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PARTIAL SUBSTITUTION OF CHEMICAL FERTILIZERS BY ALGAL EXTRACT AND CALCIUM ON POTATO (*SOLANUM TUBEROSUM* L.) PRODUCTION IN NORTH SINAI

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Abstract

A field experiment was carried out during winter season 2018/2019 in Baloza region, North Sinai Governorate, Egypt. Potato (*Solanum tuberosum* L.) c.v. Sponta, grown in sandy soil under drip irrigation system in Desert Research Centre farm. Experiment studied the effect of applied N fertilizers in the form of ammonium sulphat 20.5% N at 50%, 75% and 100% of recommended dose (75, 112 and 150 kg N fed^{-1}) as twice doses and spraying plants with algae extract at rates of (0, 150 and 300 $ml.fed^{-1}$), Calcium levels at (0, 60 and 120 ppm) and the interaction among the studied treatments on tubers productivity and shoots, chemical content of Potato tubers, shoots and tuber quality. Spraying of algae extract and calcium were done after 45 and 60 days from planting. Results showed that spraying potato twice with algae (300 ml/fed) combined with Calcium at (120 ppm) with 150 kg N/ fed, where were very effective in improving yield tubers and foliage (kg)/ fed, was recoded (20.53 and 10.96 ton/ fed) and gave highest increases yield parameters (tuber length (cm), tuber diameter (cm), harvest index, quality parameters (specific density g/ cm^3, starch % and enhanced protein % of tubers). Also, this treatment recoded highest values of nitrogen, potassium, phosphorus and calcium concentration and uptake in the potato tubers and shoots. The available amount of N, P and K increased after harvesting potato plants with increasing N fertigation and foliar application of algae extract, where foliar by calcium due to slightly decrease of available N in soil after harvesting.

Key words: Potato, Nitrogen, algae, Calcium, tuber producvtity, concentration of elements. Quality parameters.

Introduction

Sandy soil is generally characterized as a very poor soil in mineral nutrients and has low moisture holding capacity as well as scarcity of organic matter. Potato (*Solanum tuberosum* L.) is an important source of food worldwide. The tuber is rich in carbohydrates and certain are groups of vitamins, trace elements and minerals. Like in any other country, potato is very important food and cash crops of Egypt. It is the leading export vegetable crop and it is considered as one of the important cash crops in Egypt.

Egypt's potato average area has grown to be 42.98 ha, with average yields around 4.40 tons/ ha (Nashwa El-tatawy *et al.*, 2019). Even though production area is increased yield obtained per hectare is not as high as production area coverage and farmers get low yield because of sub-optimal fertilization. Plant nutrition is an important factor determining growth and production of specific crop.

Nitrogen (N) is usually the most limiting essential nutrient for potato growth Errebhi *et al.,* (1998) and the rate besides timing of N application are critical factors in optimizing potato tuber yield and quality Haase *et al.*, (2007) and Poljak *et al.,* (2009). Nitrogen limits crop production and is needed by most plants in higher quantities than other plant nutrients (Olfs *et al.,* 2005). To maximize yield, farmers often apply higher amounts of N fertilizer than the minimum required for maximum crop growth (Lemaire and Gastal, 1997). A higher N availability has a positive effect on vegetative growth and light interception, which increases tuber yield Bélanger *et al.,* (2000b) and Oliveira, (2000). In contrast, N stress may limit photosynthesis and negatively influences partitioning of photo assimilates from leaves to tubers (Jin *et al.,* 2015 and Robredo *et al.,* 2011). Low N rates not only result in lower yield but also reduce tuber size due to reduced leaf area and early defoliation.

Allegal Extract or Seaweed extracts (SWE) as organic bio stimulants are fast becoming accepted

practice in modern agriculture for sustainable production (Cassan *et al.,* 1992). According to the report by FAO, (2006), a substantial amount of seaweeds (15 million metric tons annually) is used as supplementary for nutrients and bio stimulants for the crop production. The beneficial effect of SWE is as a result of many components that work synergistically at different concentrations, although the modes of action still remain unknown. It is well known that SWE contains phytohormones, (Kurepin *et al.,* 2014) certain micro and macronutrients (Zhang and Ervin, 2008) and secondary metabolites as quaternary ammonium molecules, such as betaines and proline (Mackinnon *et al.,* 2010). SWE has been used as a foliar spray to increase growth, yield and quality, nutrient uptake, photosynthetic pigments and resistance to stress factors of many crops including potato (Arafa *et al.,* 2011, 2012 and 2013).

Haider *et al*., (2012) Stated that a significant improvement in growth, yield and tuber quality of potato was observed where was applied (SWE). The highest tuber yield was recorded with applications of seaweed extract at 30, 60 days from planting. The treatment also improved nitrogen, total soluble solids and protein contents of the potato tubers.

Therefore, optimizing nutritional status of a crop with mineral elements, specifically with calcium could be a feasible way to increase crop productivity. Pre-harvest application of calcium fertilization increases the content of calcium in the plant tissue. The higher calcium level in the cell prevents losses of phospholipids and proteins which enhance functionality of membrane, Malakooti, (2001). Indeed calcium have also great role to strengthen cell wall structure (Ozgen *et al.,* 2003) and facilitate uptake of some other nutrients. In addition, application of calcium nutrients during growth period increases yields (Lobato *et al.,* 2008). Furthermore, application of calcium nutrients increases potato tuber marketable yield, storage life, tuber weight, tuber size, (Ozgen *et al.,* 2003) and Hamdi *et al.*, (2015) reduces input of fungicide and lowers cost of production, (Glynn and Ian, 2009). In potato production calcium nutrients can be applied in the form of calcium chloride (Lobato *et al.,* 2008) or calcium nitrate (Hamdi *et al.*, 2015). In this regard, application of calcium nutrients during growth of potato plants can be considered as an alternative method to improve yield. Application of calcium chloride and calcium nitrate differentially affected potato plant growth and tuber yield (Seifu and Deneke, 2017). The injection of soluble form of calcium fertilizer increased calcium concentration in peel and medulla tuber tissues as compared to non-calcium treated plants even in soil which contained enough calcium for vegetative growth Tawfik, (2001).

North Sinai Governorate as newly reclaimed lands. So, the aim of the present work was to study the effect of mineral, bio-fertilizers practices, *i.e.* N fertilizers, foliar spray of Algae extract and Ca and the interaction among the previous treatments on the quantitative and qualitative parameters of potato in both tubers and the chemical composition of potato tubers and shoots.

Materials and Methods

The present investigation was carried out during the seasons of 2018 / 2019 in newly reclaimed arid land in the Agricultural Experimental Station of the Desert (31°32 03 N and 32° 362 03 E), Research Center at Researches of Baloza station, North Sinai Governorate.

The experiment was planned in a split split plot design with three replicates. The main plots were applying of three levels of Nitrogen fertilizers as (50, 75 and 100% from recommended doses) as ammonium sulphate 20.5% N (75, 110 and 150)/ fed. The subplots included foliar spray of three levels of the algae extract (Sea algae extract) as 0, 150 and 300 ml fed^{-1}. The sub subplot involved foliar spray of Calcium through growth season as 0, 60 and 120 mg l^{-1}.

Potato tuber (*Solanum tuberosum* L.) c.v. Sponta, were sown directly in the sandy soil at 15 October 2018 under drip irrigation system in rows 75 cm apart and 50 cm within hills. Drip irrigation was used with drippers (4 liter/ hour/ hill) for only one hour every two days. Potato plants were thinned after germination at two plants per hill (22400 plants/ fed.). The algae extract was obtained from Micro Production Unit at the National Research Center, Egypt.

The algae extract and calcium were applied as foliar spray twice per season after 45 and 60 days of sowing

Table 1: Initial status of some physical and chemical properties of the experimental soil.

Soil depth (cm)	pH Soil past	E. Cdsm^{-1}	Soluble Cations (me/l)				Soluble Anions (me/l)			Texture Class
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	$SO_4^{=}$	Cl^{-}	
0 - 30	8.02	1.37	3.65	4.35	5.13	0.46	3.75	0.9	3.25	Sandy
Available nutrients (ppm)	**N**		**P**		**K**		**Fe**	**Mn**	**Zn**	**Cu**
	31		2.6		40		5.52	2.18	0.97	0.28

pH: Acidity, soil extract (1 :2.5), **E.C**: Electrical conductivity **me/ l**: mille equivalent per Liter

Table 2: Chemical analysis data of the applied irrigation water.

Parameters	pH	E.Cdsm^{-1}	Soluble Cations (me/l)				Soluble Anions (me/l)			SAR
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^-	$SO_4^{=}$	Cl^-	
Values	7.23	2.6	13.9	0.43	8.20	3.50	6.0	5.0	15.2	5.75
pH: Acidity, **E.C:** Electrical conductivity, **me/ l:** mille equivalent per Liter.										

using rates of 0, 150, 300 ml/ fed. All treatments received 30 kg P_2O_5, K sulphate 50 kg K_2O/ fed, P and K were added twice doses and compost as organic manure at rate of 20 m^3 /fed and was added during soil preparation. Potato plants were harvested at the tubers mature stage (after 110 day). L.S.D. test at 0.05 was used to compare the means of treatments according to Snedecor and Cochran, (1982).

The following data were recorded:- the soil and irrigation water were analyzed at the laboratories of Desert Research Center, as shown in tables 1 and 2.

El-Salam Canal irrigation water was used and chemical analysis of the irrigation water was presented in table 2.

Growth and Yield Parameters

• Tuber yield:

Total tuber yield was measured through destructive measurements, at 110 days after sowing. At the end of experimental season, tubers were harvested on 10 June/ 2019. Total tuber yield per plot (kg) was estimated, total tubers yield/ fed (ton) were calculated. At maturity, 1 m^2 in the center of each experimental plot was chosen to be harvested for the estimation of biological parameters (diameter, length, specific density of tuber, Starch %, protein %).

• Chemical components of tubers and shoot:

Mineral contents: Calcium, nitrogen, phosphorus and potassium were determined in the digested dry matter of tubers and shoot of potato as follows:

A calcium content of Jerusalem artichoke tubers samples was determined with an Inductively Coupled Plasma (ICP) spectrometer according to Stefanssn *et al.,* (2007). Total nitrogen was determined using Microkjeldahl method, Phosphorus content was determined according to Troug and Meyer, (1939). Potassium percentage was determined by using Flame photometer according to Brown and Lilliland, (1946).

• Starch determination:

Starch content was determined according to Allefrey and Northcote, (1977). With some modifications. Three

Table 3: Effect of Nitrogen application, spraying with Algae Extract and Calcium on Fresh Weight of potato foliage and tubers.

N Rates (KgN fed^{-1})	Algae (ml.fed^{-})	Ca (ppm)							
		0	60	120	Means	0	60	120	Means
		F.W of Foliage (t fed^{-1})				F.W of Tubers (t fed^{-1})			
75	0	3.92	4.91	5.61	4.81	8.34	8.99	9.89	9.07
	150	4.99	6.86	7.31	6.39	10.22	10.25	10.48	10.32
	300	5.56	7.63	7.48	6.89	12.75	13.10	13.32	13.06
	Means	4.82	6.47	6.80	6.03	10.44	10.78	11.23	10.82
110	0	4.94	7.34	9.39	7.22	13.09	14.33	15.43	14.28
	150	8.15	8.31	9.98	8.81	13.73	15.91	17.10	15.58
	300	8.34	9.09	10.45	9.29	14.27	15.98	17.66	15.97
	Means	7.14	8.25	9.94	8.44	13.70	15.41	16.73	15.28
150	0	5.12	7.97	9.46	7.52	13.50	15.49	16.29	15.09
	150	6.15	8.62	9.92	8.23	14.82	17.93	19.25	17.33
	300	7.61	8.74	10.96	9.10	16.57	18.71	20.53	18.60
	Means	6.29	8.44	10.11	8.28	14.96	17.38	18.69	17.01
		Means of treatments							
	0	4.66	6.74	8.15	6.52	11.64	12.94	13.87	12.82
	150	6.43	7.93	9.07	7.81	12.92	14.70	15.61	14.41
	300	7.17	8.49	9.63	8.43	14.53	15.93	17.17	15.88
	Means	6.09	7.72	8.95	7.59	13.03	14.52	15.55	14.37
LSD $_{(0.05)}$	A=0.058; B=0.024; C= 0.021; AB= 0.042; AC= 0.036CB= 0.036 ABC=0.063					A=0.0624; B=0.0227; C=0.0206; AB=0.0393; AC= 0.0356 CB= 0.0356 ABC=0.0617			
*A =(N) * B = (Algae) * C = (Ca)									

replicates of tuber samples were homogenized after drying at 70°C in a volume of 2 ml 80% (v/v) ethanol. The homogenates were centrifuged (30000 × g, 10 min at 2°C) and then perchloric acid (30%, v/v) was added to solubilize starch from the pellet. The slurry was left at room temperature by laboratory complex of D.R.C

• Determination of Available Macro and micronutrients in Soil:

Available nitrogen in soil samples was extracted by 2M potassium chloride solution and determined according to the study Dhank and Johnson, (1990). Available potassium, phosphorous and micronutrients were extracted by DTPA + ammonium biocarbonate solution and measurement according to the method described by (Soltanpour, 1985).

Results and Discussions

• Potato yields and it is components:

Data present in table 3 showed the potato yields tuber and foliage (fresh weight of shoot) ton/ fed. The highest mean values of fresh yields of potato tubers and foliage fed were significantly affected by N, Sea algae extract and calcium fertilization. The yields increased with increasing N application rates from 75 to 150 where the record was obtain high rate of N (150 kg N/ fed) and gave 17.01 and 8.28 for tuber and fresh shoot ton/ fed, respectively. These results may be due to the role nitrogen important, *i.e.*, N is an integral part of chlorophyll which is regarded as primary absorbed of light energy needed for photosynthesis beside it has a benefit role in the formation of the protein. Also the increasing of yields may be due to the increase in area of leaves induced by N application, Tisdal and Nelson, (1975). In this respect many investigators found that application of N increased the yields of potato tubers and foliage (Lemaire and Gastal, 1997) and Bélanger *et al.,* (2000b) and Oliveira, (2000).

Similar results were obtained with Algae extract where sprayed after 45 and 60 days affected significantly the yields of potato tubers and foliage. It can notice that, the addition of 300 ml/ fed of algae extract gave the highest mean values 15.88 and 8.43 ton/ fed of yields tubers and foliage, respectively. The increase of the yield of potato may be due to algae extract contain many components work to increase yields of potato, this agreement with Kurepine *et al*., (2014) and Arafa *et al.,* (2011, 2012 and 2013).

Concerning the effect of calcium data indicated that the addition 120 ppm/ fed of calcium had recorded the

Table 4: Effect of Nitrogen application, spraying with Algae Extract and Calcium on the concentrations of some nutrients in shoot potato.

N Rates (Kg N red^{-1})	Algae ml. fed^{-1}	Ca PPM															
		0	60	120	Mean	0	60	120	Mean	0	60	120	Mean	0	60	120	Mean
		%N				%P				%K				%Ca			
75	0	1.23	1.26	1.27	1.25	0.138	0.142	0.166	0.149	2.57	2.59	2.61	2.59	1.03	1.05	1.07	1.05
	150	1.26	1.28	1.31	1.28	0.164	0.167	0.171	0.167	2.58	2.60	2.64	2.61	1.06	1.16	1.18	1.13
	300	1.30	1.33	1.35	1.33	0.169	0.171	0.187	0.176	2.60	2.63	2.66	2.63	1.10	1.20	1.21	1.17
	Means	1.26	1.29	1.31	1.29	0.157	0.160	0.175	0.164	2.58	2.61	2.64	2.61	1.06	1.14	1.15	1.12
110	0	1.28	1.31	1.37	1.32	0.173	0.176	0.200	0.183	2.54	2.63	2.70	2.62	1.13	1.19	1.21	1.18
	150	1.33	1.42	1.50	1.42	0.188	0.189	0.206	0.194	2.79	2.75	2.82	2.79	1.22	1.30	1.37	1.30
	300	1.45	1.45	1.64	1.51	0.201	0.210	0.212	0.208	2.83	2.89	2.94	2.89	1.28	1.41	1.58	1.42
	Means	1.35	1.39	1.50	1.42	0.187	0.192	0.206	0.195	2.72	2.76	2.82	2.77	1.21	1.30	1.39	1.30
150	0	1.22	1.47	1.58	1.42	0.205	0.212	0.221	0.213	2.87	2.89	2.99	2.92	1.27	1.36	1.40	1.34
	150	1.28	1.56	1.60	1.48	0.209	0.223	0.231	0.221	2.99	3.01	3.14	3.05	1.32	1.47	1.62	1.47
	300	1.56	1.67	1.75	1.66	0.216	0.236	0.244	0.232	3.10	3.12	3.30	3.17	1.33	1.58	1.66	1.52
	Means	1.35	1.57	1.64	1.52	0.210	0.224	0.232	0.222	2.99	3.01	3.14	3.05	1.31	1.47	1.56	1.45
Means of treatments																	
	0	1.24	1.35	1.41	1.33	0.172	0.177	0.196	0.181	2.66	2.70	2.77	2.71	1.14	1.20	1.23	1.19
	150	1.29	1.42	1.47	1.39	0.187	0.193	0.203	0.194	2.79	2.79	2.87	2.81	1.20	1.31	1.39	1.30
	300	1.44	1.48	1.58	1.50	0.195	0.206	0.214	0.205	2.84	2.88	2.97	2.90	1.24	1.40	1.48	1.37
	Means	1.32	1.42	1.49	1.41	0.185	0.192	0.204	0.194	2.76	2.79	2.87	2.81	1.19	1.30	1.37	1.29
LSD (0.05)		A=0.0248; B=0.0048; C=0.0026; AB=0.0083; AC=0.0045; CB=0.0045; ABC=0.0078				A=0.0025; B=0.0005; C=0.0004; AB=0.0009; AC=0.0007; CB=0.0007; ABC= 0.0012				A=0.036; B=0.022; C=0.019; AB=0.038; AC=0.033, CB=NS; ABC= 0.058				A=0.026; B=0.0041; C=0.0049; AB=0.007; AC=0.008; CB=0.008; ABC= 0.0145			
*A = (N) * B = (Algae) * C = (Ca)																	

Table 5: Effect of Nitrogen application, spraying with Algae Extract and calcium on concentrations of some nutrients in potato tubers potato.

N Rates (Kg N red^{-1})	Algae ml. fed^{-1}	Ca (PPM)															
		0	60	120	Mean	0	60	120	Mean	0	60	120	Mean	0	60	120	Mean
		%N				%P				%K				%Ca			
75	0	1.07	1.12	1.17	1.12	0.202	0.217	0.221	0.213	2.32	2.38	2.40	2.37	0.080	0.090	0.100	0.090
	150	1.14	1.15	1.18	1.16	0.217	0.228	0.231	0.225	2.34	2.42	2.46	2.41	0.100	0.110	0.120	0.110
	300	1.15	1.16	1.18	1.16	0.232	0.237	0.240	0.236	2.44	2.45	2.49	2.46	0.110	0.120	0.140	0.123
	Means	1.12	1.14	1.18	1.15	0.217	0.227	0.231	0.225	2.37	2.42	2.45	2.41	0.097	0.107	0.120	0.108
110	0	1.16	1.18	1.20	1.18	0.219	0.230	0.236	0.228	2.36	2.45	2.48	2.43	0.090	0.110	0.120	0.107
	150	1.21	1.25	1.27	1.24	0.241	0.247	0.254	0.247	2.45	2.53	2.60	2.53	0.100	0.120	0.130	0.117
	300	1.24	1.29	1.32	1.28	0.256	0.258	0.269	0.261	2.51	2.61	2.63	2.58	0.110	0.130	0.140	0.127
	Means	1.20	1.24	1.26	1.24	0.239	0.245	0.253	0.246	2.44	2.53	2.57	2.51	0.100	0.120	0.130	0.117
150	0	1.18	1.19	1.24	1.20	0.253	0.265	0.283	0.267	2.38	2.49	2.51	2.46	0.100	0.120	0.140	0.120
	150	1.29	1.31	1.34	1.31	0.263	0.268	0.289	0.273	2.47	2.58	2.62	2.56	0.110	0.140	0.150	0.133
	300	1.36	1.41	1.47	1.41	0.267	0.276	0.296	0.280	2.53	2.68	2.76	2.66	0.120	0.150	0.170	0.147
	Means	1.28	1.30	1.35	1.31	0.261	0.270	0.289	0.273	2.46	2.58	2.63	2.56	0.110	0.137	0.153	0.133
Means of treatments																	
	0	1.14	1.16	1.20	1.17	0.22	0.24	0.25	0.24	2.35	2.44	2.46	2.42	0.090	0.107	0.120	0.106
	150	1.21	1.24	1.26	1.24	0.24	0.25	0.26	0.25	2.42	2.51	2.56	2.50	0.103	0.123	0.133	0.120
	300	1.25	1.29	1.32	1.29	0.25	0.26	0.27	0.26	2.49	2.58	2.63	2.57	0.113	0.133	0.150	0.132
	Means	1.20	1.23	1.26	1.23	0.24	0.25	0.26	0.25	2.42	2.51	2.55	2.49	0.102	0.121	0.134	0.119
LSD (0.05)		A=0.0165; B=0.0054; C=0.0026; AB=0.0093; AC=0.0045; CB=0.0045; ABC=0.0078				A=0.0026; B=0.0005; C=0.0004; AB=0.0009; AC=0.0007; CB=0.0007; ABC= 0.0012				A=0.025; B=0.004; C=0.0032; AB=0.007; AC=0.0055, CB=0.006; ABC= 0.0096				A=0.015; B=0.0033; C=0.0028; AB=NS; AC=0.0049; CB=NS; ABC= NS			
*A = (N) * B = (Algae) * C = (Ca)																	

Table 6: Effect of Nitrogen application, sprayed with Algae Extract and Calcium on quality Parameters of tubers potato.

N Rates (KgN fed^{-1})	Algae ml. fed^{-1}	Ca (PPM)											
		0	60	120	Means	0	60	120	Means	0	60	120	Means
		Starch (%)				Protein (%)				Specific Density (g cm^{-3})			
75	0	60.20	61.20	62.2	61.20	6.63	6.98	7.27	6.96	1.005	1.012	1.013	1.010
	150	63.00	64.10	65.5	64.20	7.08	7.13	7.35	7.19	1.017	1.021	1.021	1.020
	300	65.00	65.60	66.3	65.63	7.19	7.23	7.42	7.28	1.024	1.030	1.028	1.027
	Means	62.73	63.63	64.67	63.68	6.97	7.11	7.35	7.14	1.02	1.02	1.02	1.019
110	0	61.40	61.50	61.6	61.50	7.23	7.35	7.48	7.35	1.032	1.032	1.038	1.034
	150	63.40	65.80	66.3	65.17	7.54	7.79	7.90	7.74	1.040	1.044	1.048	1.044
	300	66.00	67.10	67.7	66.93	7.73	8.04	8.21	7.99	1.050	1.050	1.054	1.051
	Means	63.60	64.80	65.20	64.53	7.50	7.73	7.86	7.70	1.04	1.04	1.05	1.043
150	0	61.60	62.70	62.8	62.37	7.35	7.42	7.71	7.49	1.059	1.055	1.060	1.058
	150	61.90	70.10	70.1	67.37	8.02	8.17	8.35	8.18	1.060	1.066	1.081	1.069
	300	63.00	70.40	71.1	68.17	8.44	8.77	9.13	8.78	1.078	1.091	1.085	1.085
	Means	62.17	67.73	68.00	65.97	7.94	8.12	8.40	8.15	1.07	1.07	1.08	1.071
Means of treatments													
	0	61.07	61.80	62.20	61.69	7.07	7.25	7.49	7.27	1.03	1.03	1.04	1.03
	150	62.77	66.67	67.30	65.58	7.55	7.70	7.87	7.70	1.04	1.04	1.05	1.04
	300	64.67	67.70	68.37	66.91	7.79	8.01	8.25	8.02	1.05	1.06	1.06	1.05
	Means	62.83	65.39	65.96	64.73	7.47	7.65	7.87	7.66	1.04	1.04	1.05	1.04
LSD (0.05)		A=0.417; B=0.253; C=0.195; AB=0.438; AC=0.338; CB=0.338; ABC=0.585				A=0.1033; B=0.0335; C=0.0163; AB=0.058; AC=0.028; CB=0.0280; ABC= 0.0488				A=0.0095; B=0.0043; C=0.0019; AB=NS; AC=NS, CB=0.0033; ABC= 0.0058			
*A = (N) * B = (Algae) * C = (Ca)													

Table 7: Effect of Nitrogen application, spraying Algae Extract and Calcium on some quality Parameters of tubers potato.

N Rates (KgN fed^{-1})	Algae ml. fed^{-1}	Ca (PPM)											
		0	60	120	Means	0	60	120	Means	0	60	120	Means
		Starch (%)				Protein (%)				Specific Density (g cm^{-3})			
75	0	68.10	64.70	63.80	65.53	3.20	3.50	4.10	3.60	4.20	4.40	4.60	4.40
	150	67.20	59.90	58.90	62.00	4.20	4.20	4.30	4.23	4.50	4.60	4.60	4.57
	300	69.70	63.60	63.60	65.63	4.20	5.30	5.50	5.00	4.60	5.10	5.10	4.93
	Means	68.33	62.73	62.10	64.39	3.87	4.33	4.63	4.28	4.43	4.70	4.77	4.63
110	0	72.60	66.10	62.20	66.97	4.20	4.70	4.80	4.57	4.50	4.80	4.90	4.73
	150	62.80	65.70	63.20	63.90	4.50	4.80	5.20	4.83	4.70	4.80	4.70	4.73
	300	63.10	63.70	62.80	63.20	4.60	4.90	5.50	5.00	4.80	4.90	5.10	4.93
	Means	66.17	65.17	62.73	64.69	4.43	4.80	5.17	4.80	4.67	4.83	4.90	4.80
150	0	72.50	66.00	63.10	67.20	4.30	4.80	5.20	4.77	4.70	4.80	4.90	4.80
	150	70.70	67.60	66.00	68.10	4.70	5.00	5.30	5.00	4.80	4.90	5.70	5.13
	300	68.40	68.20	65.20	67.27	5.00	5.30	5.70	5.33	6.00	6.10	6.30	6.13
	Means	70.53	67.27	64.77	67.52	4.67	5.03	5.40	5.03	5.17	5.27	5.63	5.36
Means of treatments													
	0	71.07	65.60	63.03	66.57	3.90	4.33	4.70	4.31	4.47	4.67	4.80	4.64
	150	66.90	64.40	62.70	64.67	4.47	4.67	4.93	4.69	4.67	4.77	5.00	4.81
	300	67.07	65.17	63.87	65.37	4.60	5.17	5.57	5.11	5.13	5.37	5.50	5.33
	Means	68.34	65.06	63.20	65.53	4.32	4.72	5.07	4.70	4.76	4.93	5.10	4.93
LSD (0.05)		A=0.071; B=0.079; C=0.047; AB=0.137; AC=0.081; CB=0.081; ABC=0.140				A=0.216; B=0.160; C=0.121; AB=0.278; AC=NS; CB=0.209; ABC= 0.303				A=0.179; B=0.103; C=0.083; AB=0.178; AC=0.144, CB=NS; ABC= 0.249			
*A = (N) * B = (Algae) * C = (Ca)													

highest mean values 15.55, 8.95 ton/ fed of tubers and foliage potato, respectively. These results are in agreement of these observed by Tawfik, (2001), Seifu and Deneke, (2017) and Hanid *et al.,* (2015). Concerning the effect of interaction, treatment (150 kg N + 300 ml of Algae extract + 120 ppm of calcium)/ fed were the best treatment and recorded the highest mean values 20.53 and 10.96 ton / fed of potato tubers and foliage, respectively.

Results in table 4 showed that, the N application, foliar spray of Algae extract and calcium affected significantly harvest index (HI), diameter and length (cm). N application at rate 150 kg N/ fed was the most rate for significant increasing of the HI and diameter & length (cm) of potato tubers as compared with other treatments. The addition of 150 kg N/ fed gave the highest mean values 67.52, 5.03 and 5.63 for (HI), diameter and length (cm) of potato tubers, respectively compared with other treatments.

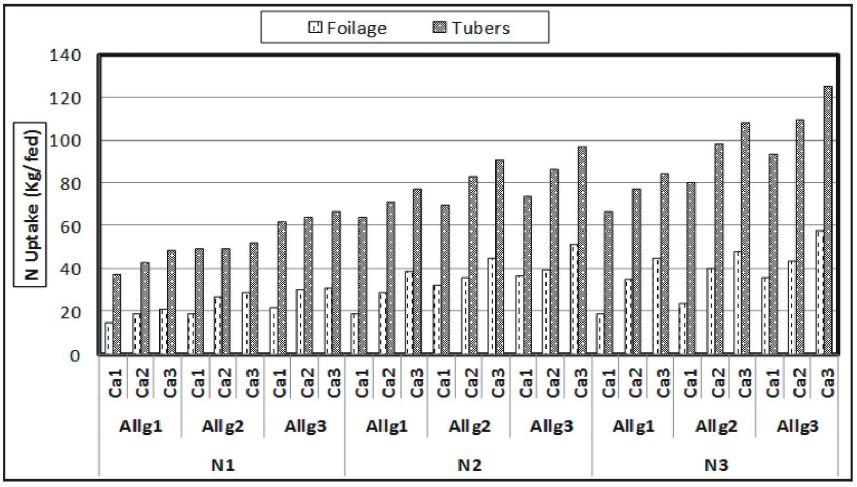

Fig. 1. Effect of Nitrogen application, Algae Extract and Calcium foliar spray on the uptake of nitrogen.

Similar results were obtained with Algae extract and calcium where spraying after 45 and 60 days from sowing affected significantly the harvest index (HI), diameter and length (cm) of tuber potato. Also the highest rate of Algae extract (300 ml /fed and calcium 120 ppm / fed had recorded the highest mean values compared to all the studied treatments of this parameter. Similar results were obtained by Haider *et al*., (2012); Lobato *et al.,* (2008); Ozgen *et al.,* (2003) and Hamdi *et al.*, (2015). With respect to the triple interaction, the results indicated addition (150 kg N +300 ml of Algae extract +120 ppm of

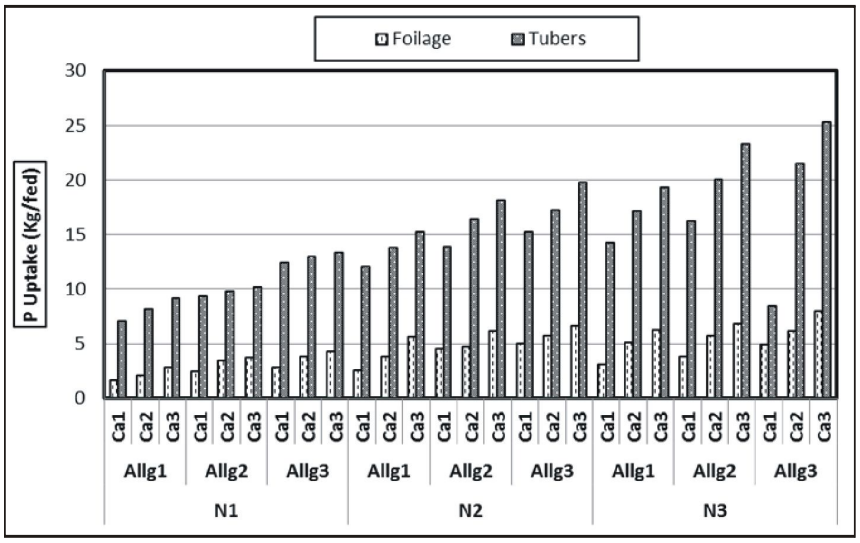

Fig. 2: Effect of Nitrogen application, Algae Extract and Calcium on the uptake of phosphorus.

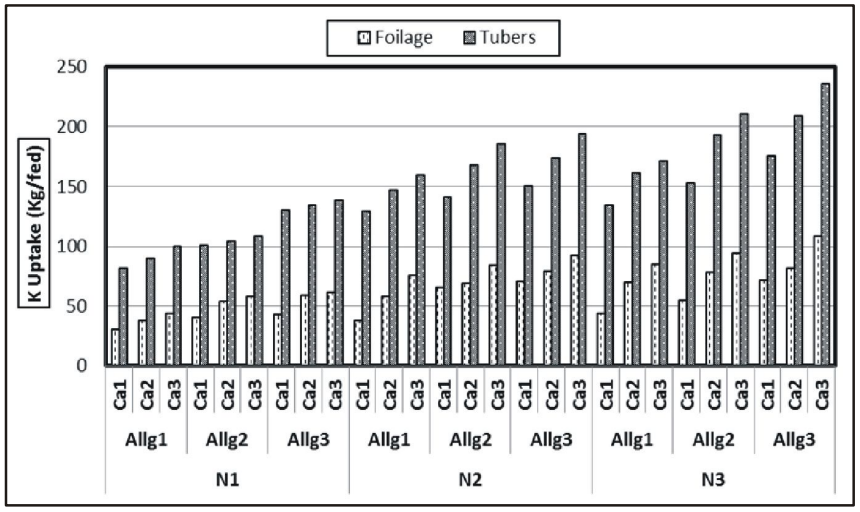

Fig. 3: Effect of Nitrogen application, Algae Extract and Calcium on the uptake of potassium.

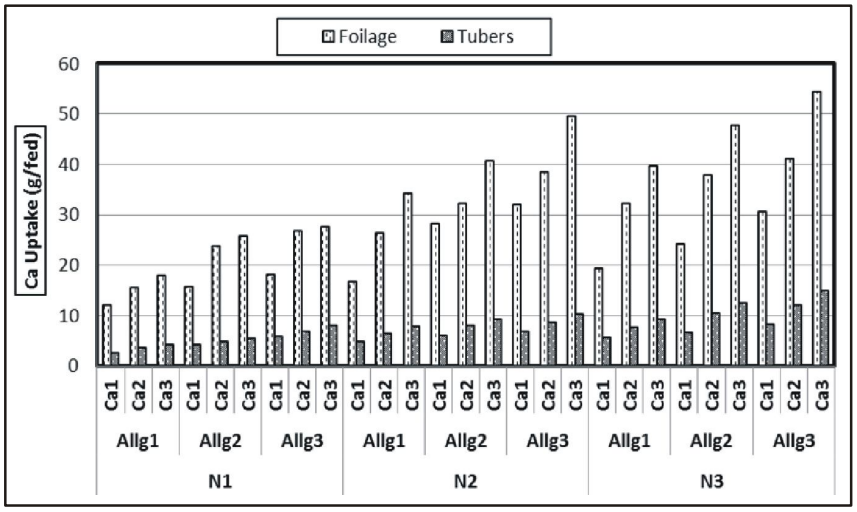

Fig. 4: Effect of Nitrogen application, Algae Extract and Calcium on the uptake of calcium.

calcium)/ fed were the best treatment for producing HI, diameter and length (cm) of potato tubers and gave highest mean values 65.20, 5.70 and 6.30, respectively.

• Mineral concentration of potato tubers and shoot:

Data shown in tables 5 & 6 and figs. 1-4 clearly indicated that nitrogen, Algae extract and calcium fertilization showed significant effect on N %, P %, K % and Ca% and uptake (kg/fed) in tubers and shoots. As for the effect of N application, the results indicated addition of 150 kg N/fed recoded the highest mean values of N%, P%, K% and Ca% in tubers potato which were 1.31%, 0.273%, 2.56% and 0.133%, respectively. Also the respective highest mean values in shoots were 1.52%, 0.222%, 3.05% and 1.45 for N%, P%, K% and Ca%. As regard to the effect of foliar spray with Algae extract after 45, 60 days from planting at rate 300 ml / fed gave the highest mean values of 1.29%, 0.62%, 2.5% and 0.132%, for N%, P%, K% and Ca% in potato tubers, respectively, while being 1.5%, 0.205%, 2.97% and 1.48% of N%, P%, K% and Ca% in shoots. Concerning the effect of Ca, data showed that,the highest mean values of N%, P%, K% and Ca% were 1.26%, 0.26%, 2.55% and 0.134%, respectively for tubers potato plants and 1.49%, 0.204%, 20.87% and 1.37% for shoots at Ca spraying rate of 120 ppm /fed.

With respect to the interaction effect among (N × Algae extract × Ca) data showed significant effects on N%, P%, K% and Ca% in both potato tubers and shoots. Also high rate fertilization of this interaction was the best treatment and recoded highest mean values of elements concentration and uptake in both tubers and shoots.

• Tubers quality:

Table 6 showed that the N application and Algae extract, Calcium effect on quality parameters of potato

Table 8: Effect of studied treatments on the available amounts of N, P and K (ppm) in soil after harvesting.

N Rates (kg N/fed)	Alage (ml /fed)	Ca(ppm)											
		0	60	120	Mean	0	60	120	Mean	0	60	120	Mean
		Available N(ppm)				Available P(ppm)				Available K (ppm)			
75	0	32.1	31.2	30.1	31.13	1.9	2.10	2.3	2.1	40.6	41.0	41.0	40.87
	150	33.3	32.2	31.3	32.27	2.3	2.4	2.6	2.43	41.4	41.1	41.2	41.23
	300	33.6	33.4	32.5	33.16	2.6	2.7	2.7	2.67	42.3	42.4	42.3	42.33
	Mean	**33.0**	**32.26**	**31.3**	**32.19**	**2.3**	**2.40**	**2.53**	**2.4**	**41.4**	**41.5**	**41.5**	**41.48**
110	0	34.7	33.4	32.4	33.5	3.1	3.2	3.2	3.16	42.2	42.1	42.2	42.16
	150	35.6	33.5	33.2	34.1	3.3	3.4	3.3	3.33	43.3	43.1	43.34	43.23
	300	36.4	34.6	33.7	34.9	3.4	3.6	3.6	3.53	44.4	44.3	44.5	44.4
	Mean	**356**	**33.83**	**33.1**	**34.17**	**4.3**	**3.4**	**3.37**	**3.34**	**43.3**	**43.17**	**43.33**	**43.26**
150	0	35.8	33.6	32.1	33.83	4.1	4.2	4.3	4.2	44.6	44.3	43.8	44.23
	150	36.7	33.8	32.3	34.27	4.3	4.3	4.3	4.3	44.8	44.6	44.7	44.7
	300	36.9	34.7	33.4	35.0	4.4	4.6	4.8	4.6	45.1	44.3	45.3	44.9
	Mean	**36.5**	**34.03**	**32.6**	**34.37**	**4.3**	**4.37**	**4.47**	**4.37**	**44.8**	**44.4**	**44.6**	**44.61**

tubers starch%, protein % and specific density g/ cm^3. Nitrogen application (150 kg N) was the most favorable for increasing and significant effect on quality parameters of potato tubers as compared with other treatments. The highest mean values of starch%, protein% and specific density g /cm^3 at addition rate 150 kg N/fed were 65.97, 8.15 and 1.071, respectively. The obtained agreed results with the findings of Errebhi *et al.,* (1998); Haase *et al.*, (2007) and Poljak *et al.,* (2009).

Concerning the effect of Algae extract on starch%, protein% and specific density g/cm^3 data indicated significant increase compared with control treatment. The highest mean values of starch%, protein% and specific density g/cm^3 at addition of 300 ml/fed Algae extract were 66.91%, 8.02% and 1.06 g/cm^3. Results may be due to the role of Algae extract containing extra components where they play important role in developing a strong growth and healthy plants, resulting increasing quality potato. These results agreed with Mackinnon *et al.,* (2010); Arafa *et al.,* (2011, 2012 and 2013) and Haider *et al*., (2012). As regard to the effect of Ca the rate of 150 ppm /fed recoded the highest values of starch%, protein% and specific density g/cm^3 where they reached to 65.96%, 7.87% and 1.05 g/cm^3 in tubers of potato plants. With respect to the interaction between 150 kg N +Algae extract 300 ml +120 ppm Ca) / fed which is conceder the most effective treatment for increasing the quality parameters of potato tubers indicated 71.1%, 9.13% and 1.08 g/cm^3 for starch%, protein% and specific density g/cm^3, respectively.

• Mineral content in soil after harvesting:

Data in table 8 showed that, studied available elements N, P and K (ppm) after harvesting. Addition of N fertilization increased the extractable amount of N, P and K. The mean values of available N (ppm) in soil after harvesting reached to 32.19, 34.17 and 34.37(ppm) with 75, 110 and 150 kg N/ fed, respectively. Where mean values of available P (ppm) reached to 2.4, 3.34 and 4.37 (ppm), while being available K reached to 41.48, 43.26 and 44.61 (ppm). For the addition of N and Algae extract, the data showed that they increased the extractable amount of N, P and K (ppm). Generally the highest mean values of available N, P and K (ppm) were 35 pm for N, 4.6 ppm for P and 44.9 ppm for K with addition 150 kg N/ fed combined with 300 ml/ fed Algae extract. Moreover, the foliar spray of Calcium combined with N application, they showed that slightly increase of the extractable amount of K and P after harvesting, while being there were decrease slightly of N extractable in soil after harvesting. These results may be due to the role of Calcium due to it is important roles in developing a strong root system and cell wall of potato plants which able to send more vital compound to tubers and increase the growth and yield.

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