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EFFECT OF BENTONITE AND ZEOLITE ORES ON POTATO CROP (*Solanum tuberosum* L.) UNDER NORTH SINAI CONDITIONS.

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ABSTRACT

Two Field experiments were carried out on sandy soil at El-Sheikh Zwaied Research Station of Desert Research Center, North Sinai during 2009 and 2010 growing seasons. The aim of this study was to investigate the effect of bentonite at rates of 4, 5 and 6 ton/fed. , zeolite at rates of 1, 2 and 3 ton/fed. and control treatment added solely or in combination on growth, yield and its components, as well as chemical composition of potato plants. Results revealed that soil application of bentonite and zeolite wheather added solely or in combination enhanced plant growth, improved tuber yield and its components as well as chemical composition, except Na and Cl. Also, increasing the rate of bentonite and zeolite induced gradually improvement of growth and yield characters. In addition, the highest growth parameters, yield and its components, as well as chemical constituents were, generally, obtained with application 4 ton bentonite combined with 3 ton zeolite per fed. followed by 5 ton bentonite combined with 2 ton zeolite per fed. While, sodium and chloride content decreased with increasing rate of bentonite and zeolite; the highest contents were observed with control treatments.

Keywords: potato plants *Solanum tuberosum* L., vegetative growth, yield, chemical composition, Zeolite, Bentonite, sandy soil.

INTRODUCTION

Potato (*Solanum tuberosum* L.) was selected for this study due to its economic importance in Egypt. It is the leading exportable vegetable crop and one of the important cash crops in Egypt.

The bentonite is a rock containing clay minerals (Tawfiq, 2009). Bentonite increased the mineral nutrient content, the colloid content of soil, which, in turn, decreased leaching of different nutrients (Sitthaphanit *et al*. 2010). Also, Iskander *et al*. (2011) showed that bentonite could raise the storage capacities of soil for water and fertilizer. In addition, bentonite reduced soil fixation for phosphorus and potassium. Early studies had shown that it is possible to increase number and size of potato tubers by bentonite as soil amendment throughout the growing period (Jena and Kabi, 2012). Bentonite had a broad application prospect in agriculture. It can decrease decomposition rate of organic substance and improve humification coefficient, so it can raise the quantity and quality of organic matter, improve the sandy soil fertility, growth, yield and chemical composition of plants (Tawfiq, 2009). Also, Anas *et al*. (2009) at El Fayoum found that application of 12.5 ton organic compost plus 10 ton bentonite /fed. led to the best use efficiency of available water and nutrients for maximize the return of growth, yield, macro and micronutrient contents of peanut. Aghdak *et al*. (2010) showed that the highest growth and yield parameters of snap beans were observed by using bentonite (10%). The same trend was found by Reguieg *et al.* (2012) and Hassan and Mahmoud (2013) who showed that addition of bentonite increased percentage of the morphological vegetative growth parameters and seed yield of faba bean and corn plants. In the same respect, Shaheen *et al*. (2013) showed that application of bentonite as soil conditioner for sandy soil had a positive significant effect on all measured characteristics of vegetative growth, tuber yield and chemical tuber quality of potato plants, except for protein and N contents.

Zeolite is rocky volcanic deposits formed millions of years ago which contains basic metals clinoptiolite (Palesa *et al*. 2011). Zeolite had ability to absorb gases and used as soil amendment to improve its performance as well as to provide a high proportion of mineral fertilizer required for plants (Zoltán and Williams, 2005). Also, zeolites improve nutrient use efficiency through increasing P availability from phosphate rocks, reducing leaching losses of K+ and slow-release fertilizer (Jia-fang *et al*. 2009). Incorporation of zeolite into soil improves nitrogen assimilation, increases soil absorption, reduces nitrogen nitrification and reduces fertilizer wash off from soils (Ghasemi *et al*. 2012). In addition, zeolite had been used on some types of soil and on a number of crops, such as potato (Vosátka and Gryndler, 2000) and carrot (Jia-fang *et al*. 2009). Also, zeolite increased growth and yield of cucumber and tomato plants, also increased available water capacity of a sandy soil when used as a soil conditioner (Rydenheim, 2007). Mahmoodabadi *et al*. (2009) detected that zeolite increased growth, yield and macronutrient of soybean. Another study carried by Patrícia *et al*. (2010) on tomato and lettuce indicated that concentrated zeolite enriched with N, P and K was an adequate slow-release source of nutrients to plants. Peter *et al*. (2011) found that 20 % zeolite increased significantly all measured parameters. Other investigators found similar stimulatory effect of zeolite on cucumber (Bozorgi *et al*. 2012), eggplant (Azam *et al*. 2012) and (Hassan and Mahmoud, 2013) on faba bean and corn plants.

The objective of this work was to investigate the effect of different rates of bentonite or zeolite wheather applied alone or in combinations between them on potato production in sandy soil. Al-Arish location (El-Sheikh Zwaied region) was chosen for this study because of its soil is very poor in clay which, in turn, characterized by very low fertility and water holding capacity.

MATERIALS AND METHODS

The present work was carried out during the two successive summer seasons of 2009 and 2010 at the Experimental Station of Desert Research Center at El Sheikh Zwaied, North Sinai Governorate. The aim of this study was to investigate the effect of different rates of bentonite and zeolite Ores on plant growth and yield and its components, as well as chemical constituents of potato tubers (*Solanum tuberosum* L.). The analysis of bentonite and zeolite is shown in Tables (A and B) according to El-Ahram Company for Mining and Natural Fertilizers, Giza, Egypt and Delta Bio.Tec.. Potato seeds (cv. Valor cultivar) were sown in the second week of January of both seasons in sandy soil and irrigated with drip-irrigation system. The physical and chemical analysis of the experimental soil was carried out according to Piper (1950) and Jackson (1973) respectively, as presented in Tables (C and D). Irrigation water analysis following Richards (1954) and presented in Table (E).

Table(A): Chemical analysis (%) of Bentonite Ore

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	MnO	P_2O_5	CaO	Na_2O	K_2O
56.10	0.56	12.50	2.99	1.17	0.33	0.06	0.82	10.18	1.07	1.21

Table (B): Physical and Chemical analysis of Zeolite Ore.

Physical Properties		Chemical analysis of zeolitie		Heavy Metal Analysis of zeolite	
Porosity	49.30%	SiO_2	71.00%	As	<5.8 ppm
Pore volume	52%	CaO	3.40 %	Cd	<0.15 pm
Real density	2.6321 g/cm3	Fe_2O_3	1.70%	Hg	<0.05ppm
Apparent density	2.4049 g/cm3	AL_2O_3	11.80%	Pb	<16 ppm
Cation exchange capacity	150-180 meq/g	K_2O	2.40%	Se	<50 ppm
pH value	7.14	MgO	1.40%	Mo	<5 ppm
Clinoptilolite content	95% in weight	Na_2O	0.40%	Ni	<10 ppm
Hardness	2.5-3.5 mohs	TiO_2	0.10%	Cr	12 ppm
Total surface area	800 m2/g			Cu	<10 ppm
Oil absorbing	57(ml/100G)			CO	<10 ppm
Water absorbing	57%			Fe	84 ppm

Table (C) : Physical properties of North Sinai Research Station soil at depth 0-30 cm

Particle size distribution %				Texture class	Practical density g/cm^3	Bulk density g/cm^3	Porosity%	Organic matter %	Moisture retention %		Available soil water%	Infiltration rate	
Coarse sand %	Fine sand %	Silt%	Clay%						Field Capacity	Wilting point		cm/hr	class
0.3	98.5	0.69	0.51	sandy	2.64	1.62	38.6	0.12	2.99	0.89	2.1	30.8	V.R

Table (D): Chemical properties of North Sinai Research Station soil at depth 0-30 cm

CaO_3 %	pH	E.C.dS/m	Soluble Cations (me/l)				Soluble anions (me/L)				Exchangable Cations (m/100g)			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	Cl^{-}	Ca^{++}	Mg^{++}	Na^{+}	K^{+}
1.45	7.81	0.31	1.04	0.35	1.56	0.17	-	0.87	1.2	1.05	2.36	0.09	0.35	0.03

Table (E): Chemical analysis of irrigation water

Parameters	Values
pH	7.4
Sodium adsorption ratio	5.45
E.C. dS/m	0.76

Soluble Cations (me/l) Ca^{++}, Mg^{++} , Na^{+} and K^{+}	1.44 , 1.70, 3.92 and 0.18, respectively
Soluble anions (me/L) CO_3^{-} , HCO_3^{--} , SO_4^{-} and Cl^{-}	**0 , 1.66, 3.29 and 2.3, respectively**

The experiment included 16 treatments of soil amendments which were as follows:

1- Control (without bentonite or zeolite)
2- Bentonite 4 ton/fed. (B 1)
3- Bentonite 5 ton/fed. (B 2)
4- Bentonite 6 ton/fed. (B 3)
5- Zeolite 1 ton/fed. (Z 1)
6- Zeolite 2 ton/fed. (Z 2)
7- Zeolite 3 ton/fed. (Z 3)
8- B 1 + Z 1
9- B 1 + Z 2
10- B 1 + Z 3
11- B 2 + Z 1
12- B 2 + Z 2
13- B 2 + Z 3
14- B 3 + Z 1
15- B 3 + Z 2
16- B 3 + Z 3

The investigated soil amendments were mixed with the surface soil layer (0-20 cm) before planting. Sprouted seed pieces were planted at 10 cm depth and 25 cm apart within the row. The treatments were arranged in complete randomized block design with three replicates. The area of each plot was 10.5 m^2 (1/400) /fed., (2 line x 10.5 m long x 0.5 m wide). All experiment area received the recommended dose of organic and mineral fertilizers. Farmyard manure (FYM) was applied at the rate of 30 m^3/fed. before planting. Recommended dose of phosphorus fertilizer as superphosphate (15.5% P_2O_5) was added during soil preparation at rate of 75 kg P_2O_5 /fed. Potassium fertilizer (48% K_2O) was used as a source of potassium at rate of 100 kg K_2O /fed. divided into two equal portions, half of potassium fertilizer was applied during soil preparation and the another half was added to the soil after 45 days from planting. Ammonium sulphate fertilizer (20.5% N) was applied at the rates of 200 kg N/fed. divided into three equal doses, the first was applied to the soil during soil preparation, the second dose was applied after complete emergence and the third dose was added after 60 day from sowing. The other common agricultural practices for growing potato plants according to the recommendations of Ministry of Agriculture and Land Reclamation (Egypt) were followed.

Recorded data:

A- Vegetative growth characters and chlorophyll content:

Plant samples of foliage were taken after 90 days from planting to record plant height (cm), shoots number, fresh and dry weight of shoots/ plant, leaf area (cm^2) was measured by using leaf area meter (Model 3100 Area Meter. Li- Cor. Inc. Lincoln, Nebrask USA). Also, total chlorophyll content in fully expanded leaves was measured as SPAD units using Minolta Chlorophyll Meter (model SPAD 502) according to A.O.A.C. (1990).

B- Tuber yield measurements.

Tubers No./Plant, tuber diameter, tuber length, average tuber weight, tuber dry matter % tuber yield/plant (g) and total tuber yield (ton /fed.) were studied.

C- Chemical composition

Samples of tubers were taken at harvesting time (110 days from planting) for total soluble solids (TSS), protein and starch determination. Samples were dried at 70ºC; ground, digested and assigned for analyzing N, P, K, Ca, Na, Cl accumulation in tubers (based on tuber dry weight and element percentage in tubers). The mineral contents were estimated using the wet ash procedure for the dry powdered samples (Johnson and Ulrich, 1959). Nitrogen was determined using modified micro-Kjeldahl according to method of Huphries (1965). Potassium, sodium and calcium contents were determined using flame photometer according to methods of Brown and Lilland (1964). Chloride was also determined by the method described by Richards (1954). Phosphorus was determined by modified spectrophotometer method according to Rowell (1993). Total soluble solids of the fresh potato tubers sap were done using a hand refractometer (Cox and Pearson,١٩٦٢). Protein content was calculated by multiplying N content by 6.25 (Ranganna, ١٩٧٧). Starch content was calculated according to the formula of Burton (1948): Starch (%) = 17.546+0.891 (Tuber dry matter% -24.18).

Statistical Analysis:

All obtained data were subjected to statistical analysis of variances and the least significant difference (LSD at 5%) method was used to test the difference among the treatment means according to the procedure outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

A-Vegetative Growth and chlorophyll content:

Data concerning the effect of bentonite and zeolite on potato growth parameters, *i.e.,* plant height, leaf area, number of shoots and fresh and dry weight of whole plant as well as total chlorophyll content were presented in Table (1). Obtained results indicated that application of either bentonite or zeolite wheather added solely or in combination significantly increased all the investigated growth parameters and chlorophyll content as compared with control treatment. Results also, revealed that the highest values of the investigated growth parameters and chlorophyll content were, generally, recorded with application of bentonite at the rate of 4 t/fed. combined with zeolite at the rate of 3 t/fed. followed by bentonite at the rate of 5 t/fed. combined with zeolite at the rate of 2 t/fed.. Results of bentonite are in agreement with those obtained by Reguieg *et al*. (2012) on *Vicia faba* and Shaheen *et al*. (2013) on potato. Zeolite results are in confirmation with those obtained by Noemi, (2006) using pepper, industrial tomato, pickling cucumber, lettuce and cabbage plants. In addition, Peter *et al*. (2011) found that bentonite and zeolite increased chlorophyll content in tomato leaves.

T1

The positive effect of bentonite addition on plant growth and chlorophyll content may be due to its positive effect on water holding capacity (Iskander *et al*. 2011), decreasing leaching of different nutrients through its higher colloid content (Sitthaphanit *et al*. 2010), stimulating the merestimatic activity for producing more tissues and organs, since it plays major roles in the synthesis of structural (Marisa *et al*. 2009) and its vital contribution in several biochemical processes that related to plant growth (Marschner, 1995).

As for improvement of growth characters as a result of zeolite application may be due to improving soil conditions which, in turn, enhancing photosynthetic and other metabolic activity which led to an increase in various plant metabolites responsible for cell division and elongation because application of a natural zeolite is considered a slow plant-nutrient releaser (Jiang *et al*. 2004; Na *et al*. 2011; Patrícia *et al*. 2010). Jiang *et al*. (2004) added that incorporation of zeolite into soil improved nitrogen assimilation, reduced nitrogen nitrification and reduced fertilizer wash off from sandy soil which, in turn reduced leaching losses of exchangeable cations, especially K^+. Moreover, Gan (2005) reported that zeolite and bentonite, as carriers of chemical fertilizers and modifying the fertilizers to become long-acting ones, so as to cause the release of the available constituents of the fertilizers to be in balance with the crop needs, raised the use ratio of these components, and reduced environmental pollution. Furthermore, Hinsinger (2001) stated that bentonite and zeolite increased macronutrient and micronutrients in the soil, thus, encouraged plant growth because they are essential nutrients. The same trend was found by Hassan and Mahmoud (2013) who showed that the increased percentages of the morphological vegetative growth parameters of faba bean and corn plants were due to soil conditioning natural zeolite combined with bentonite clay deposits to Ismailia sandy soil.

B-Yield and its components:

Data presented in Table (2) indicated that application of either bentonite or zeolite wheather applied solely or in combination with each other significantly increased yield parameters (tubers No. /plant, tuber diameter, tuber length, tuber average weight, tuber yield/plant and total tuber yield (ton /fed.) as compared with control treatment. Also, results revealed that the highest values of the investigated yield parameters were recorded with application of 4 ton bentonite per fed. combined with 3 ton zeolite per fed. followed by 5 ton bentonite combined with 2 ton zeolite per fed.

Results of bentonite are in agreement with those obtained by Aghdak *et al*. (2010) on *Phaseulus vulgaris*, Anas *et al*. (2009) on peanut at El Fayoum and Jena and Kabi (2012) on potato. The same trend was found by Shaheen *et al*. (2013) who stated that application of bentonite as soil conditioner for sandy soil had a positive significant effect on all measured characteristics of tuber yield of potato plants. Zeolite results are in agreement with those obtained Vosátka and Gryndler (2000) on potato, Azam *et al*. (2012) on eggplant, Jia-fang *et al*. (2009) on carrot and Bozorgi *et al*. (2012) on cucumber.

The positive effect of bentonite or zeolite on yield and its components may be attributed to their beneficial effects on improving nitrogen assimilation (Bozorgi *et al*. 2012), increasing soil absorption (Sitthaphanit *et al*. 2010), reducing nitrogen nitrification and reduces fertilizer wash off from soils (Sheta *et al*. 2003). In addition, Tawfiq (2009) stated that zeolite improved efficiency of water use by increasing soil water holding capacity and water availability to plants. Moreover, Gan (2005) added that bentonite and zeolite, as carriers of chemical fertilizers and modifying the fertilizers to become long-acting ones, tended to cause the release of the available constituents of the fertilizers to be in balance with the crop needs, raise the use ratio of these components, and reduce environmental pollution. Furthermore, Hassan and Mahmoud (2013) recorded that the increased percentage of the morphological vegetative growth parameters and seed yield of faba bean and corn plants were due to soil conditioning natural zeolite combined with bentonite clay deposits to Ismailia sandy soil. Bentonite and zeolite application increased micronutrient and macronutrient in the soil which encouraged plant growth and yield due to improving photosynthesis, nitrogen, protein, enzyme and carbohydrate metabolism.

C- Chemical composition:

Data recorded in Table (3) indicated that all the studied chemical constituents, except Na and Cl, of potato plants significantly increased with different levels of either bentonite or zeolite wheather applied solely or in combination as compared with control treatment. Also, results revealed that the highest values of the investigated chemical constituents, except Ca, Na and Cl, of potato tubers were recorded with application of 4 ton bentonite combined with 3 ton zeolite per fed. While the highest value of calcium were recorded with application of 6 ton bentonite per fed.. While, the highest values of Na and Cl were recorded with control treatment. The obtained results of bentonite were supported by Aghdak *et al*. (2010) on snap beans; Anas *et al*. (2009) on peanut and Jena and Kabi (2012) who found that 60 kg bentonite/ha increased significantly uptake of N, P, K, Ca, Mg, S, Fe, Mn, Zn and Cu by hybrid rice-potato cropping. The same trend was found by Shaheen *et al*. (2013) who revealed that application of bentonite as soil conditioner for sandy soil had a positive significant effect on all measured characteristics of chemical quality of potato tubers, except for protein and N contents.

Zeolite results are in agreement with those obtained by, Mahmoodabadi *et al*. (2009) on soybean, Anas *et al*. (2009) on peanut and Patrícia *et al*. (2010) on lettuce cucumber and tomato; they indicated that concentrated zeolite enriched with N, P and K was adequate slow-release source of nutrients to plants.

Improvement in nutrient contents as a result of application bentonite and zeolite might be due to bentonite or zeolite does not break down over time but remains in the soil to improve nutrient retention. This result was supported by Gan (2005) who stated that zeolite and bentonite, as carriers of chemical fertilizers and modifying the fertilizers to become long-acting ones, so as to cause the release of the available constituents of the fertilizers to be in balance with the crop needs, raise the use ratio of these components, and reduce environmental pollution. Increasing macro and micronutrients in rooting zone which caused an increase of its absorption by plants, consequently increased the ability of plants roots to uptake more elements in plant tissues (Ali *et al*. 2001).

T 2

T3

CONCLUSION

The present study led to demonstrate that application of bentonite and zeolite whether added solely or in combination had a significant positive effect on growth, yield and chemical composition, except Na and Cl, of potato plants grown in sandy soil. Generally, it can be conclude that application of bentonite and zeolite significantly increased the growth, yield and chemical composition of potato. A rate of 4 ton bentonite/fed. combined with 3 ton Zeolite/fed. or 5 ton bentonite/fed. combined with 2 ton Zeolite/fed. were ideal for potato, as a source of nutrients, could be recommended. Further studies may be required to state to what extent can bentonite or zeolite application replace mineral fertilization without decreasing yield of potato plants grown on sandy soil

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تأثير خام البنتونيت والزيوليت على محصول البطاطس تحت ظروف شمال سيناء .

شادية بسطروس داود يوسف
مركز بحوث الصحراء بالمطرية – القاهرة- مصر

أقيمت تجربتان حقليتان بمحطة بحوث الشيخ زويد، محافظة شمال سيناء خلال موسمى الزراعة الصيفى المتعاقبة عامى ٢٠٠٩ و ٢٠١٠ لدراسة تأثير معدلات مختلفة من خام البنتونيت (٤، ٥، ٦ طن/فدان) و معدلات مختلفة من خام الزيوليت(١، ٢، ٣ طن/فدان) والتفاعل بينهم بالاضافة الى معاملة الكنترول على النمو والمحصول ومكوناته، وكذلك المكونات الكيميائية لدرنات البطاطس صنف "فالور". زرعت درنات البطاطس في الأسبوع الثاني من يناير في كلا الموسمين في التربة الرملية واستخدام نظام الري بالتنقيط ، وتم توزيع المعاملات فى قطاعات كاملة العشوائية فى ثلاث مكررات.

وكانت النتائج كالتالى:-

١- أظهرت نتائج النمو الخضرى (ارتفاع النبات – عدد الافرع/نبات- الوزن الغض و الجاف /نبات) والكلورفيل الكلى، وجود زيادة معنوية فى صفات النمو الخضرى بزيادة مستويات البنتونيت والزيوليت مقارنة بالكنترول. وأفضل معاملة أعطت أعلى النتائج كانت معاملة (٤طن بنتونيت+ ٣ طن زيوليت/ف).

٢- كما اشارت النتائج الى زيادة معنوية فى المحصول ومكوناته بزيادة مستويات البنتونيت والزيوليت مقارنة بالكنترول وأعلى القيم المتحصل عليها كانت باضافة معاملة (٤ طن بنتونيت+ ٣ طن زيوليت /ف).

٣- كما لوحظ زيادة معنوية فى التركيب الكيماوى (البروتين –نشا – نسبة المواد الصلبة الكلية – الكالسيوم - النيتروجين- الفوسفور- البوتاسيوم) فى الدرنات عن الكنترول .وكانت اعلى النتائج مع معاملة (٤ طن بنتونيت+ ٣ طن زيوليت/ف)، بينما نسبة الكالسيوم وصلت الى اعلاها بإضافة البنتونيت بمعدل ٦ طن /فدان، فى حين أن قيم الصوديوم والكلوريد وصلت الى اقصاها باستخدام معاملة الكنترول.

قام بتحكيم البحث

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Table1:Effect of bentonite and zeolite on the vegetative growth characters and chlorophyll content of potato plants during the two successive seasons of 2009 and 2010.

Chract.. / Treat.	Plant height (cm)		Shoots number		Leaf area/plant (cm^2)		Fresh weight /plant(g)		Dry weight /plant(g)		Total chlorophyll (SPAD)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Control	40.7	40.9	2.1	2.6	89.2	99.3	347.7	357.7	24.7	25.5	33.2	33.1
B1	41.8	44.5	3.4	3.3	111.0	120.9	391.2	401.0	30.6	31.7	36.2	37.1
B2	52.7	50.9	4.3	3.8	115.0	125.1	378.7	397.0	39.3	39.0	47.4	47.3
B3	55.4	55.7	4.4	4.9	146.9	157.1	440.3	497.0	49.5	50.4	47.4	48.4
Z1	47.4	48.7	3.9	3.5	177.7	187.5	376.0	399.3	34.9	34.9	36.2	39.3
Z2	54.5	54.8	4.4	3.6	191.5	201.6	434.7	441.3	47.8	48.6	47.5	49.5
Z3	56.0	57.0	5.0	5.1	224.3	234.4	491.7	495.0	51.5	53.2	50.4	53.2
B1+Z1	45.4	46.5	4.5	4.6	169.1	165.2	409.0	419.7	34.9	35.5	40.7	45.0
B1+Z2	55.9	57.6	5.7	5.2	192.7	202.8	485.0	496.7	45.1	46.1	50.8	54.7
B1+Z3	63.6	62.0	6.0	6.3	223.7	252.0	545.0	527.3	50.0	51.1	43.9	49.7
B2+Z1	51.7	54.3	4.2	4.9	182.2	191.2	495.3	507.0	43.7	44.7	54.3	55.3
B2+Z2	59.6	58.0	4.4	5.1	223.2	233.1	538.3	554.3	51.1	51.7	46.7	53.8
B2+Z3	53.8	54.2	3.9	4.0	172.0	196.0	494.0	506.0	48.8	49.6	54.7	58.1
B3+Z1	48.0	57.3	3.4	4.1	181.8	194.0	420.7	431.3	47.7	48.4	46.2	53.0
B3+Z2	56.5	56.4	3.3	4.3	165.3	183.1	419.7	436.7	46.6	47.8	51.7	49.2
B3+Z3	53.2	55.1	3.1	3.4	151.1	164.6	387.0	397.7	44.2	44.8	49.2	50.0
L.S.D at 5%	3.67	3.47	0.34	0.39	15.58	15.16	18.11	14.17	4.20	4.28	2.80	2.79

B1=(4 ton bentonite /fed.) B2 = (5 ton bentonite /fed) B3 = (6 ton bentonite /fed)
Z1=(1 ton Zeolite /fed.) Z2 = (2 ton Zeolite /fed) Z3 = (3 ton Zeolite /fed)

Table 2: Effect of Bentonite and Ziolite on the yield of potato plants during the two successive seasons of 2009 and 2010

Chract.. / Treat.	Tuber length (cm)		Tuber diameter (cm)		Tubers No./plant		Average tuber weight (g)		Yield/plant (g)		Tuber dry matter %		Total yield (ton/fed.)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Control	6.3	6.5	3.2	3.3	2.5	2.3	97.2	107.2	387.7	403.3	17.3	17.3	5.2	6.2
B1	8.8	9.6	4.5	4.6	4.5	4.6	110.7	119.2	515.0	572.7	18.1	19.9	6.8	7.5
B2	8.8	10.4	5.3	5.3	5.0	5.0	117.1	125.6	652.7	677.3	18.4	19.0	8.1	8.9
B3	10.6	12.1	5.9	5.9	5.3	5.4	119.3	129.2	732.3	752.7	19.9	20.5	10.8	11.8
Z1	9.0	9.4	5.3	5.1	4.9	4.7	89.4	99.4	512.7	516.3	17.7	18.3	8.4	9.6
Z2	11.3	11.8	5.4	5.3	5.4	5.5	113.0	123.0	626.3	646.7	19.1	19.8	11.1	11.8
Z3	12.5	13.7	6.0	5.8	5.7	5.7	118.4	128.1	699.3	718.0	20.5	20.6	12.7	13.3
B1+Z1	10.8	11.3	5.4	5.5	5.1	5.2	116.7	125.9	627.7	648.0	17.9	19.4	11.1	11.9
B1+Z2	13.1	12.7	5.8	5.9	5.8	5.8	121.5	131.8	652.0	735.3	19.7	20.5	13.2	13.5
B1+Z3	13.4	13.9	6.1	6.3	6.1	6.5	123.2	133.3	841.7	912.3	20.5	21.2	14.0	14.0
B2+Z1	12.7	13.3	5.8	6.0	5.5	5.5	115.6	125.7	640.7	661.3	19.2	18.8	6.4	7.3
B2+Z2	13.7	13.8	6.4	6.5	5.7	5.9	122.0	131.8	775.7	816.0	20.4	21.1	13.4	14.0
B2+Z3	13.8	13.7	5.2	5.4	5.2	5.2	113.3	123.4	725.7	749.7	19.4	21.1	12.0	12.8
B3+Z1	13.2	13.4	5.7	5.8	5.7	6.0	114.8	125.1	759.0	775.7	20.9	21.1	11.6	12.4
B3+Z2	13.1	13.2	5.4	5.4	5.7	5.9	109.1	119.0	726.7	701.3	19.6	20.2	11.1	12.4
B3+Z3	13.3	13.3	5.2	5.2	5.1	5.6	105.5	115.8	614.0	634.7	18.7	19.0	10.0	10.9
L.S.D at 5%	0.60	0.41	0.42	0.39	0.34	0.43	5.44	5.64	39.43	32.35	0.44	0.63	1.07	1.18

B1=(4 ton bentonite /fed.) B2 = (5 ton bentonite /fed) B3 = (6 ton bentonite /fed)
Z1=(1 ton Zeolite /fed.) Z2 = (2 ton Zeolite /fed) Z3 = (3 ton Zeolite /fed)

Table 3: Effect of Bentonite and Ziolite on chemical composition of potato plant during the two successive seasons of 2009 and 2010

Chract. / Treat.	T.S.S		Protein %		Starch		N %		P %		K %		Ca %		Na %		Cl %	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Control	40.0	41.1	46.1	47.9	11.4	11.4	7.4	7.7	2.0	1.8	11.6	12.0	1.4	1.9	1.09	1.06	1.7	1.6
B1	42.6	42.8	52.5	55.7	12.1	13.8	8.4	8.9	1.9	2.4	12.3	12.7	3.0	3.0	1.03	0.96	1.6	1.5
B2	44.6	45.1	47.3	63.2	12.4	13.0	9.4	10.1	2.7	2.8	13.0	13.3	3.9	4.0	0.79	0.83	1.2	1.3
B3	47.2	47.5	72.6	71.8	13.8	14.2	11.6	11.5	3.3	3.5	14.0	14.2	4.4	4.5	0.53	0.54	0.8	0.8
Z1	44.2	44.9	50.8	56.1	11.8	12.3	8.1	9.0	2.1	2.4	12.5	12.8	2.7	2.7	0.81	0.80	1.2	1.2
Z2	45.3	45.1	67.7	77.4	13.1	13.6	10.8	12.4	2.3	2.6	13.1	13.2	2.9	2.9	0.63	0.65	1.0	1.0
Z3	47.1	47.7	75.9	79.9	14.3	14.4	12.1	12.8	3.4	3.5	13.5	14.0	3.8	3.9	0.68	0.65	1.1	1.0
B1+Z1	46.9	47.0	77.1	77.5	12.0	13.3	12.3	12.4	3.5	3.5	13.2	13.6	3.2	3.2	0.78	0.94	1.2	1.5
B1+Z2	47.5	47.1	82.0	82.8	13.6	14.3	13.1	13.2	3.7	3.7	13.7	13.9	3.7	3.8	0.68	0.86	1.1	1.3
B1+Z3	47.6	47.1	87.1	88.5	14.2	14.9	13.9	14.2	3.5	3.5	14.3	14.4	3.9	4.0	0.69	0.77	1.1	1.2
B2+Z1	46.8	47.2	86.7	86.9	13.1	12.8	13.9	13.9	3.1	3.3	14.3	14.4	4.1	4.2	0.84	0.75	1.3	1.2
B2+Z2	47.7	47.3	85.5	86.3	14.2	14.8	13.7	13.8	3.1	3.2	14.3	14.5	4.1	4.3	0.82	0.68	1.3	1.1
B2+Z3	46.7	46.4	83.3	86.9	13.3	14.8	13.3	13.9	3.0	3.0	13.9	14.2	4.1	4.4	0.72	0.68	1.1	1.1
B3+Z1	46.4	46.7	87.0	88.4	14.6	14.8	13.9	14.1	3.5	3.6	14.2	14.3	4.2	4.3	0.78	0.93	1.2	1.4
B3+Z2	46.1	46.4	84.5	86.0	13.5	14.0	13.5	13.8	3.7	3.7	13.7	14.2	4.1	4.4	0.76	0.54	1.2	0.8

B3+Z 3	45.9	46.0	79.5	80.5	12.7	13.0	12.7	12.9	3.5	3.5	13.1	13.2	4.2	4.4	0.56	0.58	0.9	0.9
LSD at 5%	0.36	0.57	3.90	4.69	0.34	0.49	0.62	0.84	0.15	0.13	0.15	0.15	0.27	0.04	0.1	0.07	0.15	0.11

B1=(4 ton bentonite /fed.) B2 = (5 ton bentonite /fed) B3 = (6 ton bentonite /fed)
Z1=(1 ton Zeolite /fed.) Z2 = (2 ton Zeolite /fed) Z3 = (3 ton Zeolite /fed)