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Effect of Bentonite Clay Injection in Sandy Soil on Yield and Tuber Quality of Potato under North Sinai Conditions

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ABSTRACT

The experiments were conducted to evaluate the effect of soil injection treatments on yield, quality and chemical composion of potato plant (Spunta cultivar), during the seasons of 2020 and 2021. The experiments were conducted at Baloza Research Station, Desert Research Center, North Sinai Governorate, Egypt. The experimental design was a randomized complete block design with three replicates, every replicate included 4 treatments (5,10 ,15 and 20 tons) of clay. The results showed that the different clay quantities (5, 10, 15 and 20 tons/feddan) effected on the potato yield parameters with significant differences between the treatments. The highest values of number of tubers/plant, average weight of tuber, tuber weight/plant and total yield/feddan of potato plant were obtained by using 20 tons of clay quantity/feddan treatment, followed by 15 tons of clay/feddan treatment and then 10 tons of clay/feddan treatment, It is clear that the highest values of average tuber dry weight, average tuber size, average tuber length and average tuber diameter of potato tubers were obtained by using 20 tons of clay quantity/feddan, followed by 15 tons of clay/feddan treatments and then 10 tons of clay/feddan treatment, The highest values of carbohydrate % in tuber and tuber content of TSS of potato plant were recorded by using 5 tons of clay quantity/feddan treatment, followed by 10 tons of clay/feddan treatment and then 15 tons of clay/feddan treatment.

KEYWORDS: potato, yield, quality, clay quantities.

1. INTRODUCTION

Potato *solanum tuberosum* L. is considered one of the most important vegetables in all over the world. The global cultivated area of potatoes reached amounts to 18132694 hectares, with a total production of 376 million tons (FAO 2021). In Egypt potatoes is classified the fourth vegetable production and potatoes are considered the second most important vegetable

crop after tomatoes in terms of cultivated area. The cultivated area of the potato crop 392 thousand acres, with an average production of 11 thousand tons and 600 kilograms, with a total production of 4 million and 200 thousand tons annually including a winter loop of 211 thousand acres, a summer loop of 150 thousand acres, and an indigo loop of 40 thousand acres (Ministry of Agriculture and Land Reclamation 2021).

It is known to us that large quantities of irrigation water and fertilizers are lost by leakage deep in the sandy lands, due to the weakness of its natural and chemical properties, and as a result of the water poverty that Egypt is going through now and the limited water unit, as well as the steady population increase, which has become affecting the Egyptian food security. There were many attempts to improve the natural and chemical properties of sandy soil to increase production and reduce losses in irrigation water and mineral fertilizers, such as adding organic fertilizers, adding polymers, and transporting clay from the delta to the modern reclamation areas. Modern reclamation, hence the idea of separating silt and clay, dissolving them and injecting them with drip irrigation water to improve the soil's texture and properties and increase its retention of water and fertilizers and provide them to the plant, which is reflected in the health of the plants and thus increasing the crop and its quality as well as maintaining the cleanliness of the environment from pollutants and diseases that are transmitted with clay soil to sandy soil. Sandy soils in desert areas suffer from a lack of organic matter, poor physical and chemical properties, In addition to severe loss of irrigation water and mineral fertilizers as a result of deep seepage, which leads to severe loss of irrigation water and mineral fertilizers added due to deep water seepage.

Many studies have indicated that soil amendment by adding clay and silt is a very effective method that leads to improving properties. The physical and chemical properties of this soil and thus increase its fertility and its ability to give abundant production of the crops grown in it. One study indicated that increasing the proportion of bentonite mineral to more than 5% in sandy soil through clay amendment of sandy soil increases its fertility of micro and macro (essential) nutrients (karbout et al.2015). On the other hand, montmorillonite mineral, which is 75% of Bentonite are is characterized by a high swelling ability when exposed to water, which makes it ideal for preserving water and reducing its high loss rates. Therefore, when bentonite is added to sandy soil, its ability to retain water increases and fertilizer loss decreases. It is known that the area of bentonite particles (silt and clay) is thousands of times greater than the area of sand particles. When added to sandy soil, it increases the ability of sandy soil to retain nutrients and irrigation water. It also contributes to providing an ideal environment for microorganisms in the soil. Therefore, adding calcium bentonite to sandy soil, it preserves the water contained in it and liberates it much easier than other types of bentonite (Crokar 2004 and Larkin et al. 2020). Also, calcium mineral bentonite can carry 1:5 times its weight in water, so it is used in agriculture because it is more stable (Wahab et al. 2010 and El-Demerdash et al. 2019). To coarse sandy soil is a promising technique to increase the production of biomass and improve the characteristics of the cation exchange capacity of this poor soil. Moreover, it was found that the addition of clay mineral (bentonite) at high rates provides barley plants with large amounts of water when irrigating (Eldardiry and Elhady 2015) and is considered an addition to clay soil. Rich in nutrients to sandy soil, it works to increase its content of minerals and thus increase the production of the crop grown in it. In addition, the sub-clay soil contains a low content of nutrients (Hall et al. 2010, Lawrence et al. 2015 and Yang et al. 2020) and when adding high percentages of silt and clay (bentonite), which contain 10% of different forms of hydronic acid (K.Na.Mg.Ca), it works to reduce the acidity of the sandy soil very significantly during the long-term cultivation period, and also works to improve the cation exchange property of sandy soil due to the formation of stable mineral aggregates on

the metal particles present in the clay (Czaban and Siebielec, 2013).

The study in our hands aims to know the effect of use of clay injection rates in sandy soil on yield, quality and chemical composion of tuber potato.

2. MATERIAL AND METHODS

This research was conducted at the experimental farm of Baloza Research Station (Latitude 31 01 42.01 N; Longitude 32 35 27.89 E); Desert Research Center, North Sinai governorate, Egypt during two successive summer growing seasons of 2020 and 2021 to study the effect of clay injection rates in sand soil on water use efficiency of potato crop (*Solanum tuberosum* L.) C.V. Sponta on tuber yield and its quality as well as chemical composition of tubers.

2.1. Materials

2.1.2. Soil

The purpose of this investigation is to study clay injection rates effectiveness on determine and their impression on yield and its quality and chemical composition of potato crop.

One – kg of each collection soil samples was made and analyzed chemically in the central Laboratory Desert Research Center, Egypt (Table 1).

Table 1. Chemical analysis of the experimental soil.

	Soluble Cations (mg/100g)				Soluble Anions (mg/100g)				PH	EC (ds/m^2)	SAR	ESP
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Co_3^{2-}	Hco_3^{-}	Cl^{-}	So_4^{2-}				
Soil	10.1	5.2	13.2	1.1	-	5	14.4	10.2	7.89	2.95	3.30	3.48

2.1.2.1 Clay injection rates:-

Bentonite clay mineral at rates of 5, 10, 15 and 20 Tons/Feddan were compared with no addition. The bentonite was collected from the same, AL-Ahram Metallization Company for the two cultivating seasons.

One – kg samples from bentonite and analyzed chemically and physically in the central Laboratory Desert Research Center, Egypt (Table 2&3).

Table 2. The Phisical analyses of bentonite.

Particle size distribution %							
sand	**silt**	**clay**	**p_b g/cm^3**	**FC %**	**WP %**	**AW %**	**FSI %**
7.55	14.29	78.16	0.57	45.40	16.76	28.68	108

Table 3. The chemical analyses of bentonite.

Cations and anions of soluble salts %										
EC (ds/m)	**PH**	**CEC Cmole/kg**	**Na^{+}**	**K^{+}**	**Ca^{++}**	**Mg^{++}**	**Cl^{-}**	**$HCO3^{-}$**	**$CO3^{-}$**	**$SO4^{-}$**
0.77	7.61	94.36	0.50	0.24	4.06	2.78	0.80	2.52	-	4.25

2.2 Methods:

2.2.1 Soil preparation:

The soil of the experimental field was prepared with two vertical tillage then soil fag with 40cm depth, chicken manure mixed with calcium super phosphate and agricultural Sulfur at a recommended dose were applied within fags at depth of 10cm and 10cm of soil had been covered the fertilizers mixture(Table 4).

Table 4. Chemical analysis of the experimental Chicken manure.

Sample	Ph at 1:10	EC (dS/m) at1:10	O.M (%)	C (%)	C/N	N %	P %	K %	ppm			
									ss	CO	Ni	pb
Chicken manure	8.10	9.98	35.60	17.80	6.49	2.74	0.763	2.68	*	*	5.85	1.15

The experimental field divided into three equal parts, each part idealizes a replicate, the treatments were randomly distributed within each replicate. The experimental plot was 10.5m2 (0.6 m width and 17.5 m length).The hoses in the sub surface treatment were at the 20 - 25 cm depth and covered with the soil before the irrigation.

After the experimental field was prepared and the irrigation hoses extended whereby the treatment, the whole experiment field was irrigated for one week to organic manure analyzing then another week to clay injection whereby treatments. The divided sterilized potato tubers were planted on January 15th 2020 and 2021 at 20cm depth and with 30cm apart between hales in wet soil. The experiment field irrigated until sport emergence. Every plot content 52 plants. After 10 days of emergence, the traditional practices was done, i.e. recommended dose of mineral fertilizers, disease and pest control and weed resistance.

2.3. Data recorded:-

2.3.1. Yield measurement:-

A. Average number of tuber per plant.
B. Average weight of tuber (g).
C. Average tuber weight/plant (kg).
D. Total yield/feddan (ton).

2.3.2 Quality measurements:-

A. Average tuber dry weight (g). (cm3).
B. Average tuber size (cm3).
   Which measured by liquid displacement as follow. .
   V = Vt - Vo

Where:-
V = tuber size, Vt = tuber size + liquid size, Vo = liquid size.

C. Average tuber length (cm).
D. Average tuber diameter (cm).

2.3.3. Chemical composition of plant:

A. Total soluble solids (TSS), determined by refract meter.
B. Total carbohydrates percentage it was determined in tuber dry mater according to Shaffer and Hartman as described in A.OA.C. (1970).
C. Total proteins percentage in tuber was calculated from previously determined total nitrogen content in tuber by multiplying N-values by 5.75.

2.3.4. Soil preparation:

The soil of the experimental field was prepared with two vertical tillage then soil fag with 40cm depth, chicken manure mixed with calcium super phosphate and agricultural Sulfur at a recommended dose were applied within fags at depth of 10cm and 10cm of soil had been covered the fertilizers mixture(Table 5).

2.4. Experimental design and Statistical analysis:

The collected data were statistically analyzed by the analysis of variance using Costat package. The Comparison among means was done using ANOVA test the p=0.05 level of significance. The data were statistically analyzed according to Sendecor & Corchran (1980).

3. RESULTS AND DISCUSSION

3.1. Soil characteristic:

It is clear from the data in table (5) the different clay quantities (5, 10, 15 and 20 tons/feddan) effected on the potato yield parameters (average number of tubers/plant, average weight of tuber, average tuber weight/plant and total yield/feddan) with significant differences between the treatments. The highest values of number of tubers/plant, average weight of tuber, tuber weight/plant and

Table 5. Effect of the different clay quantities on yield parameters of potato plants (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Soil Q. (ton)	Average number of Tubers		Average weight of tuber (g)		Average tuber weight/plant (kg)		Total yield/fed (ton)	
	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S
5	5.55 d	5.63 d	57.13 d	68.13 d	0.317 d	0.384 d	6.34 d	7.67 d
10	5.93 c	6.02 c	63.91 c	72.55 c	0.379 c	0.437 c	7.58 c	8.74 c
15	6.31 b	6.37 b	67.18 b	76.10 b	0.424 b	0.485 b	8.48 b	9.70 b
20	6.64 a	6.69 a	75.56 a	81.16 a	0.502 a	0.543 a	10.03 a	10.86 a

total yield/feddan of potato plant were obtained by using 20 tons of clay quantity/feddan treatment, followed by 15 tons of clay/feddan treatment and then 10 tons of clay/feddan treatment, while the lowest values were recorded with the clay quantity 5 tons/feddan treatment with significant differences between them, the same results were found in the second season.

The potato plant yield parameters under different clay quantities in the second season were higher than the first season; the maximum average number of tubers of potato plant was 6.69 tubers/plant in the second season by the soil quantity 20 tons/fed treatment while the lowest average number of tubers of potato plant was 5.63 tubes/plant by the soil quantity 5 tons/fed treatment. Moderate responses the average number of tubers of potato plant of potato plants were recorded by soil quantities 10 and 15 tons/fed (6.02 and 6.37 tubers/plant) respectively.

The maximum average weight of tuber of potato plant was 81.16 g/tuber in the second season by the soil quantity 20 tons/fed treatment while the lowest average weight of tuber of potato plant was 68.13 g/tuber by the soil quantity 5 tons/fed treatment. Moderate responses the average weight of tuber of potato plant were recorded by soil quantities 10 and 15 tons/fed (72.55 and 75.10 g/tuber) respectively.

The maximum average tuber weight/plant of potato plant was 0.543 kg/plant in the second season by the soil quantity 20 tons/fed treatment while the lowest average tuber weight/plant of potato plant was 0.384 kg/plant by the soil quantity 5 tons/fed treatment. Moderate responses the average tuber weight of potato plant were recorded by soil quantities 10 and 15 tons/fed (0.437 and 0.485 kg/plant) respectively.

The maximum total yield/feddan of potato plant was 10.86 tons/fed in the second season by the soil quantity 20 tons/fed treatment while the lowest total yield/feddan of potato plant was 7.67 tons/fed by the soil quantity 5 tons/fed treatment. Moderate responses the total yield/feddan of potato plant were recorded by soil quantities 10 and 15 tons/fed (8.74 and 9.70 tons/fed) respectively. Similar results have been reported by Larkin et al. (2021), AL-Jawadi and Hassan (2022), Hlisnikovský et al. (2021), Tolba et l. (2023) and Umme Salma et al. (2022).

Data in table (6) obtain the effect of the different clay quantities (5, 10, 15 and 20 tons/Feddan) on potato tubers quality parameters (average tuber dry weight, average tuber size, average tuber length and average tuber diameter) in the two studied seasons. It is clear that the highest values of average tuber dry weight, average tuber size, average tuber length and average tuber diameter of potato tubers were obtained by using 20 tons of clay quantity/Feddan, followed by 15 tons of clay/Feddan treatments and then 10 tons of clay/Feddan treatment, while the lowest values were recorded with the clay quantity 5 tons/feddan treatment with significant differences between them, the same results were found in the second season.

The potato tubers quality parameters under different clay quantities in the second season were higher than the first season; the maximum average potato tuber dry weight was 22.69 g/tuber in the second season by the soil quantity 20 tons/fed treatment while the lowest average potato tuber dry weight was 20.52 g/tuber by the

Table 6. Effect of the different clay quantities on the potato tubers quality parameters (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Soil Q. (ton)	Average Tuber Dry Weight (g)		Average Tuber Size (cm^3)		Average Tuber Length (cm)		Average Tuber Diameter (cm)	
	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S	1st. S	2nd S
5	18.65 d	20.52 d	67.82 d	75.97 d	6.73 d	7.27 d	4.67 d	5.50 d
10	19.18 c	21.13 c	71.89 c	78.63 c	7.38 c	8.00 c	5.32 c	6.40 c
15	19.84 b	21.91 b	76.53 b	82.63 b	8.31 b	8.96 b	6.25 b	7.76 b
20	20.57 a	22.69 a	80.78 a	88.94 a	83.58 a	9.28 a	6.51 a	8.12 a

soil quantity 5 tons/fed treatment. Moderate response the average number of tubers of potato plant of potato plants were recorded by soil quantities 10 and 15 tons/fed (21.13 and 21.91 g/tuber) respectively.

The maximum average potato tuber size was 88.94 cm3/tuber in the second season by the soil quantity 20 tons/fed treatment while the lowest average potato tuber size was 75.97 cm3/tuber by the soil quantity 5 tons/fed treatment. Moderate responses of the average potato tuber size were recorded by soil quantities 10 and 15 tons/fed (78.63 and 82.63 cm3/tuber) respectively. These results agree with that of Youssef and Shadia (2013), Shengtao Xu et al. (2015), Al-Hamed et al. (2017) and Shubha et al. (2018).

It is clear from the data in table (7) the different clay quantities (5, 10, 15 and 20 tons/feddan) effected on the tuber chemical quality of potato plant (% of carbohydrate in tuber, tuber content of TSS, and total protein content) with significant differences between all the treatments.

The highest values of carbohydrate % in tuber and tuber content of TSS of potato plant were recorded by using 5 tons of clay quantity/feddan treatment, followed by 10 tons of clay/feddan treatment and then 15 tons of clay/feddan treatment, while the lowest values were recorded with the clay quantity 20 tons/feddan treatment with significant differences between them, the same results were found in the second season.

Table 7. Effect of the different clay quantities on tuber chemical quality of potato plants (*Solanum tuberosum* L.) during the two successive cultivated seasons.

Soil Q. (ton)	Total carbohydrate contents in dry tubers (%)		TSS		Total protein (%) in tubers	
	1st. S	2nd S	1st. S	2nd S	1st S	2nd S
5	19.25 a	21.09 a	5.32 a	6.16 a	1.24 d	1.44 d
10	19.03 b	20.83 b	5.05 b	5.80 b	1.47 c	1.72 c
15	18.89 c	20.65 c	4.93 c	5.86 c	1.78 b	2.09 b
20	18.64 d	20.37 d	4.73 d	5.68 d	1.84 a	2.16 a

The tuber chemical quality of potato plant under different clay quantities in the second season were higher than the first season; the maximum carbohydrate % in tuber of potato plant was 21.09 % in the second season by the soil quantity 5 tons/fed treatment while the lowest carbohydrate % in tuber of potato plant was 20.37 % by the soil quantity 20 tons/fed treatment. Moderate responses the carbohydrate % in tuber of potato plant were recorded by soil quantities 15 and 10 tons/fed (20.65 % and 20.83 %) respectively.

The maximum tuber content of TSS of potato plant was 6.16 in the second season by the soil quantity 5 tons/fed treatment while the lowest tuber content of TSS of potato plant was 5.68 by the soil quantity 20 tons/fed treatment. Moderate responses the tuber content of TSS of potato plant were recorded by soil quantities 10 and 15 tons/fed (5.80 and 5.86) respectively.

The maximum value of Protein % in tubers of potato plant was 2.16 in the second season by the soil quantity 20 tons/fed treatment while the lowest value of Protein % in tubers of potato plant was 1.44 by the soil quantity 5 tons/fed treatment. Moderate responses of Protein % in tubers of potato plant were recorded by soil quantities 10 and 15 tons/fed (1.72 and 2.09) respectively. These results are in harmony with the findings of other researches Mousa (2017), Abdel Naby et al. (2018), Martins et al. (2018), Larkin et al. (2021) and Afrad et al. (2022).

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الملخص العربي

تأثير حقن التربة الرملية بطين البنتونيت الطبيعى على محصول وجودة درنات البطاطس تحت ظروف شمال سيناء

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[١]قسم الأنتاج النباتي، مركز بحوث الصحراء، القاهرة، مصر.
[٢]قسم البساتين، كلية الزراعة، جامعة بنها، القليوبية، مصر.

أجريت التجارب لتقييم تأثير معاملات حقن التربة على المحصول والجودة والتركيب الكيميائي لنبات البطاطس (صنف سبونتا) خلال موسمي ٢٠٢٠ و ٢٠٢١. أجريت التجارب بمحطة بحوث بالوظة بمركز بحوث الصحراء بشمال سيناء. مصر. كان التصميم التجريبي عبارة عن تصميم القطاعات العشوائية الكاملة بثلاث مكررات، تضمنت كل مكررة ٤ معاملات (٠،٥،١٠،١٥،٢٠ طن) من الطين. أظهرت النتائج أن الكميات الطينية المختلفة (٥، ١٠، ١٥، ٢٠ طن/فدان) أثرت على صفات إنتاجية البطاطس مع وجود فروق معنوية بين المعاملات. تم الحصول على أعلى القيم لعدد الدرنات/نبات، ومتوسط وزن الدرنات، ووزن الدرنات/نبات، والمحصول الكلي/فدان لنبات البطاطس باستخدام ٢٠ طن كمية طين/معاملة فدان، يليها ١٥ طن معاملة طين/فدان ومعاملة ١٠ طن طين/فدان. ثم معاملة ٥ طن طين/ فدان، ومن الواضح أنه تم الحصول على أعلى القيم لمتوسط الوزن الجاف للدرنة ومتوسط حجم الدرنة ومتوسط طول الدرنة ومتوسط قطر الدرنة لدرنات البطاطس باستخدام ٢٠ طن كمية الطين/ فدان، تليها معاملة ١٥ طن طين/ فدان. ١٠ طن معاملة طين/ فدان ثم ٥ طن معاملة طين/ فدان، تم تسجيل أعلى قيم نسبة الكربوهيدرات في الدرنات ومحتوى الدرنات من المواد الصلبة الكليةTSS لنبات البطاطس باستخدام ٥ طن معاملة طين/ فدان، تليها ١٠ طن معاملة طين/ فدان ثم معاملة ١٥ طن طين/ فدان.

الكلمات المفتاحية: البطاطس،المحصول، الجوده، كمية الطين.