et al.,* 2019 and Singh *et al.,* 2020). The physiological disadvantages of tubers were occurring when potato splits and still growing as the following, a) Because of the difference in planting depth, b) Uneven absorption of water and when the core tissue inside the tuber grows faster than the outer tissues, c) Each of these physiological problems relate to fluctuations in soil moisture and d) These cracks generally begin at the bud or the apical end of the potato and extend longitudinally (Selman *et al.,* 2008 and Pavek and Thornton 2009). Potato tuber cracks increases when relatively poor growing conditions are rapidly followed by relatively good growing conditions, such as prolonged moisture stress or high temperatures followed by excessive rainfall or irrigation (Selman *et al.,* 2008 and Nebiyu, 2015). The objective of this study was to reduce the unmarketable tubers via reducing the potato tuber greening and cracks.

MATERIAL AND METHODS

The experiment was carried out in a private farm at Kafr El-Zayat city, Gharbia governorate, Egypt (latitude 30.867344' N and longitude 30.802303' E) during two successive summer seasons of 2020 and 2021. This experiment was to study the effect of planting depth (10, 15, 20 and 25 cm) on growth, productivity and quality of potato cv. "Kingsman". The soil texture of the experiment site was clay loam. The aim of this experiment was to reduce the physiological defects of yield and marketable yield (Green and Cracks of tuber). Potato tubers seeds were obtained from Daltex Rock Agriculture Company Kafr El-Zayat, Gharbia, Egypt. The tuber seeds were kept in shaded area for two weeks before cultivation to develop the sprouts. The sprouting potato planted into open field at the first week of January in the two seasons of 2020 and 2021. Every treatment included 3 replicates and each replicate consisted of 3 rows, each row was 3.5 m long and 80 cm width. The distance between rows was 80 cm apart and between plants was 25 cm.

A manual digger was used for planting tubers with different four depths such as 10, 15, 20 and 25 cm (Figure 1). All agro-management applied such as pests control were performed whenever it was necessary, surface irrigation and fertilization as recommended in the commercial production of potato according to Ministry of Agriculture, Egypt. Likewise, potato hills with a flat top were formed prior to planting tubers pieces by hand and remove sufficient soil and the tuber pieces were placed with the cut surface down and the sprout up according to Bohl and Love (2005). Planting depth was measured (ruler centimeters) from the top of the tubers pieces to the top of the hill. Concerning, day after planting (DAP) to harvest was 125 days in both seasons. The trial was arranged each year in a randomized complete block design with three replicates.

Recorded Data:

Vegetative characteristics:

Earliness of potato sprouts emergence, number of stems per plants, plant height, leaf area, number of leaves per plant, average length of stolons per plant, and number of stolons per plant. Data were characterized after 90 days from cultivation.

Yield characteristics:

Tubers fresh weight, size, number, total yield, total marketable yield and physiological defects (greening weight and cracks). These data were taken at harvesting date (after 125 days from cultivation).

Data procedures:

Earliness of potato sprouts emergence was recorded by counting the plants from the beginning tuber cultivation until the time of 90 % emergence potato plants.

Number of stems per plant was counted.

Plant height (cm) was estimated by a ruler from the hill soil surface to the plant apical meristem.

Leaf area index (cm^2) was measured using a portable leaf area meter (YMJ-A, Zhejiang Top Cloud Agri Technology Co., Ltd, China) as described by (Liu *et al.,* 2015).

Number of leaves per plant was counted.

Average length of stolons (cm) was estimated from stem underground to the tuber by a ruler.

Number of stolons was counted.

Fresh weight of tubers per plant was weighed in grams by a digital balance.

The size of tubers was measured in cm^3 by immersing the tubers in a container filled with water and the displaced water was measured by a graduated jar.

Number of tubers per plant was counted.

Total yield was weighed in (ton/fed) by a digital balance.

Green tuber weight protruding from the top of the hill were weighed in (ton/fed) by a digital balance.

Cracks was weighed in (ton/fed) by a digital balance.

Total marketable and un-marketable yield were weighed in (ton/fed) by a digital balance.

Statistical analysis:

The experiment was statistically analyzed in a randomized complete block design one-way ANOVA with three replicates. The obtained data was subjected to the analysis of one-way ANOVA and L.S.D. method at 5% level of significance according to Snedecor and Cochran (1980).

RESULTS AND DISCUSSTION

Vegetative characteristics:

The effect of planting depth on vegetative growth characteristics of potato was shown in Table (1) during seasons of 2020 and 2021. These results showed that the shallow planting depth at 10 cm produced the highest values in all studied vegetative growth characters of potato plants, except planting depth at 20 cm was achieved highest value in number of stems per plant. The results indicated that there was no significant difference in length of stolons per plant and number of stolons per plant in both seasons. However, the planting depth at 25 cm recorded the lowest values for all vegetative characteristics in the obtained depth.

The results showed that earliness of emerge of potato sprouts were exhibited in shallow planting depth at 10 cm compared to the other treatments. These may be due to the potato sprouts having to come across a long distance of the ground to emergence compared to the shallow planting depth (Sultana *et al.,* 2001). A Similar study found that a gradual increase in planting depth is associated with an increase in the time to emergence and further delay emergence of tuber sprouts and fewer crop producers (Bohl and Love 2005).

The results show that more stems produced when planted at 20 cm depth could be due to warmer temperatures and an increase in the number of stems was given. But other varieties can be increased in stem number that tuber cuttings planted close to the soil surface produce more stems than those planted deeper (Stalham *et al.,* 2001). Finally, it can be checked for the unique growth characteristic of each species that needs adjustments in management techniques to reach the maximum yield of field tubers (Bohl *et al.*, 2011). The plant height of potato was decreased with the increase in planting depth, similar results were also found by Abbasifar *et al.* (1996) and Kumar *et al.* (2015). However, the increase in plant height was attributed to the earlier emerges of plants at 10 cm planting depth compared to another planted depth (Singh *et al.,* 2020).

Potatoes produced the largest leaf area at 10 cm planting depth during the 2020 and 2021 seasons, respectively. These may be attributed to the increased nutrient absorption time with the earlier onset of the other treatments, in both seasons. But the optimal leaf area was at a depth of 20 cm for planting. These results are consistent with those found by (Chehaibi *et al.,* 2013 b and Ilyas and Ayub., 2017). The overall trend of leaf number was significantly higher in the shallow planting depth. This increase in traits may increase the plant's vegetative growth and nutrition consumption to produce new leaves without increasing the overall yield of tubers.

Yield characteristics:

As the mean values illustrated in Table (2), there was a significant effect in planting depths for all studied yield characters of potato tuber, in both seasons. These results exhibited that the planting depth at 20 cm produced the best values for fresh weight of tuber per plant and size of tubers per plant, except for the number of tuber per plant which led to show the highest value at 10 cm depth. On the other hand, the lowest values of average fresh weight and tuber size per plant were obtained from the planting depth at 25 cm.

Some scientific reports discussed the effect of planting depth on fresh weight of tuber per plant and size of tubers per plant (Bohl and Love, 2005 and Joshi *et al.,* 2019) whose mentioned that the significant responses of the fresh weight of tuber per plant and the size of tubers per plant could be as a result of transferring nutrition from leaves to tubers storage if planted at an appropriate planting depth. Similarly, the results of Arab *et al.* (2011) indicated that the suitable planting depth for a potato variety Agria was at 20 cm. In addition, the relation between the significance of mean values of yield attributes and planting depth were varied according to

the examined potato variety (Pavek and Thornton, 2009 and Kumar *et al.,* 2015). Another research refers to the fact that the highest average fresh weight of tuber attribute to stolon length determines the location of the tubers in the soil (Chehaibi *et al.,* 2013a and Nebiyu., 2015).

The results in Table (3) showed that most of the planting depth treatments at 20 cm had a significant effect on total yield and marketable yield compared to other treatments, in both seasons. While, shallow planting depth at 10 cm gave the highest value for the physiological disadvantages of potato tubers. However, the lowest value of total yield, marketable yield and physiological disadvantages of potato tuber was registered at 25 cm, 10 cm and 20 cm planting depth respectively.

The planting depth at 20 cm improved crop's capability for producing photosynthetic matters and increased fresh weight of tuber by storage carbohydrates in tuber and ultimately, incremental of total tuber yield per hectare at this planting depth (Arab *et al.,* 2011). Also, our results indicated that the marketable yield differed significant may be due to the improvement in the quality of tuber through lower physiological disadvantages (green weight and tuber cracks). The height green tuber weight at 10 cm was due to shallow planting depth, it is side of the hill and sunlight exposure tuber in surface soil (Bohl and Love, 2005). Additionally, the longer stolons found on stems of the shallowest-planted seed pieces may have exacerbated tuber greening by positioning tubers nearer the sides of the hill. These results agree with (Stalham *et al.,* 2001 and Pavek and Thornton, 2009). A conversion of amyloplasts into chloroplasts in the potato tuber after light exposure is known as tuber greening and is one of the major causes for the low total marketable yield of potato tuber (Plich *et al.,* 2020). Generally, Un-likely height green weight of tuber because it's decreased marketable yield. The physiological defects of tuber (cracks) were relative to fluctuations in (soil moisture and uneven uptake of water) may be the difference in planting depth led to the core tissue inside the tuber grows faster than other the outer tissues of tuber cause of cracks (Nebiyu, 2015). Generally, the shallow at 10 cm and deeper at 25 cm increased tuber cracks due to the difference in water uptake, unlike this planting depth so it caused decreased quality and quantity of potato tubers marketing and the best treatments were at a planting depth of 20 cm.

CONCLUSION:

Finding of the result indicated that among four different planting depths, the planting depth at 20 cm recorded significant increase in all vegetative growth, yield and quality of potato. Also, it recorded the lowest tuber greening and cracks.

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Table 1: Effect of planting depth on physical characteristics at 90 days from cultivation date during 2020 and 2021 seasons.

Treatments	Emergency 90% (Days)		No. stem/ plant		plant height (cm)		Leaf area (cm²)		No. Leaves / plant		length of stolon cm /plant		No. Stolon /plant	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
10 cm	40.0	35.6	2.4	2.7	39.3	37.7	242.9	256.4	14.6	12.3	4.4	5.2	9.0	7.7
15 cm	42.0	37.0	2.2	2.4	30.0	31.6	224.8	239.2	13.0	10.3	3.9	4.9	8.0	6.7
20 cm	42.3	37.1	2.7	2.9	37.5	36.7	237.7	248.4	13.6	12.0	3.8	4.6	8.0	6.7
25 cm	43.0	39.0	1.9	2.1	29.8	30.3	215.8	194.8	11.3	9.7	3.8	4.2	7.7	6.3
L.S.D 5 %	0.57	0.38	0.43	0.27	1.42	1.6	0.28	0.39	1.10	0.94	NS	NS	NS	NS

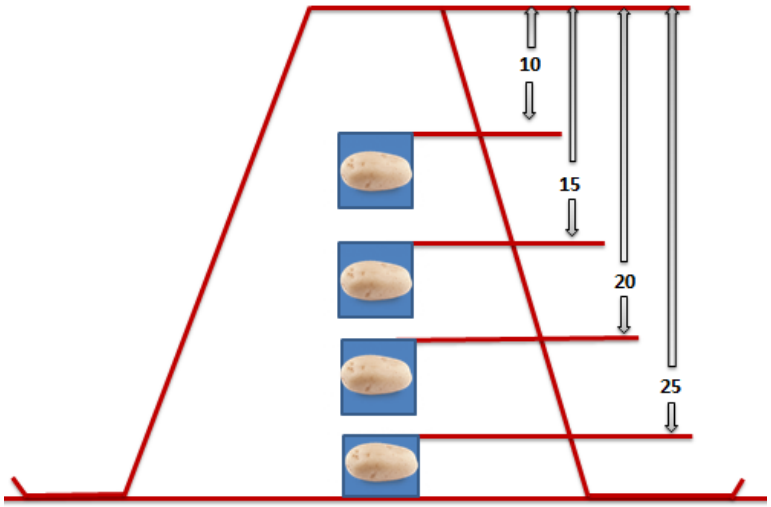

Figure 1: Showing the cultivation of potatoes with different planting depths 10, 15, 20 and 25 cm.

Table 2: Effect of planting depth on fresh weight, size of tubers and number of tuber at 125 days during 2020 and 2021 seasons.

Treatments	Fresh weight of tuber (g /plant)		Size of tubers per plant (cm^3)		No. tuber /plant	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
10 cm	590.00	567.30	531.60	523.30	7.00	7.30
15 cm	635.00	570.26	582.60	572.30	5.30	5.30
20 cm	687.28	656.30	629.00	614.00	5.30	5.50
25 cm	573.30	511.60	515.00	516.00	5.00	5.00
L.S.D 5 %	3.90	4.54	2.30	2.55	1.45	1.55

Table 3: Effect of planting depth on total yield, marketable yield and physiological disadvantages of potato tuber at 125 days during 2020 and 2021 seasons.

Treatments	Total yield (ton/fed)		Marketable yield (ton /fed)		Physiological disadvantages of potato tuber (ton/fed)			
					Green tuber		Cracks	
	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season	1st Season	2nd Season
10 cm	16.25	15.60	14.16	13.90	1.00	0.75	1.09	0.96
15 cm	16.38	15.20	15.73	14.90	0.25	0.11	0.41	0.22
20 cm	17.27	16.38	17.03	16.25	0.00	0.00	0.24	0.14
25 cm	15.11	14.85	14.63	14.57	0.00	0.00	0.48	0.28
L.S.D 5 %	0.56	0.36	0.76	0.94	0.12	0.14	0.19	0.14

تأثير عمق الزراعة على النمو الخضري والمحصول وجودة البطاطس

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الملخص العربي

أجريت تجربتان حقليتان بمزرعة خاصة بكفر الزيات بمحافظة الغربية بمصر (خط عرض 30.867344 شمالاً وخط طول 30.802303 شرقاً) ، خلال موسمي الصيف المتتاليين 2020 و 2021 لبحث تأثير عمق الزراعة (10 ، 15 ، 20 ، 25 سم) على النمو الخضري وإنتاجية وجودة البطاطس (*Solanum tuberosum* L.) صنف كنجسيان. تربة التجربة كانت طينية خفيفة في الملمس. بشكل عام كان هناك فروق معنوية بين المعاملات المختلفة لعمق الزراعة في كلا الموسمين. تم الحصول على أعلى معنوية عند عمق زراعة 10 سم في ظهور نباتات البطاطس، ارتفاع النبات ، مساحة الورقة ، عدد الأوراق لكل نبات ، عدد الدرنات لكل نبات ، وزن الدرنات الخضراء للفدان ، وتشقق الدرنات للفدان. علاوة على ذلك ، أظهر عمق الزراعة 20 سم أن أعلى قيمة معنوية لعدد السيقان لكل نبات ووزن الدرنات الطازج لكل نبات وحجم الدرنات لكل نبات والمحصول الكلي والمحصول التسويقي للفدان. بينما أقل القيم لنفس الصفات ظهرت من عمق الزراعة 25 سم فيما عدا المحصول التسويقي عند 10 سم وتشقق الدرنات عند 20 سم في كلا الموسمين. ومع ذلك ، لم يكن هناك فرق معنوي بين المعاملات على طول المدادات للنبات وعدد المدادات للنبات في كلا الموسمين. أوصت هذه الدراسة بأن عمق الزراعة عند 20 سم سجل أفضل القيم لمعظم المعاملات بما في ذلك أقل إخضرار للدرنات والتشققات.

الكلمات الاسترشادية: البطاطس، جودة الدرنات، المحصول، عمق الزراعة، التشقق، الإخضرار