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EFFECT OF BIO-AND MINERAL FERTILIZERS ON GROWTH, YIELD AND TUBER QUALITY OF POTATO PLANTS:
2- YIELD AND TUBER QUALITY

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ABSTRACT

Decreasing NPK dose less than the recommended dose decreased significantly tuber yield [measured as tubers yield (g) per plant, tubers numbers per plant, tubers dry weight per plant and total yield (ton/fed.) as well as its components from protein, ascorbic acid ,starch, N, P ,K, total soluble solids and specific gravity in both studied seasons. In contrast, inoculation of any bacterial strains used induced significantly these parameters and the most effective treatments were found with NFB+PDB+SB followed with NFB+PDB and lastly with SB.

The interaction treatments indicate that, plants received mixed three strains of used bacteria plus 50% or 75% NPK (from recommended dose) showed high values regarding yield and its components from crude protein and ascorbic acid , total soluble solids and specific gravity. The level of 75%NPK produced additive effects in this respect. NPK fertilizers at 50% only may be saved if potato tubers were inoculated with non-symbiotic fixing bacteria without serious effects on the tuber yield.

Nitrate and nitrite concentrations were decreased significantly with decreasing mineral fertilizers dose in both seasons. Similarly, Nitrate and nitrite levels were decreased significantly when potato tubers inoculated with each of the bio-fertilizers used in comparession with those of uninoculated plants. Inoculation with either mixed strains of used bacteria or NFP+PDB gave the highest reduction in the levels of both nitrate and nitrite in potato tuber.

Plants received 50% or 75% NPK (from recommended dose) produced the highest reduction in nitrate and nitrite levels compared with the control (100% recommended dose of NPK) while, the lowest reduction of both nitrate and nitrite were detected in tubers produced from plants inoculated with NFB.

Decreasing NPK dose, overall bio-fertilizers used, decreased the percentages of reducing sugars, insoluble carbohydrates and total carbohydrates whereas increased non-reducing sugars and total sugars in potato tubers during the two growing seasons.

Bio-fertilizers application alone significantly decreased reducing sugars and total sugars whereas increased non-reducing sugars, insoluble carbohydrates and total carbohydrates percentages in the tubers of potato plants inoculated with each of the three bacterial strains used in comparison to those of uninoculated one. The most effective treatments was found with NFB+PDB+SB. Again, NFB strain was more effective than PDB followed with SB.

The interaction treatments, show that bio-fertilizers significantly decreased reducing sugars and total sugars whereas increased non-reducing sugars, insoluble carbohydrates and total carbohydrates percentages in potato tubers of plants grown under any dose of NPK used in comparison to the corresponding control (uninoculated). Again, the best treatment was found with NFB+PDB+SB. Plants received only half the dose of the recommended NPK fertilizers together with the dual inoculation recorded considered increases in non-reducing sugars, insoluble carbohydrates and total carbohydrates in the tubers whereas, decreased that of reducing sugars and total sugars percentages.

It could be concluded that the use of only bio-fertilizers for the production of potatoes is insufficient, so, they must be used together with mineral NPK fertilizers. Adding bio-fertilizers (naimly, *Azospirillum brasilense* , *Psuedomonas fluerences* and *Bacillus circulance*) to 50% of the mineral NPK fertilizers from the recommended dose (90 kg N + 37.5 kg P_2O_5 + 48 kg K_2O/fed.) exhibited resistance of potato grown against NPK stress and induced its yield.

The recommendation may reduce the extensive use of mineral fertilizers (about 50%) without affecting on potato productivity productivity. In addition the reduction of 50% from the mineral NPK fertilizers used might help for reducing the production cost as well as diminishing the environmental pollution and minimizing the harmful effects of using chemical fertilizers on human health.

Keywords:- Potato, bio-and mineral fertilizers; NPK, NFB, PDB, SB.

INTRODUCTION

Chemical fertilizers, particularly nitrogen salts are commonly used for increasing potatoes growth and its yield (Hussein and Radwan, 2002 a &b). It is one of the most important vegetable crops in Egypt. Several investigators showed that mineral sources of N-fertilizers, especially NO_3^- salts, accumulate more NO_3^- and NO_2^- ions within the plant tissues, which represented a serious problem for human health because their absorption into the blood. They may oxidize Fe^{++} of hemoglobin to Fe^{+++} and producing methemoglobin, which cannot transport oxygen (Swann, 1975).The toxicity of NO_3^- may be due to the formation of carcinogenic N-nitrous compounds by reaction with amino compounds. The toxic ions of nitrate and nitrite forming from nitrification are well known as an environmental pollutant (Alexander, 1977).

Great efforts have been directed to overcome the problems of chemical fertilizers which are generally represented in increasing costs as well as environmental pollution and its negative effects on human health. These efforts have been given to decrease the recommended chemical fertilizer doses by application of bio-fertilizers (Abd El-Naem *et al.*, 1999). Bio-fertilization is used in order to compensate a part of the mineral fertilizer doses, taking in consideration the complementary or synergistic effects of such combination between bio-and mineral fertilization. This could be of economic value from the applied point of view of minimizing the used doses of the mineral fertilizers and consequently reduce agricultural costs as well as soil pollution. In addition, the bio-fertilizers are increasingly used in modern agriculture due to the extensive knowledge in rhizosphere biology and the discovery of the promotive function of special groups of microorganisms such as *Azospirillum, Azotobacter, Acetobacter, Bacillus, Serratia* and *Pseudomonas* which known as plant growth promoting rhizobacteria (PGPR). Such beneficial effects of these promoting rhizobacteria may be attributed to the biological nitrogen fixation and production of phytohormones (gibberillin, cytokinin like substances and auxins) that promote root development and proliferation, resulting in efficient uptake of water and nutrients (Hartmann *et al.*, 1983 and Devlin and Witham, 1985)

Application of bio-fertilizer is an important economically to reduce the cost of fertilizers and ecologically to reduce pollution of the environment (Verma, 1990). Using bio-fertilizer for potato plants as a substitute for the N-chemical fertilizer may be recommended to reduce nitrate and nitrite contents and improve the yield quality (Abdel-Ati,1998; Hammad and Abdel-Ati, 1998; Abdel-Naem *et al.*,1999; El-Banna and Tolba, 2000).

Using bio-fertilizers for potatoes by inoculated with certain microorganisms plays an important role in decreasing the concentrations of nitrate and nitrite ion and their toxicity as well as increasing growth promoters (Kawthar *et al.,* 2002) without affecting on plant growth and productivity (Hammad and Abdel-Ati, 1998) .

The present investigation aimed to study to what extent bio-fertilizers can replace some of the recommended NPK mineral fertilizers without affecting on potatoes growth and productivity. Yield and its quality were evaluated aiming to decreasing the production cost, minimizing the environmental pollution, hendring the serious problem of NO^{-}_{3} and NO^{-}_{2} accumulation and improving the nutritional values of the potato tubers as an edible parts.

MATERIALS AND METHODS

Two field experiments were carried out at the Agriculture Experimental Station, and laboratories of the Agric. Botany Dept., Faculty of Agriculture, Mansoura University, Egypt during the two growing seasons of 2001/2002 and 2002/2003.Different rates of the recommended NPK mineral fertilizers and three strains of non-symbiotic bacteria as a bio-fertilizers sources of N, P and K were evaluated.

Potatoes tubers; (*Solanum tuberosum*, L. Solanaceae) Spunta cv (imported from Holland) were used in the present investigation and obtained from Agric. Res. Çenter (ARC), Ministry of Agric., Egypt. Tubers were divided to pieces, averaging approximately 50 g weight.

Soil samples and analysis:

Twenty surface samples (0-20 cm depth) were taken at ten different locations before the experimental design, air dried, grounded, mixed and kept in plastic bags for the analyses.

The mechanical and chemical analyses of the soil used were carried out in the two growing seasons as described by Jackson (1973) and Page *et al.*, (1982) and presented in Table (I).

The international pipette method with ammonium hydroxide as a dispersing agent was used for mechanical analysis. The percentages of organic matter using the wet digestion method (Konova, 1966) and calcium carbonate using Collin's Calcimeter (piper, 1947) were also determined. The PH values were determined in the soil paste extract using a Gallenkamp PH-meter (Jackson, 1973).

The chemical analysis (Jackson, 1973) that have been carried out invaded the following estimations in the 1:5 soil:water extract: Electrical conductivity (EC using wheatstone bridge; Electric conductivity meter

(Jackson, 1973), the total soluble salts (TSS) by evaporation (gravimetrically) also in the soil paste extract, cations (Ca^{++}, Mg^{++}, K^+ and Na^+) and anions (HCO_3^-, CO_3^-, SO^- and CL^-). Calcium + magnesium were determined by versenate solution using eriochrome black T as a reagent. Calcium by versenate solution using ammonium purporate as a reagent. Potassium and sodium by Zeiss Flame Photometer. Carbonate and bicarbonate by titration with HCL using phenolphthalein as an indicator of the CO^- and methyl orange for the HCO_3^-. Sulphate using gravimetrically by precipitating with 5% barium chloride solution ....etc. Chloride using Mohr's method by silver nitrate solution using saturated potassium chromate solution as a regent (Richard's, 1954). For the nutritional states analysis in the soil used (Jackson, 1973), total nitrogen using the conventional method of Kjeldahl, available phosphorus in the sodium bicarbonate solution using Colorimeter at a wavelength of 725 µm, available potassium using, Zeiss Flame Photometer, calcium and magnesium were determined. Micronutrients concentrations were also determined in the digestive extract of NHO_3 + HCL + H_2SO_4 mixture of the samples according to Chapman and Pratt (1961) by using the Atomic Absorption of GBC-902 Double Beam.

Table (1): The physiochemical properties of the experimental soil used during the two growing seasons of 2001/2002 and 2002/2003.

Season	1. Mechanical Analysis				Organic Matter	Calcium carbonate	PH (1:2.5 soil: water suspension)	Soil texture
	Soil Fraction %							
	Coarse sand	Fine sand	Silt	Clay				
2001/2002	2.43	21.43	27.66	48.29	0.99	2.09	7.80	Clayey
2002/2003	2.58	22.50	25.92	49.00	1.10	2.12	7.65	

	2. Chemical Analysis								
	EC dsm^{-1} soil paste extract at 25 C°	CATIONS (meq/L)				ANIONS (meq/L)			
		Ca^{++}	Mg^{++}	Na^+	K^+	HCO_3^-	$CO_3^=$	$SO_4^=$	Cl^-
2001/2002	1.31	5.33	4.22	10.40	0.39	2.44	-	7.68	10.63
2002/2003	1.45	5.21	4.11	10.99	0.37	2.07	-	7.80	11.00

	3. Nutrients Analysis mg/100 g soil		
	N	P	K
2001/2002	25.00	8.30	268..91
2002/2003	33.00	8.50	335.10

Experimental design:

Farm yard manure has been added during soil preparation in organic fertilization at dose of 40 m^3/fed. The experiments comprised of 24 treatments included three different rates of the recommended NPK mineral fertilizers used individually or in combinations with three strains of non-symbiotic bacteria as a bio-fertilizer sources for N, P and K. The experiments design used was a two factor randomized complete block system distributed as a split plot combined with five replications. Each plot was (14 m^2) included four ridges, each five meters long and 70 cm apart; the distance between hills was 25 cm apart.

Bio-fertilizer treatments:

Three strains of non-symbiotic bacteria were used in the present investigation as bio-fertilizers sources; "*Azospirillum brasilense*" , nitrogen-fixing bacteria (NFB) , "*Pseudomonas fluorescens*" , phosphate-dissolving bacteria (PDB) and "*Bacillus circulans*" , silicate bacteria (SB) which able to release K from clay minerals (Monib *et al.*, 1984). The two former strains were obtained from Microbiol. Res.Dept., Soil, Water and Environ. Res. Inst., ARC. Giza, Egypt, whereas the third organism was obtained from Microbiol. Dept., Fac. of Agric., Mansoura Univ. Egypt. All bacterial strains were multiplied in nutrient liquid broth and centrifuged then prepared again in suspension. Liquid broth cultures contains $5x10^8$, $9x10^8$and $2.15x10^8$ cells/ml of NFB, DPB and SB, respectively.

Microbial inoculum treatments:

As recommended by the Pathology Dept. Ministry of Agric. Egypt,potato tubers pieces were sterilized with Vitavax Kapetan 1% at the rate of 1.25 kg/ton. and then inoculated with bacteria suspension, individually or in combinations directly before planting to form the following treatments:

1- Without bio-fertilizers.
2- Inoculation with *Azospirillum brasilense* (NFB).
3- Inoculation with *Pseudomonas fluorescens* (PDB).
4- Inoculation with *Bacillus circulans* (SB).
5- Inoculation with (NFB + PDB).
6- Inoculation with (NFB + SB).
7- Inoculation with (PDB + SB).
8- Inoculation with (NFB + PDB + SB).

Mineral fertilizer treatments:

As recommended by the Agric. Res. Center, Egypt, nitrogen fertilizer in the form of ammonium nitrate (33.3% N) was used at the dose of 180 kg N/fed. at three equal doses. The first was used after emergence (18-21 days from planting), whereas the second and third doses were applied before the 2^{nd} and the 3^{rd} irrigations respectively (31 and 46 days from planting). Calcium superphosphate (15.5% P_2O_5), as a source of phosphorus, at the dose of 75 kg P_2O_5 /fed., was added to the soil before planting and during soil preparation. Potassium sulphate (48 % K_2O) was used as a source of potassium at the dose of 96 kg K_2O/fed. at two times, the first half was added with the first addition of N-fertilizer, and the second with the third doses of N-fertilizer.

The mineral fertilizer treatments were used at the three following different rates:

1- 100% NPK from the recommended dose (control).
2- 75% NPK.
3- 50% NPK.

These treatments were used with or without the bio-fertilizer treatments. The treatments were arranged in a factorial complete randomized block design system as previously mentioned. Each treatment was replicated 5 times. Three of them were kept tell the end of the experimental period; 105 days from planting, and used for yield estimation.

Planting procedure:

The treated potato pieces were planted in the ridges at 12-15 cm depth (25 cm apart) on 12nd October, 2001 and 15th October, 2002 growing season, respectively. Irrigation was done immediately. All usual cultural practices of potatoes cultivation were carried out according to the procedures that recommended by the Ministry of Agric. Egypt. Harvesting was done after 105 days from planting dates in both seasons.

Tubers yield and their quality:

At harvesting (105 days from sowing), a sample of 5 plants during the two growing seasons were chosen at random from each treatment to determine tubers yield per plant (g), total tubers yield (ton/fed.). Tubers number per plant, tubers dry weight per plant (g) were also recorded.

For the tubers quality; total soluble solids (%) was determined by using KarllZiess hand Refractometer as described by Cox and Pearson (1962).

Specific gravity of tuber was calculated according to Abdel-Aal (1971) as follows:

$$\text{Specific gravity (g/cm}^3\text{)} = \frac{\text{Tuber mass (g)}}{\text{Tuber volume (cm)}^3}$$

Total soluble carbohydrate (sugars) and total soluble phenol were extracted from 5 g crude tuber dried from each treatment by ethanol 70%, and kept overnight at room temperature (Kayani *et al.*, 1990) before being filtered. Protein was precipitated by using trichloroacetic acid (TCA). The ethanol extracts were used for total soluble phenols estimation and sugar determination as described below.

For reducing sugars (R.S) determinations, 10 ml of the cleared extract was mixed with 2 ml of arsenomolybdate solution (modified Nelson' s solutions; Naguib 1964). The mixture was kept in boiling water bath for 15 minutes, then cooled rapidly in running tap water. Three ml of arsenomolybdate solution were added and the mixture was shaken till effervescence stopped and the intensity of the colour was measured by Milton Roy Spectronic 1201 spectrophotometer at 620 nm against a blank containing only distilled water and modified Nolson's reagent. The amount of reducing sugars in the plant material was calculated through a calibration standard curve using series of standard solutions of pure D-glucose at the concentrations ranged from 5-100 µg/0.1 ml.

For estimation non-reducing sugars (NRS), 10 ml of the cleared extract previously mentioned, were mixed with 5 ml of 1.5 N hydrochloric acid and the mixture was kept in a water bath at 60 °C for 30 minutes (Naguib, 1964) and the reducing values were determined as described before. The differences between the value obtained by this methods and that of reducing sugars is an estimate of non-reducing sugars content as sucrose.

Total carbohydrates were determined as described by Amberger (1954). Hydrolsis was carried out in the homogenates of 5 g crude dried materials by boiling it for 3 hours with 5 ml 25% hydrochloric acid. After the precipitation of protein and neutralization, direct reducing sugars were determined in the hydrolysates as previously mentioned as glucose.

The modified Micro-Kjeldahl apparatus of Parnars and Wagner as described by Jones *et al.*, (1991) was employed for total N determination, Crude protein was also calculated according to (A.O.A.C., 1984).

For total P and K determinations, 0.4 g crude dried kept powder from each sample was wet digested with a mixture of concentrated sulphuric acid and perchloric acid, then heated until become clear solution (Peterburgski, 1968). After digestion, the cleared solution was quantitatively transferred into 100 ml meajering flask with distilled water and kept for determinations. Phosphorus was determined spectrophotometrically by Milton Roy Spectronic 1201 at wave length of 725 nm using stannous chloride reduced molybdophosphoric blue colur method in sulphoric acid system as described by Jackson (1973). Potassium was determined Flamephotometrically using Jenway Flamephotometer model CORNING 400 (Peterburgski, 1968).

The nitrate and nitrite concentrations in the tubers were estimated according to Singh, 1988) with modifications. 0.2 g of finely grounded sample with 50 ml of 2% acetic acid in a conical flask is shaken for 20 minutes in a rotary shaker and filtered through 10 ml from the extract + 1/2 gm from a mixture (37 gm of citric acid + 5 g manganese sulphate monohydrate + 2 g sulphanil amide + 1gm of N-1-naphthylethelendiamine dihydrochloride and 1 g of finely powder zinc. A pinkish purple colour is developed. Colour intensity of the filtrate or the supernatant liquid is measured in a colourimeter at 540 nm and determined by standard curve .

Vitamin C was determined according to the method described by (Mazumdar and Majumdar, 2003) using titrimetric estimation with 2,6 dichlorophenol indophenol dye solution.

The amount of ascorbic acid was determined as follows;

Vitamin C (mg per 100 g)= e x d x b / c x a

whereas; a = Weight of sample.
b = Volume made with metaphosphoric acid.
c = Volume of aliquot taken for estimation.
D = Dye factor.
E = Average burette reading for sample.

All data were statistically analyzed according to the technique of analysis of variance (ANOVA). Least Significant Difference test (L.S.D.) method was used as published by Gomez and Gomez (1984).

RESULTS AND DISSCUSION

Tubers yield:

Data presented in Tables (2) show the mean values of tubers yield (g) per plant, tubers numbers per plant as well as tubers dry weight per plant and total yield (ton/fed.) of potato plants as affected by mineral and/or bio-fertilizers used during the two growing seasons of 2001/2002 and 2002/2003.

Table (2) : Effects of mineral and/or bio-fertilizers on tubers yield (g) per plant, tubers numbers per plant, tubers dry weight (g) per plant and total tubers yield (ton/fed) of potato plant grown during the two growing seasons of 2001/2002 (S1) and 2002/2003 (S2).

Treatments		Tubers yield (g) / plant			Tubers numbers /plant			Tubers dry weight (g) /plant			Total tubers yield (ton/fed.)		
M-Mineral NPK	B-Bio-fertilizer	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
Control 100%	Without	425.710	538.224	481.965	3.59	5.03	4.31	63.890	87.668	75.780	9.730	10.790	10.260
	NFB	470.738	588.562	529.700	4.77	5.53	5.15	74.093	92.171	83.129	11.128	12.138	11.635
	PDB	468.841	585.218	526.980	4.65	5.66	5.15	73.743	91.670	82.705	11.062	12.182	11.620
	SB	457.062	508.887	482.975	4.64	5.14	4.89	69.690	88.540	79.115	10.397	11.280	10.840
	NFP+PDB	487.041	597.602	542.320	5.34	6.33	5.83	78.386	95.362	86.875	11.311	12.387	11.850
	NFB+SB	483.310	589.203	536.255	5.31	5.97	5.64	77.350	94.353	85.851	11.180	12.262	11.720
	PDB+SB	475.328	595.362	535.345	5.08	5.86	5.47	75.329	92.566	83.950	11.161	12.178	11.670
	NFB+PDB+SB	492.152	598.911	545.530	5.56	6.48	6.02	80.848	97.421	89.135	11.342	12.483	11.910
	Mean	470.022	575.245	3522.64	4.87	5.75	5.31	74.541	92.094	83.317	10.914	11.962	11.438
75%	Without	481.980	428.655	375.326	3.95	5.07	4.51	60.433	85.922	73.175	8.053	9.164	8.605
	NFB	558.481	499.405	440.332	4.42	5.52	4.97	72.610	86.901	79.755	9.698	10.908	10.305
	PDB	562.723	497.640	432.962	4.30	5.48	4.89	72.485	86.913	79.695	9.641	10.878	10.265
	SB	502.652	454.500	406.350	4.13	5.47	4.80	70.044	82.730	76.385	8.960	9.920	9.440
	NFP+PDB	573.947	515.138	456.328	5.60	5.93	5.76	77.173	88.910	86.040	10.472	11.519	10.995
	NFB+SB	562.980	507.890	452.802	5.46	5.91	5.69	74.660	87.699	81.180	10.226	11.197	10.715
	PDB+SB	565.232	505.030	444.831	5.34	5.60	5.47	73.951	86.977	80.465	10.123	11.132	10.625
	NFB+PDB+SB	582.668	530.000	477.329	5.70	5.96	5.83	79.239	93.659	86.450	10.639	11.630	11.135
	Mean	435.782	548.782	492.282	4.86	5.62	5.24	73.198	86.839	80.018	9.726	10.795	10.261
50%	Without	328.144	456.678	392.410	2.57	3.67	3.12	48.671	71.560	60.115	6.440	7.431	6.935
	NFB	408.478	516.452	462.465	3.14	4.24	3.69	55.857	77.070	66.465	8.112	8.830	8.471
	PDB	405.141	518.680	461.910	3.25	3.78	3.51	55.224	77.503	66.362	8.092	8.812	8.452
	SB	359.491	481.649	420.570	2.92	3.78	3.35	49.260	73.122	61.190	7.038	8.000	7.520
	NFP+PDB	417.520	537.901	477.710	4.22	4.33	4.27	60.081	80.896	70.490	8.539	9.607	9.075
	NFB+SB	408.832	533.062	470.945	4.29	4.31	4.30	58.893	78.202	68.545	8.271	9.231	8.750
	PDB+SB	410.451	527.022	468.735	3.96	4.00	3.98	57.480	77.030	67.255	8.219	9.078	8.650
	NFB+PDB+SB	430.001	546.686	488.343	4.39	4.45	4.42	61.378	83.593	72.485	8.549	9.928	9.338
	Mean	384.756	514.766	449.761	3.59	4.07	3.83	55.855	77.372	66.613	7.933	8.865	8.399
Mean	Without	376.393	492.293	434.343	3.37	4.59	3.98	60.330	79.050	69.690	8.073	9.127	8.600
	NFB	438.737	555.777	496.432	4.11	5.11	4.60	67.476	85.383	76.430	9.640	10.627	10.133
	PDB	436.760	554.127	496.268	4.07	4.97	4.52	67.190	85.357	76.274	9.603	10.627	10.115
	SB	407.633	497.730	452.682	3.91	4.81	4.35	62.996	81.463	72.230	8.800	9.733	9.267
	NFP+PDB	453.630	569.816	511.723	5.05	5.53	5.29	71.880	88.390	80.135	10.107	11.173	10.640
	NFB+SB	448.313	561.747	505.030	5.02	5.41	5.21	70.300	86.750	78.525	9.833	10.797	10.395
	PDB+SB	443.537	562.537	503.037	4.79	5.15	4.97	68.920	85.526	77.223	9.893	10.897	10.315
	NFB+PDB+SB	466.493	576.090	521.291	5.22	5.63	5.42	73.823	91.556	82.690	10.243	11.347	10.795
LSD at 5% for:	SxM		2.551			0.140			NS			NS	
	SxB		0.047			0.089			1.156			NS	
	MxB		3.124			0.144			NS			NS	
	SxMxB		4.418			0.244			NS			NS	

Data indicate that, tuber yield (measured as tubers yield (g) per plant, tubers numbers per plant, tubers dry weight per plant and total yield (ton/fed.) during the two growing seasons was decreased with decreasing dose of NPK fertilizers, overall the bio-fertilizers used. It can be observed the correlative significant decreases in total yield (ton/fed.) with the gradual decrease in NPK doses. Many researchers, in different countries, revealed that, NPK have active role to increase tubers yield and its components (Su-Niangui *et al.*,2005). NPK have also supreme effect on plant growth and hence affect tubers yield and its components (Singh *et al.*, 2005). Nitrogen, phosphorus and potassium are essential for potato plants as well as they are basic for nucleic acid, NAD, NADP, co-enzymes, ATP, meristimatic cells of plants, nucleic proteins and they are share through ATP in active amino acids to protein synthesis (Arish and Bardisi, 1999). In addition to the role of mineral fertilizer application for higher photosynthesis and translocation rate of photosynthates from foliage to tubers (Ashour, 1998).

Bio-fertilization exerted positive effects in this respect particularly with the combined treatment of NFB+PDB+SB. The comparative studied between the three bacterial strains used indicated that, in spite of the slight increases in tuber yield [tubers yield (g) per plant, tubers numbers per plant, tubers dry weight (g) per plant and total yield (ton/fed.)] recorded with SB strain compound with either of NFB or PDB, both inoculation with each of them had a significant effects on the tuber yield compound with the dual inoculation with all bio-fertilizers used which produced the highest yield values. Therefore, the increasing effects of the bio-fertilizers used was arranged as follows in a descending order: NFB+PDB+SB, NFB+PDB, NFB+SB, PDB+SB, NFB, PDB and SB. The increase of tubers numbers and tubers dry weight (g) per plant may be due to the treating potato tubers with bacteria or bio-fertilizer stimulated plant roots, absorption of nutrients and photosynthesis process which led to produce vigorous plants, numerous tubers, bigger tuber size and total tuber yield (Abdel-Ati *et al.*, ; El-Gamal (1996) and Hammad and Abdel-Ati (1998).

With respect to the interaction effect of strains of used bacteria and mineral fertilizer rates, the data in the same tables indicate that, tubers numbers per plant was significantly increased when the plants inoculated with strains of used bacteria. Whereas, tubers dry weight per plant was not significantly influenced. The interaction treatments showed an additive effects on potatoes tubers yield parameters during the two growing seasons compared with the corresponding control. When the different NPK doses were associated with the bio-fertilizers used, a higher significant increaments in the tuber yield over the control (plants grown under the recommended dose of NPK; 100% without inoculation) attained their maximum.

Results in the Tables (XXVII and XXVIII) indicate also that, tuber yield [measured as : tubers yield per plant, tubers numbers per plant and tubers dry weight (g) per plant and total tuber yield (ton/fed)] were increased significantly as a result of inoculation with bacterial strains used and the different doses of NPK treatments. Inoculation with NFB was the most effective treatment at any doses of NPK. Data in the same tables, show that, plants inoculated with NFB + PDB gave highest values than that inoculated with either NFB+SB or PDB+SB. The plants treated with mixed strains of used bacteria (NFB+PDB+SB) was the most effective in this respect. These results are true during the two growing seasons. Moreover, it was found that, inoculation with each of bacterial strains used under the control (100% recommended NPK) gave high values more than the uninoculated The highest increases in yield and its components were obtained by the combination of mineral fertilizers at the rates of 100% NPK interacted with the bio-fertilizers especially (NFB+PDB+SB). The same trend was obtained in the two growing seasons.

Concerning the effects of interaction treatments between bio-and mineral fertilizers on tubers numbers and tubers dry weight (g) per plant, the data presented in the same tables show that, tubers numbers and tubers dry weight (g) per plant were significantly increased with all used bacterial strains inoculation interacted with mineral fertilizer doses. It appears that, plants inoculated with NFB showed high significant effect on tubers number and tubers dry weight (g) per plant compared with both PDB and SB. Plants inoculated with either of NFB+PDB showed high values than inoculated with NFB+SB or PDB+SB. Inoculation with mixed strains of used bacteria were the most effective in this respect. Similarly, the inoculated plants with any of the three bacterial strains and grown under 75% NPK gave high values regarding yield compared with the uninoculated ones grown under 100% NPK. In addition, data indicate that, plants received mixed strains of used bacteria plus 75% NPK (from recommended dose) showed high values than control (100% recommended NPK). It is worth mentioning that, 1/2 rate of the recommended dose of NPK fertilizers may be substituted by the inoculation with the dual inoculation with either of NFB, PDB or SB when used individually or incombinations without significant reduction in the tuber yield.

One of the most important finding, is that potato plants which received only half dose of the recommended NPK fertilizers incombination with NFB+PDB+SB significantly surpassed the control plant in their tuber yield as represented by tubers yield per plant, tubers numbers per plant and tubers dry weight (g) per plant and total tuber yield (ton/fed). These results are true during the two growing seasons. This clearly indicates that the absence of half of the quantities of the recommended NPK fertilizers may be compensated by inoculation with NFB+PDB+SB under the field conditions. It is well established that bio-fertilizers can minimize the amount of the added inorganic NPK fertilizers to the soil up to 50% and consequently lessening soil pollution. Moreover, it appears that, inoculation with mixed strains of used bacteria counteracted the depressing effects of 50% NPK dose on yield parameters. Therefore, this treatment gave, generally, the best results compared with other treatments under this dose.

The increase in tubers yield per plant and potatoes tubers yield per faddan under mineral and/or bio-fertilizers may be due to their effects on increasing plant vigor growth represented by plant height, number of branches and leaves per plant as well as leaf area per plant (Tables V-VI), mineral content in the shoots (Tables XIX-XXIV), photosynthetic pigments

(Tables XIII-XVI) and endogenous phytohormones (Tables XXV and XXVI) as well as tubers numbers per plant (Tables XXVII and XXVIII). The replacement of some mineral fertilizers by bio-fertilizers was previously reported with other plant species (Mohamed, Faten 2007). Kumar *et al.,* (1998) working on wheat reported that, *Azospirillum* could be used to replace some of the N fertilizers. Prasad *et al.,* (1998) indicated that, bio-fertilizers can be used for meeting part of N requirement of crops. Aly *et al.,* (1999) added that, about half of the applied N fertilizers could be saved if wheat grains were inoculated with nonsymbiotic fixing bacteria without serious effects on the yield.

It is reported that, the bio-fertility maintain the nutrients supply to the plants during growing period more available than mineral fertilizers (Abou-Hussein *et al.*,2002). The great efficiency of the bio-fertilizers inoculation are in agreement with those obtained by Fares (1997) who concluded that, multi-inoculation with *Azotobacter* + *Rhizobium* + VAM in the presence of half the normal dose of inorganic N fertilizers and rock-phosphates as a P-fertilizer increased wheat growth and its yield.

The enhancing effect of non-symbiotic bacteria present in nitrogen-fixing bacteria (*Azospirillum brasilense*), phosphate-dissolving bacteria (*Pseudomonas fluorescens*) and silicate bacteria (*Bacillus circulans*) on yield and its component may be attributed to one or more of the following factors: stimulating effect of nitrogen-fixing bacteria such as: enhanced N2-fixation or increased N assimilation by plants and plant growth stimulation (Okon, 1985; Kapulnik *et al.,* 1985), enhanced mineral uptake in the plant (Kloepper *et al.,* 1989; Stancheva *et al.,* 1995), improved root growth and functions (Martin *et al.,* 1989; Sarig *et al.,* 1992); Fallik *et al.,* 1994), produces the phytohormones indole acetic acid, gibberellins and cytokinin, also reduce of abscic acid, these phytohormones, particulary IAA, play an essential role in plant growth stimulation in general and in stimulating symbiosis between legumes and rhizobia (Alexander, 1982; Martin *et al.,* 1989; Subba Rao, 1993; Frankenberegr and Arshad, 1995; Bashan and Holguim, 1997; Muhammad *et al.,* 1999; Kawthar *et al.,* 2002), produced amino acids (Hartmann, 1989), as well as phenolic compounds (El-Morsi *et al.,* 2000) and improved water status of plant, increasing nitrate reductase activity and antifungal compounds (Hedge *et al.,* 1999).

The positive effect of phosphate-dissolving bacteria (PDB) on potato yield may be attributed to many factors, the ability to bring out insoluble phosphorus in the soil into soluble forms by secreting organic acids such as formic, fumaric acetic and succinic, these acids lower the PH and bring out the dissolution of bound forms of phosphate compounds and render them available for growing plants, the reduction of soil PH lead to an increase the availability of some nutrients such as Fe, Zn, Mn and Cu which would be reflected on plant uptake (El-Dahtory *et al.,* 1989; Hauka *et al.,* 1990) and activity on N2-fixing bacteria, which enhanced the plant growth and yield (Abdel-Ati *et al.,* 1996; Ashour, 1998), increased the values of K% (El-Shahawy, 2003), its ability to release plant promoting substances, mainly IAA, gibberellic and cytokinin like substances which stimulated plant growth and yield (Saber *et al.,* 1998), synthesis of some vitamins e.g., B12 (Sobh *et al.,* 2000), increasing amino acid content (Hanafy Ahmed *et al.*, 2002), increasing the water and mineral uptake from the soil (El-Agrodi *et al.*, 2003).

The role of silicate bacteria (*Bacillus circulans*) in accelerated weathering of primary minerals, supplying great amounts of both water-soluble and amorphous potassium was previously reported. Soil inoculation had a significant effect on the release of this element from higher forms, which was reflected in plant uptake (Mansour *et al.*, 1984; Monib *et al.*, 1984 and Afify and Bayoumy, 2001), played a pronounced role in biological weathering (Zahra *et al.*, 1984), characterisitics of nitrogen –fixing from Egyption soils (Wahab, 1980), a synergistic effect increased P uptake (Raj *et al.*, 1981), antimicrobial activity (Perez *et al.*, 1993), production of thermotolerant B-amylase (Kawan *et al.*, 1993) and providing plants with available Fe, Mn and Zu (Hauka *et al.*, 1996).

Furthermore, plant growth promoting rhizobacteria (PGPR) can result from one or more mechanisms including biological control through competition, production of siderophores or antibiotics and induce disease resistance, and direct growth promotion through phytohormones production and increased nutrient availability through nitrogen fixation or organic and inorganic phosphate-dissolvation (Kloepper, 1993 ; Chabot *et al.*, 1996).

It could be concluded that, the use of bio and NPK fertilizers may be related to favourable effects on NPK level within the plant tissues and the role of plant growth promoting rhizobacteria (PGPR) on the growing plants and photosynthetic pigments, that possibly increased the efficiency of photosynthesis and resulted in more accumulation of stored food in the tubers. The beneficial effect of bio-fertilizers on yield and its components appear to be attributed to the vigorous plants growth and the higher amounts of metabolites synthesized by those plants in addition to the role of bio-fertilizers on absorbing nutrients by the plant roots especially P, Zn, Fe, Mn and Cu which play an important roles in activation of the various metabolic processes, and to increasing the amounts of N-fixation by *Azotobacter* and *Rhizobium* (Mohamed, Faten, 2007).

Yield quality:

Nutritive value of the tubers

Total soluble solids, specific gravity as well as levels of nitrate and nitrite:

The effects of mineral and/or bio-fertilizers on the percentages of total soluble solids, specific gravity as well as the levels of nitrate and nitrite in the potato tubers grown during the two growing seasons of 2001/2002 and 2002/2003 are presented in Table (3).

Data indicate that, neither mineral fertilizers nor bio-fertilizers had statistical effects on total soluble solids and specific gravity in potato tubers. Decreasing NPK dose from the recommended dose 100% to 50% decreased significantly total soluble solids and specific gravity of potato tubers in both studied seasons. By contrast, it was found that inoculation of any bacterial strains used induced significantly these parameters during the two growing seasons.

Table (3): Effects of mineral and/or bio-fertilizers on total soluble solids and specific gravity (g/cm³) as well as the levels of nitrate and nitrite (ppm) in the tubers of potato plants grown during the two growing seasons of 2001/2002 (S1) and 2002/2003 (S2).

Treatments		Total soluble solids (%)			Specific gravity (g/cm³)			Nitrate (ppm)			Nitrite (ppm)		
M-Mineral NPK	B-Bio-fertilizer	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
Control 100%	Without	4.770	4.910	4.840	1.027	1.085	1.056	69.750	72.440	71.095	0.570	0.600	0.585
	NFB	5.310	5.440	5.375	1.025	1.091	1.058	65.060	68.940	67.000	0.550	0.580	0.565
	PDB	5.360	5.510	5.435	1.030	1.087	1.058	64.760	68.130	66.445	0.560	0.580	0.570
	SB	5.190	5.360	5.275	1.027	1.083	1.055	64.390	68.690	66.540	0.550	0.570	0.560
	NFP+PDB	5.670	5.830	5.750	1.028	1.135	1.081	63.470	67.730	65.600	0.530	0.570	0.550
	NFB+SB	5.520	5.610	5.656	1.027	1.111	1.069	63.220	67.420	65.320	0.520	0.560	0.540
	PDB+SB	5.570	5.720	5.645	1.030	1.090	1.060	62.690	66.330	64.510	0.510	0.560	0.535
	NFB+PDB+SB	5.810	6.070	5.940	1.064	1.119	1.091	61.720	65.100	63.410	0.510	0.550	0.530
Mean		5.400	5.556	5.478	1.032	1.100	1.066	64.383	68.098	66.240	0.537	0.571	0.554
75%	Without	4.610	4.780	4.695	1.016	1.078	1.047	60.060	61.500	60.780	0.510	0.550	0.530
	NFB	5.190	5320	5.255	1.026	1.098	1.062	59.230	59.890	59.560	0.490	0.510	0.500
	PDB	5.270	5.410	5.340	1.027	1.094	1.061	59.710	58.720	59.215	0.470	0.503	0.487
	SB	5.080	5.220	5.150	1.018	1.080	1.049	57.240	56.900	57.070	0.470	0.490	0.480
	NFP+PDB	5.580	5.680	5.630	1.040	1.120	1.080	55.400	56.320	55.860	0.460	0.490	0.475
	NFB+SB	5.420	5.480	5.450	1.020	1.108	1.064	58.360	55.810	57.085	0.460	0.480	0.470
	PDB+SB	5.470	5.580	5.525	1.032	1.096	1.064	53.610	55.530	54.570	0.450	0.470	0.460
	NFB+PDB+SB	5.713	5.910	5.812	1.045	1.116	1.080	52.730	54.440	53.585	0.440	0.457	0.448
Mean		5.292	5.422	5.357	1.028	1.099	1.063		57.389	57.216	0.469	0.494	0.481
50%	Without	4.480	4.670	4.575	1.007	1.063	1.035	54.330	56.870	55.600	0.450	0.520	0.485
	NFB	4.983	5.220	5.102	1.015	1.091	1.053	52.770	55.560	54.163	0.430	0.480	0.455
	PDB	5.070	5.310	5.190	1.022	1.078	1.050	52.260	54.330	53.297	0.400	0.460	0.430
	SB	4.887	5.110	4.998	1.017	1.069	1.043	51.850	54.010	52.930	0.397	0.470	0.433
	NFP+PDB	5.380	5.520	5.450	1.040	1.116	1.078	51.470	53.620	52.545	0.380	0.450	0.415
	NFB+SB	5.220	5.400	5.310	1.022	1.097	1.059	51.080	52.780	51.930	0.390	0.450	0.420
	PDB+SB	5.290	5.420	5.355	1.030	1.096	1.063	50.320	52.440	51.380	0.370	0.440	0.405
	NFB+PDB+SB	5.530	5.710	5.620	1.054	1.105	1.079	49.790	51.703	50.747	0.370	0.420	0.395
Mean		5.105	5.295	5.200	1.026	1.089	1.058	51.734	53.914	52.824	0.398	0.461	0.430
Mean	Without	4.620	4.787	4.703	1.017	1.075	1.046	61.380	63.603	62.492	0.510	0.557	0.533
	NFB	5.161	5.327	5.244	1.022	1.093	1.058	59.019	61.463	60.241	0.490	0.523	0.507
	PDB	5.233	5.410	5.322	1.026	1.086	1.056	59.911	60.393	59.652	0.477	0.514	0.496
	SB	5.052	5.230	5.141	1.021	1.077	1.049	57.827	59.867	58.847	0.472	0.510	0.491
	NFP+PDB	5.543	5.677	5.610	1.036	1.124	1.080	56.780	59.223	58.002	0.457	0.503	0.480
	NFB+SB	5.387	5.497	5.442	1.023	1.105	1.064	57.553	58.670	58.112	0.457	0.497	0.477
	PDB+SB	5.443	5.573	5.508	1.031	1.094	1.062	55.540	58.100	56.820	0.443	0.490	0.467
	NFB+PDB+SB	5.684	5.897	5.791	1.054	1.113	1.084	54.747	57.081	55.914	0.440	0.476	0.458
LSD at 5% for: SxM			NS			0.003			NS			NS	
SxB			NS			0.002			0.536			0.009	
MxB			NS			0.004			0.895			NS	
SxMxB			NS			0.006			1.265			NS	

The most effective treatments were found with NFB+PDB+SB followed with NFB+PDB. Worthy to note that total soluble solids and specific gravity in potato tubers, overall NPK dose, did not statistically differ than that found in plants inoculated with either NFB or PDB if used individually or incombination with SB strain.

Concerning the effects of mineral and bio-fertilizers, data also clearly show that, the percentages of both total soluble solids and specific gravity of potato tubers under different doses of NPK were increased significantly as a result of inoculation of bacterial strains used. Inoculation with PDB was the most effective in this respect at all treatments of NPK during the two growing seasons. The interactions treatments between inoculation of double or mixed bacterial strains used, data in the same tables indicate that, inoculation with either NFB+PDB or mixed of the three strains used of bacteria were the most effective in this respect. These results are true during the two growing seasons.Compared with the control (100% recommended NPK), data in Table (2) indicate that, plants received mixed three strains of used bacteria plus 50% or 75% NPK (from recommended dose) showed high values.

The level of 75%NPK produced additive percentages of total soluble solids and specific gravity of potato tubers. In addition, the data indicate that about half of the applied NPK fertilizers could be saved if potato tubers were inoculated with non-symbiotic fixing bacteria without serious effects on the tuber yield. In this connection, Mahmoud and Amara (2000) found that, tomato inoculation with *Bacillus spp.* and *Pseudomonas* isolates alone or incombination with NPK rates enhanced total yield and its quality. They added that the isolates used reduced the cost of tomato production by minimizing the use of chemical fertilizers doses (N,P and K) reaching to 50% of the recommended one.

Specific gravity of potato tubers is commonly used to measure the processing quality of potatoes production. The high specific gravity may be likable or unlikable, for example: at high specific gravity make potatoes starched or mealy and that is likable in the two cases; the baked and mashed because it improve the tasty (Tawfik, 2001). Also, the high specific gravity is likable in making shapes because it increase the final production of the weight unit of fresh tubers. High specific gravity have a great important in making shapes, for example: every increase about 0.005 on the specific gravity means increase about 10 kg of make shapes per ton of the uncovered tubers (Maclean *et al.*, 1966). Moreover, the high specific gravity decrease the use of the oil which on making shapes and expand increase the period of storing shapes (Smith, 1968).

In this context, Marschner, (1995) noted that, potassium ion is essential for starch formation. The results of the present investigation indicate that, both bio-and mineral fertilizers increased formation of photosynthetic pigments and carbohydrate metabolism and nutrients uptake , consequently enhancing translocation of assimilates to the tubers.

Regarding the effects of mineral and/or bio-fertilizers on nitrate and nitrite levels in potato tubers during the two growing seasons of 2001/2002 and 2002/2003, data in Table (3) also indicate that these parameters were decreased significantly with decreasing mineral fertilizers dose in both seasons. Similarly, Nitrate and nitrite levels were decreased significantly when potato tubers inoculated with each of the bio-fertilizers used in compression with those of uninoculated plants.

The data in the same tables indicate that, the levels of both nitrate and nitrite in potato tubers were decreased as a result of inoculation with each used bacterial strains in plants grown under the different doses of NPK treatments during the two growing seasons. Inoculation with either mixed strains of used bacteria or NFP+PDB gave the highest reduction in the levels of both nitrate and nitrite in potato tuber. Therefore, plants received 50% or 75% NPK (from recommended dose) produced the highest reduction in nitrate and nitrite levels compared with the control (100% recommended dose of NPK) while, the lowest reduction of both nitrate and nitrite were detected in tubers produced from plants inoculated with NFB.

Abou-Hussein *et al.,* (2002 a,b & c). confirmed the suggestion that, several plant species accumulate NO^-_3 as a result of excess of nitrogen or mineral fertilization. Walker (1990) noted a close correlation between the application of N-fertilizer and nitrate accumulation.

The reduction in both nitrate and nitrite levels noticed in potato tubers as a result of bio-fertilizers application may be attributed to their effects on increasing growth promoting substances concentrations i.e. auxins, gibberellins and cytokinins as noticed in the present investigation which may released or formed nitrate reductase enzyme in the plants (Hartman *et al.,* 1983). Hanafy Ahmed *et al.,* (2002) mentioned that, treatments with bio-fertilizer lead to utilization the accumulated nitrate in plant to produce proteins for plant structure or storage nitrate in the vacuoles hence, decrease nitrate translocation to the sweet pepper fruits.

Gianquinto and Borin (1992) concluded that, bio-fertilizers application decreased nitrate accumulation in tomato plants. Hanafy Ahmed (1997) reported that, the organic fertilizer increased both growth promoting substance, and nutrients uptake i.e. Zn, Mn and K which might be indirectly reduced nitrate accumulation in the fruits or directly through its effect on increased nitrate reduction and decreased nitrate translocation to fruits. Fengo and Ito (1998) mentioned that, increasing potassium fertilizer level resulted in reducing nitrate accumulation in some vegetable crops.

Vancheva and Ivanova (1997) and Farouk Gadallah (2004) showed that the complete mineral N level 100% N significantly accumulate more concentration of nitrate and nitrite as compared to the treatments of mineral N fertilizers at rates of 25% and 50%. Hanafy Ahmed *et al.,* (1997) reported that using bio-fertilizers combined with 50% N supply decreased nitrate accumulation in Jews mallow and radish leaves and this decrease may be result mainly due to the reduction in mineral N application level. It might be suggested by Hartmann *et al.*, (1983) that under the effect of bio-fertilizers, some growth promoting substances, e.g. auxins, gibberellins and cytokinins could be formed or released. These phytohormones, especially of cytokinins, could be related to nitrate reductase content in plants which in turn could affect nitrate accumulation in plants. In this context, Knypl (1979) reported that, cytokinins enhance the activity of nitrate reductase and markedly enhanced the efficiency of nitrate reductase induction in many plant species.

Abdin *et al.*, (1993) mentioned that, plant hormones like benzyladenine (as a cytokinin) enhance the level of nitrate reductase gene expression.

Crude protein, ascorbic acid and starch:

The effects of mineral and/or bio-fertilizers on crude protein (%), ascorbic acid accumulation (mg/100 g F.wt.) and starch (%)of potato tubers plants during the two growing seasons of 2001/2002 and 2002/2003 are presented in Table (4).

The obtained data show a gradual decrease in the percentages of protein, ascorbic acid and starch of potato tubers as the NPK doses decreased. The present data also strongly confirmed the absolute superiority of plants fertilized with the recommended dose of NPK fertilizers.

The use of all bio-fertilizers used, overall NPK doses, induced significantly increases in percentages of crude protein, ascorbic acid and starch of the potato tubers in both studied seasons. The superiority values were associated with the use of NFB+PDB+SB followed with NFB+PDB and NFB+SB over the control in a descending order. Comparing the three strains when used individually, it was found that inoculation with NFB was preferable followed with PDB and lastly with SB. The superiority of using the bio-compound of strains used compared to any of the individual treatment may be due to the synergetic action of fixing nitrogen.

Nitrogen enhances protein synthesis, growth and photosynthetic processes (El-Shahawy, 2003).

Data presented in Table (3) indicate also that, all bio-fertilizers used counteracted the depressing effects of mineral NPK stress on the percentages of crude protein and ascorbic acid in potato tubers during the two growing seasons. Therefore, potato tuber protein were increased significantly during the two growing seasons as a result of inoculation with either of used bacteria strains interacted with NPK fertilizers doses. However, ascorbic acid was not influenced significantly by bio-fertilizer application and their interaction with any mineral fertilizers doses used in both seasons. Inoculation with *Azospirillum brasilense* (NFB) was more effective than other strains when used individually. The application of combined strains caused highest values in this respect followed by inoculation with NFB+PDB.

Compared with the control (100% recommended NPK), data in the same tables indicate that, the interaction between NPK doses and mixed of the three bacterial strains used decreased significantly the tubers protein and ascorbic acid accumulation with exception potato tubers formed from the plants received mixed three strains of used bacteria plus 75% NPK from the recommended dose. There is no significant differences between 100% NPK recommended dose (control) and the mixed three strains of used bacteria plus 75% NPK from recommended dose. The highest crude protein and ascorbic acid accumulation was found in potato tubers formed from mixed three strains plus 75% NPK from the recommended dose.

The most interesting finding is that potato plants received only half the dose of the recommended NPK fertilizers together with the dual inoculation recorded considerable increases in crude protein and ascorbic acid levels in potato tubers. These results suggest the possibility of the promoting effects of the bio-fertilizers on photosynthetic activity and consequently photosynthetic products. Moreover, increasing the available N will enhance the biosynthetic of amino acids, enzymes and protein as well as some phytohormones such as auxins (Ghallab and Salem, 2001).

Table (4): Effects of mineral and/or bio-fertilizers on crude protein percentage (%), ascorbic acid accumulation (mg/100g Fwt) and starch percentage (%) in potato tuber of plants grown during the two growing seasons of 2001/2002 (S1) and 2002/2003 (S2).

Treatments		Crude protein (%)			Ascorbic acid (mg/100 g F.wt.)			Starch (%)		
M-Mineral NPK	B-Bio-fertilizer	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
Control 100%	Without	8.525	8.781	8.653	23.425	23.986	23.705	71.780	72.310	72.045
	NFB	8.881	9.237	9.059	23.645	24.205	23.925	72.230	73.290	72.760
	PDB	8.655	8.994	8.825	23.620	24.184	23.902	71.970	72.870	72.420
	SB	8.656	8.844	8.750	23.605	24.165	23.885	72.080	73.070	72.575
	NFP+PDB	8.987	9.350	9.169	23.680	24.236	23.958	72.610	73.830	73.220
	NFB+SB	8.925	9.269	9.097	23.655	24.207	23.931	72.703	73.920	73.312
	PDB+SB	8.662	9.037	8.849	23.640	24.203	23.921	72.567	73.640	73.103
	NFB+PDB+SB	9.031	9.475	9.253	23.700	24.286	23.993	73.440	74.320	73.880
Mean		8.790	9.123	8.957	23.621	24.184	23.903	72.422	73.406	72.914
75%	Without	8.131	8.431	8.281	21.930	21.851	21.890	70.070	70.710	2.292
	NFB	8.475	8.912	8.693	22.232	22.249	22.241	71.870	72.630	1.947
	PDB	8.269	8.675	8.472	22.181	22.152	22.166	70.820	72.390	2.095
	SB	8.175	8.455	8.315	22.179	22.048	22.114	71.790	72.570	1.918
	NFP+PDB	8.606	9.112	8.859	22.336	22.450	22.393	72.080	73.010	1.807
	NFB+SB	8.512	8.956	8.734	22.286	22.352	22.320	72.280	73.260	1.799
	PDB+SB	8.312	8.725	8.519	22.280	22.349	22.315	71.190	73.100	1.821
	NFB+PDB+SB	8.637	9.156	8.896	22.433	22.530	22.481	73.160	74.520	1.606
Mean		8.390	8.803	8.596	22.232	22.248	22.240	71.656	72.774	72.122
50%	Without	7.681	7.981	7.831	20.534	20.799	20.667	67.620	68.300	2.584
	NFB	8.006	8.350	8.178	20.813	21.277	21.045	68.000	69.410	2.230
	PDB	7.787	8.094	7.941	20.826	21.289	21.057	68.080	69.170	2.357
	SB	7.737	8.025	7.881	20.680	21.008	20.844	68.120	69.330	2.255
	NFP+PDB	8.100	8.450	8.275	21.033	21.440	21.237	68.930	69.700	2.151
	NFB+SB	8.050	8.319	8.185	20.901	21.360	21.130	68.800	70.030	2.071
	PDB+SB	7.819	8.125	7.972	20.884	21.376	21.130	69.000	69.080	2.168
	NFB+PDB+SB	8.187	8.500	8.344	21.200	21.455	21.327	70.170	70.750	1.908
Mean		7.921	8.225	8.076	20.484	21.251	20.867	68.588	69.469	68.968
Mean	Without	8.112	8.398	8.255	21.963	22.212	22.088	2.417	2.153	70.132
	NFB	8.454	8.833	8.643	22.230	22.577	22.404	2.027	1.737	71.258
	PDB	8.237	8.588	8.412	22.209	22.542	22.375	2.226	1.883	70.883
	SB	8.189	8.441	8.315	22.155	22.407	22.281	2.016	1.722	71.140
	NFP+PDB	8.564	8.971	8.768	22.350	22.709	22.529	1.894	1.583	71.429
	NFB+SB	8.496	8.848	8.672	22.281	22.640	22.460	1.883	1.551	71.727
	PDB+SB	8.264	8.629	8.447	22.268	22.643	22.455	1.906	1.615	70.799
	NFB+PDB+SB	8.618	9.044	8.831	22.444	22.757	22.601	1.738	1.429	72.310
LSD at 5% for: SxM			0.018			NS			0.011	
SxB			0.015			NS			0.014	
MxB			0.022			NS			0.017	
SxMxB			0.031			NS			0.024	

The counteraction effects of bio-fertilizers and its replacement to some NPK as well as their effects on increasing tubers protein may be attributed to their effects on reducing nitrate concentration in the tubers as shown in the present investigation. This reduction may be induce the accumulation and utilization of nitrate in plant to produce proteins (Hanafy Ahmed, *et al.*,2002).

It is important here to mentioned that the beneficial effects of bio-fertilizers inoculation with appropriate strains might be attributed to increase; 1) the symbiotic N fixation in the soil, 2) levels of free amino acids in the cell-sap, development and physiological enzymatic activity and growth rate of roots (Ghallab and Salem, 2001).

The stimulating effects of both bio and mineral fertilizers on ascorbic acid content may be related with the reduction nitrate concentration in the tubers as previously shown. In this context; Cieslik (1994) concluded that, there is an inverse correlation between levels of nitrate and ascorbic acid concentration in potato tubers. Abd El-Naem *et al.,* (1999) reported that, ascorbic acid content is important value in potato tubers due to one or more of these reasons : it inhibits discoloration by reducing O-quinones to O-diphenols; and/or it acts as an antioxidant against certain kinds of stress, e.g. prevention of many infections diseases.

As for the effects of mineral and/or bio-fertilizers on starch content of potato tubers plants, data in the present investigation show that, treatments with each of all bacterial strains used overall NPK doses treatments, increased significantly starch in potatoes tubers compared with treatment of uninoculated potatoes tubers. These results are true during the two growing seasons. Data show also that, Decreasing NPK dose than the recommended dose (100 % NPK) decreased starch % significantly overall all strains of inoculated bacteria used. The inverse correlation results between starch and sugars were recorded in the two growing seasons. The two growing seasons were significantly different in the starch percentage overall inoculation of bacteria strains and/or NPK doses. The first season produced potato tubers having less starch % and high sugars whereas the reverse was found in plants grown in the first season due to the differences in the environmental condition.

Concerning the interaction treatments, data in the same tables show that, the inoculation of either of each bacterial strains used counteracted the depressing effects caused by decreasing NPK doses less than the recommended dose on starch. These results are true during the two growing seasons. Similarly, the statistical analysis show, in general, a significant differences on starch % regarding the interaction effects between seasons, minerals, bio-fertilizers and seasons x mineral x bio-fertilizers during the two growing seasons. However, the interaction between all bio-fertilizer treatments used and seasons (SxB) showed insignificant effects .

Again, it could be mentioned that, starch percentage with the mixed three strains of used bacteria plus 75% NPK (from recommended dose) showed high alue compared with the control (100% NPK recommended dose). These results are true during the two growing seasons.

The stimulating effects of both bio or/and mineral fertilizers as well as their interactions on starch content may be attributed to their effects on enhancing of photosynthetic pigments (Helaly, *et al.*, 2009) and different plant hormones (Helaly and Ramadan, 2009 b) and consequently an increase in photosynthetic capacity and assimilation rate resulted in more accumulation of starch in potato tubers. Goffart and Gulot (1994) added that, increasing N fertilizer caused more accumulation of starch in the formed tubers.

Reducing, non-reducing sugars, total sugars as well as insoluble carbohydrates and total carbohydrates percentages:

The effects of mineral and/or bio-fertilizers as well as their interactions on the percentages of reducing sugars, non-reducing sugars, total sugars, insoluble carbohydrates and total carbohydrates in potato tubers at harvesting; 105 days from planting during the two growing seasons of 2001/2002 and 2002/2003 are presented in table (5).

Data show that decreasing NPK dose, overall bio-fertilizers used, decreased the percentages of reducing sugars, insoluble carbohydrates and total carbohydrates whereas increased non-reducing sugars and total sugars in potato tubers during the two growing seasons in comparison to plants grown under full NPK recommended dose (100%).

Bio-fertilizers application alone significantly decreased reducing sugars and total sugars whereas increased non-reducing sugars, insoluble carbohydrates and total carbohydrates percentages in the tubers of potato plants inoculated with each of the three bacterial strains used in comparison to these of uninoculated one. The most effective treatments was found with NFB+PDB+SB. Moreover, NFB strain was more effective than PDB followed with SB. These results are true during the two growing seasons.

Regarding the effects of interaction treatments, data in the same tables show that bio-fertilizers significantly decreased reducing sugars and total sugars whereas increased non-reducing sugars, insoluble carbohydrates and total carbohydrates percentages in potato tubers of plants grown under any dose of NPK used in comparison to the corresponding control (uninoculated).The highest values were recorded in inoculated plants grown under 100% NPK. Again, the best treatment was found with NFB+PDB+SB. In comparison with the control, the same tables show that plants received only half the dose of the recommended NPK fertilizers together with the dual inoculation recorded considered increases in non-reducing sugars, insoluble carbohydrates and total carbohydrates in the tubers whereas, decreased that of reducing sugars and total sugars percentages. Such trend was true during the two growing seasons. Moreover, the results in the present investigation showed that using each of the bio-fertilizers strains used increased resistance of potato grown against NPK stress especially under 50% dose. This could be explained as due to capability of potatoes treated with bio-fertilizers used to established powerful sink of stress. Thus, the high positive responses induced by intensive bio-fertilization with respect to the nutrients, crude protein present suggest the possibility of the promoting effects on photosynthetic products, mainly sugars.

Table (5): Effects of mineral and/or bio-fertilizers on reducing sugars, non-reducing sugars, total sugars, insoluble carbohydrates and total carbohydrates percentages in potato tuber of plants grown during the two growing seasons of 2001/2002 (S1) and 2002/2003 (S2).

Treatments		Reducing Sugars(%)			Non-reducing sugars (%)			Total Sugars(%)			Insoluble carbohydrates (%)			Total Carbohydrates(%)		
M-Mineral NPK	B-Bio-fertilizer	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
Control 100%	Without	0.737	0.760	0.748	1.128	1.354	1.241	1.869	2.114	1.991	72.431	72.259	72.345	74.300	74.373	74.337
	NFB	0.610	0.651	0.631	1.130	1.360	1.245	1.740	2.011	1.876	72.590	73.719	73.155	74.330	75.730	75.030
	PDB	0.590	0.621	0.605	1.132	1.362	1.247	1.722	1.993	1.858	72.436	73.630	73.033	74.158	75.623	74.890
	SB	0.672	0.719	0.696	1.155	1.386	1.271	1.827	2.105	1.966	72.397	73.286	72.843	74.224	75.391	74.807
	NFP+PDB	0.500	0.572	0.536	1.162	1.402	1.282	1.665	1.974	1.820	72.973	73.086	73.029	74.638	76.060	75.349
	NFB+SB	0.530	0.598	0.564	1.163	1.400	1.281	1.706	1.998	1.852	72.834	73.902	73.368	74.560	75.902	75.231
	PDB+SB	0.526	0.570	0.548	1.176	1.410	1.293	1.689	1.990	1.840	72.886	74.079	73.482	74.575	76.069	75.322
	NFB+PDB+SB	0.482	0.521	0.502	1.168	1.408	1.288	1.650	1.929	1.789	73.483	74.345	73.914	75.233	76.274	75.754
Mean		0.581	0.626	0.604	1.152	1.385	1.268	1.733	2.014	1.874	72.754	73.538	73.216	74.502	75.678	75.090
75%	Without	0.664	0.700	0.682	1.308	1.424	1.366	1.972	2.124	2.048	71.040	71.770	71.405	73.012	73.894	73.453
	NFB	0.500	0.543	0.522	1.312	1.430	1.371	1.812	1.973	1.893	72.351	73.147	72.749	74.163	75.120	74.642
	PDB	0.483	0.547	0.515	1.316	1.433	1.374	1.799	1.980	1.890	72.214	73.001	72.607	74.013	74.981	74.497
	SB	0.560	0.600	0.580	1.328	1.438	1.383	1.888	2.038	1.963	71.306	73.088	72.197	73.194	75.126	74.160
	NFP+PDB	0.420	0.510	0.465	1.332	1.444	1.388	1.752	2.038	1.853	72.429	73.492	72.961	74.181	75.530	74.855
	NFB+SB	0.443	0.533	0.488	1.336	1.446	1.391	1.779	1.954	1.879	71.431	73.534	72.482	73.210	75.493	74.351
	PDB+SB	0.450	0.520	0.485	1.350	1.457	1.404	1.793	1.979	1.885	72.339	73.339	72.839	74.132	75.318	74.725
	NFB+PDB+SB	0.384	0.450	0.417	1.353	1.462	1.408	1.737	1.912	1.824	73.117	74.660	73.889	74.854	76.572	75.713
Mean		0.488	0.550	0.519	1.329	1.442	1.386	1.817	1.992	1.904	72.028	73.254	72.646	73.845	75.255	74.550
50%	Without	0.564	0.679	0.622	1.482	1.543	1.512	2.046	2.222	2.134	68.893	69.481	69.187	70.939	71.703	71.321
	NFB	0.471	0.543	0.507	1.490	1.551	1.521	1.961	2.094	2.028	68.824	70.188	69.506	70.790	72.282	71.536
	PDB	0.459	0.567	0.513	1.494	1.553	1.523	1.953	2.120	2.036	68.838	69.981	69.410	70.791	72.101	71.446
	SB	0.490	0.558	0.513	1.502	1.563	1.532	1.992	2.121	2.056	69.122	70.192	69.657	71.114	72.313	71.713
	NFP+PDB	0.427	0.477	0.452	1.509	1.567	1.538	1.936	2.044	1.990	69.258	70.208	69.733	71.194	72.252	71.723
	NFB+SB	0.440	0.500	0.470	1.508	1.570	1.539	1.948	2.070	2.009	69.484	69.650	69.567	71.432	71.720	71.576
	PDB+SB	0.435	0.497	0.466	1.513	1.586	1.550	1.948	2.083	2.015	69.598	70.530	70.064	71.148	72.613	71.881
	NFB+PDB+SB	0.390	0.440	0.415	1.515	1.588	1.552	1.905	2.028	1.967	70.455	71.133	70.794	72.369	73.161	72.765
Mean		0.460	0.533	0.496	1.502	1.565	1.533	1.961	2.098	2.029	69.309	70.170	69.716	71.222	72.267	71.745
Mean	Without	0.655	0.713	0.684	1.306	1.440	1.373	1.962	2.153	2.058	70.788	71.170	73.979	72.750	73.323	73.037
	NFB	0.527	0.579	0.553	1.311	1.447	1.379	1.838	2.026	1.932	71.255	72.351	71.804	73.094	74.377	73.736
	PDB	0.511	0.578	0.544	1.311	1.449	1.382	1.825	2.031	1.928	71.163	72.204	71.683	72.987	74.235	73.611
	SB	0.574	0.626	0.600	1.328	1.462	1.395	1.902	2.088	1.995	70.943	72.189	71.565	72.844	74.277	73.560
	NFP+PDB	0.449	0.520	0.484	1.334	1.471	1.403	1.784	1.991	1.887	71.553	72.262	72.089	73.338	74.614	73.976
	NFB+SB	0.471	0.544	0.507	1.336	1.472	1.404	1.811	2.016	1.913	71.250	72.362	71.806	73.067	74.372	73.719
	PDB+SB	0.470	0.529	0.500	1.346	1.484	1.415	1.810	2.017	1.913	71.608	72.649	72.063	73.285	74.667	73.976
	NFB+PDB+SB	0.419	0.470	0.444	1.345	1.486	1.416	1.764	1.956	1.860	71.170	73.379	72.884	74.152	75.336	74.744
LSD at 5% for: SxM			0.011			0.001			0.002			NS			0.002	
SxB			NS			0.002			0.003			0.265			0.003	
MxB			0.023			0.002			0.003			NS			0.004	
SxMxB			0.032			0.003			0.005			NS			0.005	

Esmail (2005) attributed the decrease in polysaccharides under stress condition to the increase in hydrolytic enzyme activities. Consequently the sugars was increased. Salama and Helaly (1981) found that decreasing K in the plant media resulted in diminching of carbohydrates. A production of higher energy by means of respiration in order to overcome the relatively low nutrient elements especially at 50% NPK from the recommended dose. Since carbohydrates are the principle substances used in respiration, a depression in the carbohydrates content in the plants grown under nutrient stress could be expected.

The increase of total carbohydrates content due to bio-fertilizers used as shown in the present study was supported by Michaeel *et al.*, (2000) and Mohamed, Faten (2007). In the present investigation bio-fertilizers in the presence of mineral NPK fertilizers at 75% from the recommended dose attained the minimum reduction for all certain of carbohydrate fraction. The same trend was shown in plants received bio-fertilization combined with 50% from the recommended dose but to a greater extract.

As shown in the present investigation, bio-fertilizers significantly increased both mineral and leaf chlorophylls and carotenoides concentrations than those of uninoculated plants. These results are good explanation to the obtained results regarding the favorable role of bio-fertilizers on growth characters. The enhancing effect of bio-fertilization on growth and photosynthetic pigments with the same treatment may explain the increase of total carbohydrates level. Ghulam *et al.*, (1998) reported that the beneficial effects of the bio-fertilizers may be attributed to the production of growth promotive substances from rhizospheric microorganisms such as IAA and GA_3. Similarly, Fallik *et al.*, (1989) found that *Azospirillum* produce several plant hormones in liquid culture mainly; IAA and to a lesser extent IBA and I 3-methanol (Crozier *et al.*, 1988), several gibberellins (Bottini *et al.*, 1989) , ABA (Kolp and Martin 1989) and cytokininis (Horeman *et al.*, 1986). The role of cytokinin on increasing pigments synthesis and decreasing its breakdown (Arteca, 1996). IAA'and other phytohormones influenced on the physiological processes correlated with growth stimulation (Davies 1995) and carbohydrates accumulation .

Nutrient constituents; nutritive value of the tubers:

The effects of mineral and/or bio-fertilizers on nitrogen, phosphorus and potassium concentrations (mg/g D.Wt.) and its content (mg/plant) in potato tubers at harvesting; 105 days from planting during the two growing seasons of 2001/2002 and 2002/2003 are presented in table (6 and 7).

The data indicate that decreasing NPK dose less than the recommended one decreased the concentrations of N, P and K and their contents in the potato tubers grown on the two growing seasons. The decrease was a concentration dependent. The decreasing rate was more pronounced when NPK dose mineral fertilizers decreased from 75% to 50% from the recommended dose. The decreases in the nutrients concentrations associated with mineral stress may be due to decreasing minerals levels and their availability in the plant media and the reduction of their uptake and translocation to the tubers. Supportive evidences with these results were reported by Beuerlein et al., (1992).

Data presented in the same tables show that, a significant increase in the concentrations of N,P and K and their content in potato tubers due to the application of all bacterial strains used compared with uninoculated plants. This increase may be due to the favourable effect of bacterial strains as a bio-fertilizers on the nutrients availability and more absorbing various nutrients occurred by the roots system. Comparing the values of nitrogen content of the potato tubers with the strains used, it was found that inoculation with *Azospirillum brasilense* (NFB) was found to be more effective in this respect. Moreover, application of NFB+PDB showed high values of N,P and K content in the potato tubers compared with those produced from plants treated with NFB+SB or PDB+SB. Although, bio-fertilization with either of NFB+PDB+SB was the most effective in this respect. These results are true during the two growing seasons.

On the other hand, more promotive effects were recorded when the different NPK fertilizer doses were associated with the bio-fertilizers inoculation. Although the positive effects of the single bio-fertilizers treatments either with NFB, PDB or SB on the corresponding nutrients content, NFB+PDB+SB treatment was found to be more effective treatment under all NPK doses examined. Comparing the three bacterial strains used, the data indicated that inoculation of *Pseudomonas fluorescens* (PDB) was the most effective on increasing P concentration and its content. Similarly, NFB and SB (*Bacillus circulans*) increased the contents of N and K respectively. A synergistic effects were recorded in plants inoculated with mixed of used bacterial strains under the different doses of NPK during the two growing seasons. Therefore, inoculation with NFB+PDB+SB was the most effective in this respect.

The interactions data strongly confirmed the superiority of the recommended NPK dose combined with the dual treatments of the three bacterial strains used i.e. NFB+PDB+SB which resulted in the highest additive effects on the nutrients accumulation and their content which surpassed all other bio-fertilizers treatments. This strongly emphasize the importance of bio-fertilizers mixture (NFB+PDB+SB) in enhancement the uptake and accumulation of N,P and K in the produced tubers. This treatment (NFB+PDB+SB) resulted a considerable and even significant increase in nutrients concentration and their content. These results are in agreement in both growing seasons. However, the various between them were insignificant overall bio-fertilizers, minerals and their interactions. Similarly. inoculation with the three used bacterial strains at 75% and 50% NPK from recommended dose, with the superiority of the former, recorded high values compared with the control (100% NPKrecommended dose) but the lower values were found in uninoculated plants. These results are true during the two growing seasons. This means that the inoculation of potato plants grown under nutrients stresses up to 50% from the recommended dose with NFB+PDB+SB resulted a promotive effect on root development and consequently their function in the uptake of both water and nutrients. These findings clearly show that the reduction in the applied NPK fertilizers 50% can be compensated by the inoculation of NFB+PDB+SB without any significant reduction in potatoes productivity.

Table (6): Effects of mineral and/or bio-fertilizers on nitrogen (N), phosphorus (P) and potassium (K) (mg/g Dwt) in potato tuber of plants grown during the two growing seasons of 2001/2002 (S1) and 2002/2003 (S2).

Treatments		N Concentration (mg/g wt)			P Concentration (mg/g wt)			K Concentration (mg/g wt)		
M-Mineral NPK	B-Bio-fertilizer	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
Control 100%	Without	13.640	14.060	13.850	3.475	3.952	3.713	24.550	35.100	29.825
	NFB	14.210	14.660	14.435	3.620	4.008	3.814	24.650	35.200	29.925
	PDB	13.730	14.160	13.945	3.920	4.323	4.122	24.680	35.210	29.945
	SB	13.690	14.130	13.910	3.500	4.055	3.777	25.250	35.770	30.510
	NFP+PDB	14.380	14.750	14.565	4.020	4.243	4.132	24.720	35.280	30.000
	NFB+SB	14.280	14.710	14.495	3.680	4.104	3.892	25.380	35.850	30.615
	PDB+SB	13.800	14.250	14.025	3.980	4.203	4.092	25.420	35.900	30.660
	NFB+PDB+SB	14.400	14.800	14.600	4.060	4.380	4.220	25.530	36.000	30.765
Mean		14.016	14.440	14.228	3.782	4.158	3.970	25.022	35.539	30.281
75%	Without	13.010	13.490	13.250	3.361	4.018	3.689	24.000	34.360	29.180
	NFB	13.860	14.360	14.110	3.462	3.822	3.642	24.080	34.440	29.260
	PDB	13.230	13.680	13.455	3.885	4.091	3.988	24.100	34.440	29.270
	SB	13.100	13.560	13.330	3.435	3.833	3.634	24.850	35.060	29.955
	NFP+PDB	14.040	14.560	14.300	4.198	4.182	4.190	24.310	34.600	29.455
	NFB+SB	13.930	14.350	14.140	3.503	3.885	3.694	24.910	35.150	30.030
	PDB+SB	13.310	13.760	13.535	3.976	4.133	4.054	24.950	35.260	30.105
	NFB+PDB+SB	14.080	14.550	14.315	4.031	4.224	4.137	25.050	35.350	30.200
Mean		13.370	14.039	13.804	3.731	4.026	3.879	24.531	34.832	29.619
50%	Without	12.200	12.770	12.485	3.111	3.533	3.322	23.430	33.820	28.625
	NFB	12.810	13.260	13.035	3.196	3.696	3.446	23.490	33.910	28.700
	PDB	12.460	12.880	12.670	3.500	3.811	3.656	23.510	33.900	28.705
	SB	12.380	12.840	12.610	3.163	3.611	3.387	24.130	34.420	29.275
	NFP+PDB	12.970	13.420	13.195	3.559	3.841	3.700	23.600	33.930	28.765
	NFB+SB	12.880	13.370	13.125	3.280	3.622	3.451	24.200	34.520	29.360
	PDB+SB	12.510	13.000	12.755	3.530	3.833	3.681	24.320	34.570	29.445
	NFB+PDB+SB	13.100	13.520	13.310	3.611	3.910	3.761	24.380	34.600	29.490
Mean		12.664	13.133	12.898	3.369	3.732	3.550	23.882	34.209	29.046
Mean	Without	12.950	13.440	13.195	3.315	3.834	3.575	23.993	34.427	29.210
	NFB	13.627	14.093	13.860	3.426	3.842	3.634	24.073	34.517	29.295
	PDB	13.140	13.573	13.357	3.768	4.075	3.922	24.097	34.517	29.307
	SB	13.057	13.510	13.283	3.366	3.833	3.599	24.743	35.083	29.747
	NFP+PDB	13.797	14.243	14.020	3.926	4.089	4.007	24.210	34.603	29.407
	NFB+SB	13.697	14.143	13.920	3.488	3.870	3.679	24.830	35.173	30.002
	PDB+SB	13.206	13.670	13.438	3.829	4.056	3.942	24.897	35.243	30.070
	NFB+PDB+SB	13.860	14.290	14.075	3.901	4.178	4.039	24.987	35.317	30.152
LSD at 5% for: SxM		0.025			NS			NS		
SxB		NS			0.101			NS		
MxB		0.035			NS			NS		
SxMxB		0.049			NS			NS		

The enhancing effect of the bio-fertilizers on nutrient uptake may be due to the improvement of minerals nutrition and also production of growth substances by bacteria. This leads to enhance the plant growth and nutrients uptake (El-Shahawy, 2003).

Saber (1996) reported that, using bio-fertilizers with the objective of increasing the number such microorganisms and accelerating certain microbial processes to augment the extent of the availability of nutrients in a form that can be easily assimilated by the plants. Noel *et al.*,(1996) added that, the non-symbiotic N_2-fixing bacteria (*Azotobacter* and *Azospirillum* strains) produced adequate amount of IAA and cytokinins with increasing the surface area per unit root length and enhanced the root hair branching with eventual increase on the uptake of nutrients from the soil.

The phosphate-dissolving bacteria may play a desirable role as a source for certain nutrients for supplying the plants by their nutrient requirements (Saber *et al.*, 1983). The increase of phosphorus content in potato tubers due to the interaction between bio-and mineral fertilizers may be attributed to their effects on the availability of soil phosphorus which caused an increase in absorbing various nutrients (El-Agroudi *et al.*, 2003).

The increase in tubers potassium content under silicate bacteria (SB) strain reflects an enhanced growth which might be possibly due to the role of SB in supplying great amounts of both water-soluble and amorphous potassium which was reflected in plant uptake (Zahra *et al.*, 1984 and Afify, Aida and Bayoumy, Samia 2001).It could be concluded that, the increasing values of nitrogen, phosphorus and potassium as a result of inoculation with bio-fertilizers used under different doses of NPK may be due to the favorable effect of bio-fertilizer on the absorbing various corresponding nutrients during the two growing seasons. Moreover, The present results may indicate that such potato cultivar (Spunta) has less genetic and/or physiological and biochemical potential for nutrients stress. It was established that N plays an important role and indispensable function in stimulating the merstimatic activity for producing more tissues and organs, since N plays a major role in synthesis of protein, nucleic acid ,many enzymes and protoplasm formation as well as energy transfer materials (Russel, 1973).

It is known that P involve in synthesis of ATP, formation of RNA and phospholipids. In addition, P directly enhances and control many biosynthesis processes, e.g. carbohydrates and sugars formation, nucleic acids, enzymes and hormones (Yelenosky, 1985).Such bioconstituents and metabolic changes suggested to be tightly associated with nutrients stress. Yagodin, (1982) stated that, P compounds are of absolute necessary for all living organisms, nucleoproteins constituting the essential substances of the cell and for cell division and development of meristimatic tissues. K was known to has an enhancable roles associated with the whole growth activities and metabolic processes including carbohydrate metabolism, protein biosynthesis, assimilate translocation, conformation of enzymes and stomatal movement (Munson, 1972) particularly during prevailing of the nutrient stress. K activates auxin and GA_s synthesis, cell division and elongation , enhances synthesis and translocation of amino acids and sugars (Munson 1972). Furthermore, it displays an antioxidantal and gave regulatory functions against environmental stress condition (Beringer *et al.*, 1990). It induces an active and balanced hormonal status of higher IAA and GA_s levels and lower ABA and ethylene within different plant organs (Marchner, 1995). Besides, it plays a defensive, protective role against adverse effect of nutrient stress *via* its antioxidantel and gene regulatory function (Gardener, *et al.*,1985).These effects of nutrients reflected on vigorous vegetative growth of potatoes and other related plant species and consequently increase yield and improve its quality.

Table (7): Effects of mineral and/or bio-fertilizers on nitrogen (N), phosphorus (P) and potassium (K) content (mg/plant)in potato tuber of plants grown during the two growing seasons of 2001/2002 (S1) and 2002/2003 (S2).

Treatments		N Content (mg/plant)			P Content (mg/plant)			K Content (mg/plant)		
M- Mineral NPK	B- Bio-fertilizer	S1	S2	Mean	S1	S2	Mean	S1	S2	Mean
Control 100%	Without	926.02	1204.49	1065.25	243.30	329.82	286.55	1666.7	3006.9	2336.8
	NFB	1062.11	1369.66	1215.88	270.57	366.97	318.77	1842.4	3262.0	2552.2
	PDB	1031.03	1319.30	1175.16	294.36	405.29	349.82	1853.2	3280.5	2566.9
	SB	967.75	1266.99	1117.37	253.78	349.21	301.49	1784.9	3202.8	2493.9
	NFP+PDB	1141.57	1441.57	1291.57	316.75	428.81	372.78	1962.4	3399.6	2681.0
	NFB+SB	1089.98	1392.26	1241.12	280.89	372.39	326.64	1937.2	3354.3	2645.8
	PDB+SB	1081.23	1363.55	1222.39	309.48	420.51	364.99	1991.7	3423.2	2707.4
	NFB+PDB+SB	1182.70	1489.11	1335.90	328.21	441.91	385.06	2089.6	3543.2	2816.4
Mean		1059.08	1354.52	1204.89	286.30	388.20	335.58	1891.0	3309.1	2553.2
75%	Without	851.28	1091.64	971.37	219.85	305.88	262.86	1570.4	2780.5	2175.4
	NFB	999.11	1239.21	1119.16	249.78	331.96	290.87	1784.4	2992.9	2370.6
	PDB	958.98	1180.28	1069.63	281.24	355.47	318.35	1746.9	2993.3	2370.1
	SB	917.58	1121.82	1019.70	239.55	316.86	278.20	1740.6	2900.5	2320.6
	NFP+PDB	1078.11	1287.42	1182.76	307.15	371.64	339.39	1876.1	3076.3	2476.2
	NFB+SB	1027.18	1248.12	1137.65	258.83	337.47	298.15	1742.1	3057.2	2449.7
	PDB+SB	996.71	1206.74	1101.72	295.66	362.21	328.93	1862.8	3092.3	2477.5
	NFB+PDB+SB	1115.68	1362.74	1239.21	324.88	397.11	360.99	1984.9	3310.8	2647.9
Mean		991.83	1215.75	1102.65	270.83	346.49	308.07	1796.5	3025.5	2370.0
50%	Without	647.33	964.90	806.11	169.60	274.28	221.94	1234.1	2555.4	1894.8
	NFB	971.84	1080.73	1026.28	194.85	300.75	247.80	1391.2	2763.8	2077.5
	PDB	745.82	1044.18	895.00	210.71	308.88	259.79	1407.2	2748.3	2097.7
	SB	659.36	990.25	824.80	173.63	286.12	229.87	1285.2	2654.5	1969.9
	NFP+PDB	831.13	1139.30	985.21	233.91	326.00	279.95	1512.3	2880.5	2196.4
	NFB+SB	791.86	1083.37	940.24	207.19	301.43	254.31	1487.8	2799.2	2142.5
	PDB+SB	786.79	1068.63	927.71	228.30	314.83	271.56	1529.5	2841.6	2185.6
	NFB+PDB+SB	856.45	1184.26	1020.35	242.55	342.49	292.52	1594.0	3030.6	2312.3
Mean		758.96	1068.41	910.91	207.11	306.77	254.91	1430.2	2784.0	2051.0
Mean	Without	804.72	1084.84	942.63	208.93	302.69	254.03	1487.5	2778.8	2084.3
	NFB	935.77	1227.04	1079.48	237.56	332.43	283.70	1657.6	3003.8	2283.3
	PDB	908.54	1178.66	1041.81	260.67	355.16	306.92	1661.1	3004.7	2288.8
	SB	844.51	1123.92	982.09	221.15	316.72	267.51	1600.0	2916.4	2198.2
	NFP+PDB	1012.74	1286.91	1147.68	284.63	374.64	328.03	1773.9	3116.0	2405.6
	NFB+SB	966.30	1238.14	1099.73	248.47	336.56	291.10	1752.7	3066.8	2366.9
	PDB+SB	951.40	1210.43	1078.58	277.07	364.28	319.97	1791.8	3116.1	2411.4
	NFB+PDB+SB	1047.80	1342.41	1192.81	297.43	392.47	344.18	1886.3	3292.4	2543.5
LSD at 5% for: SxM		2.24			1.36			3.87		
SxB		1.09			0.84			2.57		
MxB		3.16			2.25			4.52		
SxMxB		4.08			3.44			6.13		

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تأثير التسميد الحيوى والمعدنى على النمو والمحصول وجـودة الدرنـة لنباتـات البطاطس

٢- المحصول وجودة الدرنة

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سبب نقص نسبة السماد المعدنى المستخدم عن الجرعةِ الموصّى بها ، إلى خفض وزن الدرنات , وعددها لكل نبات , والمحصول الكلى للفدان والنِسَب المئويةِ لكل مِنْ البروتين ، وحامض الأسكوربيك ، والنشا ووالنتروجين والفوسفور والبوتاسيوم مع تحسين صفات الجودة المتحصل عليها ، متمثلة فـى نـسبة المواد الصلبة الذائبة الكليّة والكثافة النوعية خلال موسمى النمو. وعلى العكس من ذلك، فقد أدى التلقيحَ بأى من السلالات البكتيرية المستخدمة ، الى زيادة هذه الصفات معنوياً . وكانت المعاملة الأكثـر فاعليـةِ هـى خليط السلالات البكتيرية الثلاثة(البكتريا المثبتة للنيتروجين , البكتريا المذيبة للفوسفات و بكتريا السليكات).

أشارت معاملات التفاعلَ بين المعاملات ، بأنّ ، النباتات التى لقحت بخليط السلالات البكتيرية الثلاثة فى وجودَ ٥٠ % أو ٧٥ % سماد معدنى (مِنْ الجرعةِ الموصّى بها) الى ارتفاع المحصول ومكوناته والبروتين الخام وحمض الأسكوربيك و نسبة المواد الصلبة الذائبة الكليّة ، والكثافة النوعية ، وكانت هـذه الصفات اكبر ما يمكن عند مستوى ٧٥ % من السماد المعدنى.

نَقصَ نسبة النتراتَ والنيتريت معنويا ، مع نقص نسبة التسميد المعدنى في موسمى النمو. كمـا نقصت عند تلقيح درنات البطاطس بكُلّ مِنْ المخصبّاتِ الحيويةِ المختبرة مقارنة بالنباتاتَ الغير ملقحة. وكان معاملة التلقيح بخَليط السلالات البكتيرية الثلاثة المستعملةِ (البكتريا المثبتة للنيتروجين , البكتريـا المذيبـة للفوسفات و بكتريا السليكات) أفضل المعاملات فى هذا الشأن.

انخفضت نسبة النترات والنيتريت فى درنات البطاطس بانخفاض نسبة التسميد المعـدنى وكـذا باستعمال اى من المخصبات الحيوية المختبرة.

نقصت النِسَب المئوية للسكريات المختزلةِ، الكربوهيدرات الغير ذائبة والكربوهيدرات الكليّة بينما زادا السكرياتَ الغيرَ مختزلة والسكرياتَ الكليّة في درنات البطاطس أثناء موسمى النمو مـع الـنقص فـى جرعات السماد المعدنى.

أدى إضافة المخصّباتِ الحيوية ، إلى نقص معنوى فى نسب السكرياتَ المختزلة ، والـسكرياتَ الكليّة ، مع زيادة السكرياتَ الغيرَ مختزلة، الكربوهيدرات الغير ذائبة والكربوهيدراتِ الكليّةِ فـى درنـات نباتاتِ البطاطس . ولقد وجد أن المعاملة الأكثر فاعلية فى هذا الشأن ، هى معاملة التلقيح بالبكتريا المثبتـة للنيتروجين ثم البكتريا المذيبة للفوسفات أو بكتيريا السليكات . ولقد شجع وجودَ الثلاثـة معـا الـى ظهـور تأثيرات إضافية فى هذا الشأن.

أدت معاملات التفاعلَ بين المعاملات ، إلى نقص معنوي فىالنسب المئوية للسكرياتَ المختزلة ، والسكرياتَ الكليّة مع زيادة السكرياتَ الغيرَ مختزلة ، الكربوهيدرات الغير ذائبة والكربوهيدراتِ الكليّةِ فـي درنات نباتاتِ البطاطس ، وذلك تحت أيّ من جرعات السماد المعدنى المستخدمة. وكانت البكتريا المثبتـة للنيتروجين ، أفضل من البكتريا المذيبة للفوسفات أو بكتيريا السليكات . ومن الجدير بالـذكر، أن درنـات النباتاتُ التى سمدت فقط بنِصْفُ الجرعةُ المستخدمة من السماد المعدنى الموصّى به ، فى وجـود التلقـيح البكتيرى كانت أكثر تركيزا فى محتواها مـن الـسكرياتِ الغيـر مختزلـة، الكربوهيـدرات الغيرذائبـة والكربوهيدرات الكليّة وأقل تركيزا فى النسبة المئوية للسكرياتِ المختزلة والسكريات الكلية.

وأستخلصت نتائخ البحث الى أن إستعمالَ المخصّباتِ الحيويةِ بمفردها دون إستعمال الأسمدة المعدنية غير كاف لإنتاج البطاطس بالكمية المتحصل عليها عند استخدام التسميد المعدنى بالجرعة الموصى بهـا ، ولـذا يوصى البحث بوجوب إستعمال المخصبات الحيوية الثلاثة معا وهى: سلالة أزوسبريلليم براسيلينز المثبتـة للنيتروجين , سلالة سيدوموناس فلوريسنس المذيبة للفوسفات وسلالة الباسلس سيركيولنس الميسرة لإطـلاق البوتاسيوم من معادن التربة مع الأسمدة المعدنية بنسبة لا تقل عن ٥٠% من الجرعة الموصـى بهـا (١٨٠ كيلوغرام نيتروجين + ٧٥ كيلوغرام فوسفور + ٩٦ كيلوغرام بوتاسيوم / فدان)

وترجع أهمية التوصية بخفض استعمالَ الأسمدة المعدنيةِ حتى ٥٠ % من الجرعة الموصى بهـا دون التأثير على انتاجية محصول البطاطس الى خفض تكا ليف الإنتاج والحد من التلوثِ البيئي مـع تقليـلْ التأثيراتَ الضارّةَ لإستعمال الأسمدة الكيميائيةِ على صحة الإنسان وتراكم النترات.