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Nano-Fertilizer Application to Increase Growth and Yield of Sweet Pepper under Potassium Levels

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Abstract

Background and objective: Under green-house conditions, two pot experiments were conducted an experimental farm at Faculty of Agriculture, Menoufia University in 2015 and 2016 summer seasons.

Methodology: This work aimed to study the effect of four rates of potassium fertilizer, 200, 250, 300 and 350kg/fed. and two rates of lithovit 2.5 and 5.0g/l water as a foliar application as well as their interactions, on growth characters, water relations, chemical composition, fruit yield and its components of the sweet pepper (Capasicum annuum L.) plants.

Results: It is very clearly in our results that all treatments used in this study at either levels of potassium fertilizer or lithovit levels as well as their interaction, led to an increase in all vegetative growth characters, total & relative water content, bound & free water, photosynthetic pigments, total carbohydrates, total soluble sugars, N, P, & K concentrations and yield and its components. Meanwhile it decreased proline concentration, peroxidase and phenoloxidase activity.

Conclusion: It could be recommended that, the use of potassium fertilizer interacted with lithovit application on sweet pepper led to increase the productivity of pepper plants in terms of quantity and quality.

Keywords: Nanotechnology; Lithovit®; Potassium fertilizer; Sweet pepper

Abbreviations: TWC: Total Water Content; RWC: Relative Water Content; TSS: Total Soluble Solids; MKP: Mono Potassium Phosphate

Introduction

Pepper *(Capsicum annuum L.)* is one of the most important vegetable plants in the world, on this case should be increasing its quantity and quality by researchers. Fertilizers are very important for plant growth and development. Most of the applied fertilizers are rendered unavailable to plants due to many factors, such as leaching, degradation by photolysis, hydrolysis and decomposition. Hence, it is necessary to minimize nutrient losses in fertilization and increase the yield and its components through the exploitation for new applications with the help of nanotechnology and nanomaterials. Nanotechnology opens a large scope of novel application in the fields of biotechnology and agricultural industries, because nano-particles have unique physicochemical properties, i.e. high surface area, high reactivity, tunable pore size and particle morphology [1]. Nano-fertilizers have emerged as an alternative to conventional fertilizers for slow release and efficient use of water and fertilizers by plants [2]. These prevent buildup of the nutrients in the soil there by eliminating the risk of eutrophication and drinking water contamination. Lithovit is a naturally occurring carbon dioxide (CO_2) foliar spray made from limestone deposits. It enhances the plant growth and results in high productivity by means of increasing the natural photosynthesis on supplying CO_2 at optimum concentration, which is much higher than in the atmosphere and at the same time does not result in an increase of the CO_2 in the atmosphere which might create a climatic problem particularly when the rate of global warming looms large over agriculture. All lithovit particles do not penetrate the stomata at once. Most of them remain as thin layer on the leaves surface and penetrate frequently when they get wet by dew at night [2].

Potassium foliar feeding is great significance for plants because its includes low cost, quick response to plant, small quantity of potassium and it provides compensation for lack of soil fixation determine [3]. This experiment aimed to study the effect of potassium fertilizer and lithovit nano particles as foliar spray alone and combined with potassium, to see its effect on pepper plants growth as well as its water relation and some chemical components and yield production and its components.

Materials and Methods

Area of study and sampling

Under green-house conditions, two pot experiments were conducted on a clay loamy soil at Faculty of Agriculture, Menoufia

University, Menoufia Governorate, Egypt in 2015 and 2016 summer seasons. This work conducted to study the effect of four rates of potassium fertilizer, 200kg (recommended dose), 250kg, 300kg and 350kg/fed. from potassium sulfate 48% K_2O. Two rates of lithovit (CO_2 nano-fertilizer which produced by using nanotechnology application) 2.5 and 5.0g/l as a foliar application as well as their interactions, on growth characters, chemical composition, fruit yield and its components of the sweet pepper (*Capasicum annuum L.*) plants.

Table 1: Main characteristics of lithovit®.

Component	Value (%)	Component	Value (%)
Calcium carbonate	79.19	Sulphate	0.33
Nitrogen	0.06	Iron	1.31
Phosphate	0.01	Zinc	0.005
Potassium Oxide	0.21	Manganese	0.014
Magnesium Carbonate	4.62	Copper	0.002
Selisium Dioxide	11.41	Clay	0.79

Lithovit® natural CO_2 as a nano - foliar fertilizer "Made in Germany" and is distributed by Filmchem L.td. It is a new top quality nanotechnological fine powder created by tribodynamic activation and micronization. Highly energized lithovit particles, sprayed finely onto the leaf surface, are taken up directly through the stomata and converted into carbon dioxide. Lithovit is 100% organic calcite carbonate from natural limestone deposits, suitable for use in organic farming in the European Community, harmless to humans and animals and not hazardous to water according EWGzoaz/a [4]. The mentioned concentrations of CO_2 were used as foliar spray on pepper leaves at 20, 40 and 60 days from transplanting, respectively (Table 1). Two plants per pot were transplanting at 1th June in both seasons in pots 30 cm diameter, each pot filled with 7kg of clay loamy soil. The chemical and physical characteristics of experimental soil in Table 2 are shown according to [5].

After showed the aforementioned treatments and throw it's applied, we applied the all agriculture ministry recommended fertilization of N, P and K for the control plants and the other treatments. The foliar applications were spraying at 20, 40 and 60 days from transplanting. Weeds and best control as well as other agriculture practices were used whenever necessary.

Sampling: Plant samples were taken after 75 days from transplanting.

The following data were recorded

Vegetative growth characters: Root length (cm), plant height (cm), leaf area per plant (cm^2 / plant) [6], leaf area index (total leaf area of plants per pot, cm^2/ pot surface area, cm^2) fresh and dry weight of hole plant (g) (Plant materials were dried in an electric oven at 70°C for 72 hours).

Water relations: Total water content (TWC, %), free and bound water [8,9], relative water content (RWC, %) [7], osmotic pressure [8], transpiration rate [9].

Photosynthetic pigments: The photosynthetic pigments were extracted from fresh leaf sample (fourth upper leaf) by 85% acetone and determined according to the method described by Wettestein's formula in [10].

Chemical analysis: Total carbohydrates and total sugars were determinate using the phenol sulfuric acid method as described by [10]. Antioxidant enzymes activities as peroxidase and phynoloxidase were determined according to [11,12]. Proline concentration was measured according the ninhydrin method of [13]. N, P and K were determined as a described by [10].

Yield and its components: fruits number per plant, fruits weight per plant and average of fruit weight were determined.

Fruit quality: ascorbic acid (V. C) (mg/100ml juice) was determined in fruit juice as described in [10], pH, total soluble solids (TSS%) was measured using a hand refractometer as described in [10], N, P and K were determined as a described by [10].

Statistical analysis: The experimental pots were arranged in a factorial experiment in two ways randomized block design with six replicates. All data collected were subjected to the standard statistical analysis following the proceeding described by [14], using the computer program of Costat Software, 1985. The analyzed data then presented in tables.

Table 2: Some chemical and physical properties of experimental soil.

Properties	Value
Physical Analysis	
Sand%	33
Silt%	34.97
Clay%	31.82
Texture	clay loamy
Chemical Analysis	
PH	7.4
O.M.%	0.81
$CaCO_3$	1.42
Ec (mmhos/cm)	1.9
Soluble Ions (meq/100g soil)	
HCO_3	0.62
Cl^-	0.45
$SO4^{-2}$	0.81
Na^+	0.47
K+	0.49
$Ca^{+2} + Mg^{+2}$	0.79
Total N (100)	0.22
Avail. P($Mg.g^{-1}$)	0.51

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Results

Growth characters

The presented data in Table 3A & 3B showed that, the root length, plant height, leaf area, leaf area index and dry weight of root and shoot of pepper plants increased with increasing the levels of potassium fertilizers when compared with the control plants. The highest increase was recorded at the second level of potassium (300kg/fed.) which reached about 46.15, 56.60, 14.86, 14.65, 35.64 and 47.32%, respectively.

Table 3A: Effect of potassium fertilizer, lithovit fertilizer and their interaction on growth characters of sweet pepper plants at 70 days during the two growing summer season of 2015.

Characters\Treatments		Root Length (cm)	Plant Height (cm)	Leaf Area (cm^2)	Leaf Area Index	Dry Weight (g)	
Potassium Levels (kg/fed.)	Lithovit Levels (g/l)					Root	Shoot
Cont.	-	9.47	38.13	236.38	0.669	0.243	0.776
250	-	11.79	44.16	548.34	1.551	0.511	2.234
300	-	13.84	59.71	576.43	1.63	1.109	4.448
350	-	12.67	54.51	488.25	1.381	0.962	3.056
Mean		11.94	49.13	462.35	1.31	0.71	2.63
-	0	9.47	38.13	236.38	0.669	0.243	0.776
-	2.5	13.36	47.59	269.85	0.763	0.838	1.015
-	5	15	53.47	311.59	0.881	1.027	2.323
	Mean	12.61	46.4	272.61	0.77	0.7	1.37
Control	0	9.47	38.13	236.38	0.669	0.243	0.776
	2.5	13.36	47.59	269.85	0.763	0.838	1.015
	5	15	53.47	311.59	0.881	1.027	2.323
250	0	11.79	44.16	548.34	1.551	0.511	2.234
	2.5	14.23	56.96	578.56	1.636	1.074	2.879
	5	18.65	61.77	604.01	1.708	1.32	3.131
300	0	13.84	59.71	576.43	1.63	1.109	4.448
	2.5	15.29	72.33	779.56	2.205	1.577	4.776
	5	18.97	81.56	821.77	2.324	1.717	5.193
350	0	12.67	54.51	488.25	1.381	0.962	3.056
	2.5	14.14	66.85	692.49	1.959	1.399	3.119
	5	17.67	69.14	717.11	2.028	1.559	4.246
Mean		15.91	63.71	596.87	1.69	1.31	3.34
LSD Potassium		0.797	4.866	19.869	0.074	0.127	0.777
at 5% Lithovit		1.599	4.345	12.548	0.082	0.188	0.203
Potassium * Lithovit		0.088	1.992	9.684	0.067	ns	0.01

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Table 3B: season 2016.

Characters\Treatments		Root Length (cm)	Plant Height (cm)	Leaf Area (cm^2)	Leaf area Index	Dry Weight (g)	
Potassium Levels (kg/ fed.)	Lithovit Levels (g/l)					Root	Shoot
Cont.	-	12.29	45.44	267.29	0.76	0.59	1.38
250	-	15.91	60.73	552.34	1.56	1.06	3.69
300	-	17.33	76.41	780.58	2.21	1.79	5.28
350	-	16	66.59	666.12	1.88	1.37	4.01
Mean	-	15.38	62.29	566.58	1.6	1.2	3.59
-	0	12.64	52.3	426.77	1.21	0.95	3.02
-	2.5	15.12	65.21	628.28	1.78	1.19	3.59
-	5	18.38	69.38	644.71	1.82	1.47	4.17
-	Mean	15.38	62.3	566.59	1.6	1.2	3.59
Control	0	8.93	39.4	244.23	0.691	0.291	0.93
	2.5	12.86	44.98	255.02	0.721	0.529	1.041
	5	15.07	51.93	302.63	0.856	0.957	2.165
250	0	13.02	57.72	416.73	1.179	0.784	3.129
	2.5	15.31	60.9	618.59	1.75	1.129	3.928
	5	19.4	63.58	621.71	1.758	1.272	4.016
300	0	14.95	60.68	585.76	1.657	1.588	4.368
	2.5	16.79	82.06	884.42	2.501	1.815	5.497
	5	20.25	86.5	871.56	2.465	1.974	5.971
350	0	13.66	51.39	460.35	1.302	1.148	3.647
	2.5	15.53	72.89	755.1	2.136	1.291	3.878
	5	18.8	75.49	782.92	2.214	1.659	4.517
Mean		16.75	67.29	636.49	1.8	1.33	3.88
LSD Potassium		0.628	2.572	23.579	0.121	0.336	0.491
at 5% Lithovit		1.934	3.587	9.587	0.027	0.211	0.089
Potassium * Lithovit		0.095	0.918	4.003	0.023	0.096	0.012

Data in Table 3 indicate clearly that, the treatments of lithovit foliar applications showed a significant increase in all growth characters of pepper plants i.e. root length, plant height, leaf area, leaf area index and dry weight of root and shoot. All growth characters were increased with increasing the levels of lithovit foliar applications. The highest increase was recorded at the higher level of lithovit (5g/l) which reached about 58.39, 40.23, 31.82, 31.69, 32.26 and 19.93%, respectively.

The interaction between potassium levels and lithovit foliar applications showed in the same table that an increase in all growth characters aforementioned at all potassium levels, and the sequences levels of increase at second, third and first levels of potassium interacted with lithovit foliar applications respectively, when compared with the control plants.

Water relations

The illustrated data in Table 4A & 4B cited that, the all levels of potassium fertilizers increased the TWC, free water, bound water, RWC and OP in leaves of sweet pepper plants. Meanwhile, the levels of potassium recorded a reduction in transpiration rate. The highest increase in these measures was recorded at the second level of potassium (300kg/fed.) by about 5.15, 29.92, 1.87, 4.35 and 24.20 %, respectively. The lithovit levels increased the TWC, free water, RWC and OP in leaves of sweet pepper plants. Meanwhile, the levels of Lithovit caused a reduction in bound water and transpiration rate, and the balance in water relations increased with increasing the levels of treatments aforementioned. The highest increase in these measures was recorded at the higher level of lithovit (5g/l) by about 1.05, 14.11, 0.78 and 9.13%, respectively. The same increase was recorded at the all interactions between lithovit and potassium fertilizers. The higher increase throws the interactions was recorded at potassium level 300kg/fed interacted with lithovit level 5.0g/l followed by 2.5g/l, respectively when compared with the control plants.

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Table 4A: Effect of potassium fertilizer, lithovit fertilizer and their interaction on water relations of sweet pepper plants at 70 days during the two growing summer season of 2015.

Characters\Treatments		TWC (%)	Free Water (%)	Bound Water (%)	RWC (%)	O.P. (bar)	Transpi. Rate (mg/g fw.h)
Potassium Levels (kg/ fed.)	Lithovit Levels (g/l)						
Season 2015							
Cont.	-	75.09	8.79	66.3	74.42	2.19	0.024
250	-	77.36	10.66	66.7	75.81	2.54	0.024
300	-	78.96	11.42	67.54	77.66	2.72	0.023
350	-	78.81	10.77	68.04	77.43	2.56	0.023
Mean	-	77.56	10.41	67.15	76.33	2.5	0.023
-	0	75.09	8.79	66.3	74.42	2.19	0.024
-	2.5	75.69	9.39	66.3	74.93	2.24	0.024
-	5	75.88	10.03	65.85	75	2.39	0.023
-	Mean	75.55	9.4	66.15	74.78	2.27	0.024
Control	0	75.09	8.79	66.3	74.42	2.19	0.024
	2.5	75.69	9.39	66.3	74.93	2.24	0.024
	5	75.88	10.03	65.85	75	2.39	0.023
250	0	77.36	10.66	66.7	75.81	2.54	0.024
	2.5	77.92	11.33	66.59	76.29	2.7	0.023
	5	78.17	11.52	66.65	76.46	2.74	0.023
300	0	78.96	11.42	67.54	77.66	2.72	0.023
	2.5	79.43	12.67	66.76	77.92	2.92	0.022
	5	79.57	12.43	67.14	77.94	2.96	0.022
350	0	78.81	10.77	68.04	77.43	2.56	0.023
	2.5	79.25	11.52	67.73	77.49	2.74	0.022
	5	79.41	11.94	67.47	77.48	2.84	0.023
Mean		78.17	11.35	66.81	76.69	2.69	0.023
LSD Potassium		0.145	0.106	0.392	0.224	0.018	0.0006
at 5% Lithovit		0.179	0.557	0.366	0.062	0.064	0.0009
Potassium * Lithovit		0.116	0.089	0.187	0.038	0.009	0.0004

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Table 4B: season 2016.

Characters\Treatments		TWC (%)	Free Water (%)	Bound Water (%)	RWC (%)	O.P. (bar)	Transpi. Rate (mg/g fw.h)
potassium Levels (kg/ fed.)	Lithovit Levels (g/l)						
Cont.	-	69.48	8.51	60.96	69.4	2.04	0.025
250	-	77.52	9.74	67.78	71.54	2.17	0.024
300	-	78.22	10.96	67.25	74.57	2.99	0.023
350	-	77.99	11.21	66.78	71.93	2.51	0.024
Mean	-	75.8	10.11	65.69	71.86	2.43	0.024
-	0	69.48	8.51	60.96	69.4	2.04	0.025
-	2.5	70.74	8.7	62.04	70.42	2.2	0.024
-	5	72.44	9.41	63.02	72.04	2.29	0.023
-	Mean	70.89	8.87	62.01	70.62	2.18	0.024
Control	0	69.48	8.51	60.96	69.4	2.04	0.025
	2.5	70.74	8.7	62.04	70.42	2.2	0.024
	5	72.44	9.41	63.02	72.04	2.29	0.023
250	0	77.52	9.74	67.78	71.54	2.17	0.024
	2.5	77.03	11.16	65.86	73.88	2.56	0.023
	5	77.95	11.33	66.62	75.19	2.64	0.022
300	0	78.22	10.96	67.25	74.57	2.99	0.023
	2.5	78.29	11.88	66.41	76.48	3.03	0.022
	5	79.11	12.2	66.91	79.19	3.15	0.022
350	0	77.99	11.21	66.78	71.93	2.51	0.024
	2.5	78.17	11.47	66.7	77.13	2.67	0.022
	5	78.89	11.89	67	77.47	2.79	0.022
Mean		76.58	11.01	65.57	75.23	2.67	0.023
LSD Potassium		0.132	0.111	0.358	0.213	0.015	0.0006
at 5% Lithovit		0.184	0.478	0.344	0.101	0.051	0.0008
Potassium * Lithovit		0.125	0.089	0.207	0.029	0.008	0.0005

Photosynthetic pigments

Data in Table 5 showed that, the pepper plants fertilized with K at all levels increased the values of leaves chlorophyll a, b and carotenoids contents in both seasons. Whereas, at K level 300kg/fed. produced the greatest values of leaves plant pigments contents.

On the same side, foliar application with 2.5 and 5.0g lithovit/l significantly increased leaves concentration of chlorophyll a, b and carotenoids as compared with the untreated plants (control) in the both of seasons. The highest values of chlorophyll a, b and carotenoids content in pepper leaves were obtained as a result of foliar spraying of 5.0g lithovit/l by about 78.96, 11.42 and 67.54% when compared with the control plants. In the same table the interaction between potassium levels and Lithovit foliar applications recorded an increase in chlorophyll a, b and carotenoids at all potassium levels. The sequences levels of increases at second, third and first levels of potassium interacted with lithovit foliar applications. The highest value throws the interactions was recorded at potassium level 300kg/fed interacted with lithovit level 5.0g/l respectively, when compared with the control plants. The results in the second season are the seamed of the first one.

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Table 5: Effect of potassium fertilizer, lithovit fertilizer and their interaction on photosynthetic pigments of leaves of sweet pepper plants at 70 days during the two growing summer seasons of 2015 and 2016.

Characters\Treatments		Chlorophyll a (mg/g d.wt.)		Chlorophyll b (mg/g d.wt.)		Carotenoids (mg/g d.wt.)	
Potassium Levels (kg/fed.)	Lithovit Levels (g/l)	2014 Season	2015 Season	2014 Season	2015 season	2014 Season	2015 Season
Cont.	-	3.03	3.12	1.16	1.23	1.03	1.01
250	-	3.16	3.22	1.22	1.28	1.08	1.09
300	-	3.47	3.7	1.83	1.94	1.46	1.47
350	-	3.15	3.61	1.24	1.52	1.08	1.12
Mean	-	3.2	3.41	1.36	1.49	1.16	1.173
-	0.0	3.03	3.12	1.16	1.23	1.03	1.01
-	2.5	3.08	3.4	1.15	1.42	1.04	1.07
-	5.0	3.39	3.51	1.35	1.46	1.24	1.36
	Mean	3.17	3.34	1.22	1.37	1.1	1.147
Control	0.0	3.03	3.12	1.16	1.23	1.03	1.01
	2.5	3.08	3.4	1.15	1.42	1.04	1.07
	5.0	3.39	3.51	1.35	1.46	1.24	1.36
250	0.0	3.16	3.22	1.22	1.28	1.08	1.09
	2.5	3.33	3.4	1.28	1.35	1.15	1.17
	5.0	3.5	3.57	1.4	1.5	1.36	1.38
300	0.0	3.47	3.7	1.83	1.94	1.46	1.47
	2.5	3.59	3.86	1.87	2.03	1.58	1.62
	5.0	3.69	3.96	1.91	2.09	1.71	1.75
350	0.0	3.15	3.61	1.24	1.52	1.08	1.12
	2.5	3.34	3.76	1.29	1.64	1.17	1.21
	5.0	3.48	3.84	1.37	1.79	1.3	1.42
Mean		3.43	3.66	1.45	1.66	1.32	1.373
LSD Potassium		0.036	0.006	0.064	0.002	0.094	0.033
at 5% Lithovit		0.015	0.016	0.013	0.007	0.038	0.024
Potassium *Lithovit		0.011	0.013	0.007	0.004	0.023	0.021

Chemical composition

Data in Table 6 showed that, the leaves chemical contents of pepper plants which fertilized by K at all levels increased the leaves total carbohydrates, total sugars, N%, p% and K%. Meanwhile, the activity of peroxidase and phynoloxidase and prolien concentration were decreased as a result of K treatments when compared with the control plants. Whereas, at K level 300kg/fed. produced the highest values of leaves chemical contents a aforementioned.

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Table 6: Effect of potassium fertilizer, lithovit fertilizer and their interaction on chemical composition in leaves of sweet pepper plants at 70 days during the growing summer season of 2016.

Characters\Treatments		Total Carbohydrates (Mg/g d. wt)	Total Sugars (Mg/g d. wt)	Per-oxidase O.D./g Fwt. after 2min.	Per-oxidase O.D./g Fwt. after 45min.	Proline conc.µg lucine/gm d.wt	N %	P %	K %
Potassium Levels (kg/fed.)	Lithovit Levels (g/l)								
Cont.	-	106.46	18.67	166.92	150.45	427.88	2.74	0.23	2.52
250	-	148.46	27. 40	162.58	144.64	409.15	2.93	0.28	2.77
300	-	217.5	36.69	154.86	134.19	372.07	3.39	0.3	3.2
350	-	196.12	29.76	159.75	139.77	389.52	3.28	0.29	3.09
Mean	-	167.14	28.13	161.03	142.26	399.66	3.09	0.28	2.9
-	0.0	106.46	18.67	166.92	150.45	427.88	2.74	0.23	2.52
-	2.5	149.87	34.75	158.34	140.73	413.22	2.86	0.28	2.73
-	5.0	162.33	38.35	149.41	129.37	416.38	3.09	0.39	3.2
	Mean	139.55	30.59	158.22	140.18	419.16	2.9	0.3	2.82
Control	0.0	106.46	18.67	166.92	150.45	427.88	2.74	0.23	2.52
	2.5	149.87	34.75	158.34	140.73	413.22	2.86	0.28	2.73
	5.0	162.33	38.35	149.41	129.37	416.38	3.09	0.39	3.2
250	0.0	148.46	27. 40	162.58	144.64	409.15	2.93	0.28	2.77
	2.5	189.42	39.12	148.55	129.29	402.72	3.09	0.29	3.04
	5.0	204.11	43.68	137.54	116.93	403.71	3.27	0.31	3.29
300	0.0	217.5	36.69	154.86	134.19	372.07	3.39	0.3	3.2
	2.5	231.39	40.58	143.57	121.64	340.38	3.51	0.34	3.46
	5.0	233.34	48.16	135.24	112.86	368.82	3.6	0.36	3.5
350	0.0	196.12	29.76	159.75	139.77	389.52	3.28	0.29	3.09
	2.5	211.57	36.34	148.34	127.28	371.6	3.44	0.31	3.27
	5.0	222.45	42.56	140.79	119.01	386.35	3.56	0.32	3.38
Mean		200.56	40.44	145.22	124.64	387.9	3.3	0.33	3.23
LSD Potassium		17.817	1.967	2.358	4.058	14.542	0.092	0.008	0.114
at 5% Lithovit		10.383	3	7.15	8.1	2.633	0.1	0.042	0.175
Potassium *Lithovit		1.625	0.933	0.175	1.675	0.825	0.033	0.009	0.017

When regard to the content of measured chemicals and were recorded in Table 6, the data showed that, the lithovit levels had a significant increase in leaves chemical compositions i.e., total carbohydrates, total sugars, N, P and K%. Meanwhile, the enzymes activity (peroxidase and phynoloxidase) and prolien were recorded a low concentration as a result of lithovit treatments when compared with the control plants. The highest increase of total carbohydrates, total sugars, nitrogen %, phosphorus % and potassium % content in pepper leaves were obtained as a result of foliar spraying of 5.0g lithovit/l as a compared with the untreated plants.

At the same table the leaves chemical contents were increased at the all interactions between potassium levels and lithovit foliar applications at the sequence's levels of increase at second, third and first levels of potassium interacted with lithovit foliar applications. The higher increase in total carbohydrates, total sugars, N%, p % and K % was recorded at potassium level 300kg/fed interacted with lithovit level 5.0g/l respectively, when compared with the control plants.

From the results in Tables 7 & 8, it is observed that, the fruit weight, fruit No./plant, fruit yield/plant, straw yield, vitamin C., total carbohydrates, T.S.S. and protein contents in fruits of pepper plants increased with increasing the levels of potassium fertilizers when compared with the yield components of control plants. The higher increase was recorded at the second level of potassium (300kg/fed.).

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Yield and its components

Table 7: Effect of potassium fertilizer, lithovit fertilizer and their interaction on yield and its components of sweet pepper plants during the two growing summer seasons of 2015 and 2016.

Characters\Treatments		Fruit Weight (gm)		Frits No./Plant		Frits Yield/Plant (gm)		Straw Yield (g/Plant)	
Potassium Levels (kg/fed.)	Lithovit Levels (g/l)	2014 Season	2015 Season	2014 Season	2015 Season	2014 Season	2015 season	2014 season	2015 season
Cont.	-	15.06	14.2	12.75	13.18	148.67	153.6	5.04	5.17
250	-	18.75	20.7	14.77	19.3	344.87	262.09	10.81	8.63
300	-	22.01	23.77	19.97	20.29	362.53	368.4	11.56	11.78
350	-	20.15	21.72	18.23	17.19	307.08	289.53	9.87	9.38
Mean		18.99	20.1	16.43	17.49	290.79	268.41	9.32	8.74
-	0.0	15.06	14.2	12.75	13.18	148.67	153.6	5.04	5.17
-	2.5	21.24	20.45	15.92	15.04	169.72	160.39	5.91	5.6
-	5.0	23.85	23.96	17.88	17.37	195.97	190.33	6.79	6.62
	Mean	20.05	19.54	15.52	15.2	171.45	168.11	5.91	5.8
Control	0.0	15.06	14.2	12.75	13.18	148.67	153.6	5.04	5.17
	2.5	21.24	20.45	15.92	15.04	169.72	160.39	5.91	5.6
	5.0	23.85	23.96	17.88	17.37	195.97	190.33	6.79	6.62
250	0.0	18.75	20.7	14.77	19.3	344.87	262.09	10.81	8.63
	2.5	22.63	24.34	19.05	20.37	363.87	389.05	11.59	12.39
	5.0	29.65	30.85	20.66	21.26	379.88	391.01	12.29	12.66
300	0.0	22.01	23.77	19.97	20.29	362.53	368.4	11.56	11.78
	2.5	24.31	26.7	24.19	27.44	490.29	556.24	15.39	17.44
	5.0	30.16	32.2	27.28	28.93	516.84	548.15	16.41	17.41
350	0.0	20.15	21.72	18.23	17.19	307.08	289.53	9.87	9.38
	2.5	22.48	24.69	22.36	24.38	435.53	474.91	13.72	14.97
	5.0	28.1	29.89	23.12	25.25	451.01	492.4	14.35	15.64
Mean		25.3	26.64	21.31	22.51	375.39	400.31	12.06	12.84
LSD Potassium		1.376	0.993	1.578	1.893	28.005	14.663	0.907	0.722
at 5% Lithovit		5.074	2.408	0.852	0.757	19.943	5.68	0.766	0.321
Potassium *Lithovit		0.138	0.321	0.697	0.798	14.202	1.798	0.578	0.028

The data in Table 7 & 8 observed that, lithovit at levels 2.5 and 5g/l. significantly increased the fruit weight, frits No. / plant, frits yield / plant, straw yield, vitamin C., total carbohydrates, T.S.S. and protein contents in fruits as compared with the control. The level of lithovit 5g/l was recorded a higher level. Similar, results were obtained in the second season. The interaction between potassium levels and lithovit foliar applications recorded an increase in all yield components at all levels of treatments under studying. Therefore, the levels sequences of increase as followed second, third and first levels of potassium interacted with lithovit foliar applications respectively, when compared with the control plants. The results in first and second season are seamed.

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Table 8: Effect of potassium fertilizer, lithovit fertilizer and their interaction on fruit chemical constituents of sweet pepper plants during the growing summer season 2016.

Characters\Treatments		PH	Vit. C (mg Ascorbic Acid / 100g f.wt. Fruit	T.S.S. (Mg/g d. wt)	Total Carbohydrates (Mg/g d. wt)	Total Protein %
Potassium Levels (kg/fed.)	Lithovit Levels (g/l)					
Cont.	-	5.11	23.74	116.76	247.96	8.92
250	-	5.37	34.27	120.51	255.91	9.26
300	-	5.48	62.51	126.97	269.63	11.11
350	-	5.43	54.82	124.54	264.48	10.72
Mean	-	5.35	43.84	122.2	259.5	10
-	0.0	5.11	23.74	116.76	247.96	8.92
-	2.5	5.28	31.38	118.72	252.12	9.22
-	5.0	5.42	35.8	123.29	261.81	9.58
	Mean	5.27	30.31	119.59	253.96	9.24
Control	0.0	5.11	23.74	116.76	247.96	8.92
	2.5	5.28	31.38	118.72	252.12	9.22
	5.0	5.42	35.8	123.29	261.81	9.58
250	0.0	5.37	34.27	120.51	255.91	9.26
	2.5	5.55	45.77	123.68	262.64	11.42
	5.0	5.67	47.62	128.68	273.26	11.88
300	0.0	5.48	62.51	126.97	269.63	11.11
	2.5	5.59	71.34	143.45	304.62	13.18
	5.0	5.75	74.23	149.33	317.11	13.49
350	0.0	5.43	54.82	124.54	264.48	10.72
	2.5	5.54	57.86	129.47	274.95	11.95
	5.0	5.61	60.48	135.34	287.4	12.5
Mean		5.55	53.06	131.5	279.24	11.65
LSD Potassium		0.046	6.077	2.185	4.548	0.337
at 5% Lithovit		0.131	2.967	1.789	3.945	0.258
Potassium *Lithovit		0.037	1.664	0.858	1.593	0.281

Discussion

The highest potassium fertilization rate (200kg/fed.) gave the tallest sweet pepper plants, and the highest number of leaves and branches per plants and the highest fresh and dry weights of leaves [15,16]. Foliar application of bio-stimulants and lithovit with or without boron application significantly increased potato growth parameters (i.e. Plant height, branch number per plant, shoot fresh and dry weights, and leaf area per plant), as well as the potato tuber number and total tuber yield per plant [17,18]. This interaction had a significant effect on plant height and number of fruiting branches/plant in both seasons, where the taller plants were obtained from plants sown late on 8thJune and received the high level of both Potasin-P (7.5cm^3/l) and CO^2 fertilizer (7.5g/l) [19].

Foliar application of potassium mono phosphate (PMP) at 200ppm concentration increased the Chlorophyll a content [15,16,20]. Lithovit gave the highest increase in total chlorophyll and this increase is due to the micro-size particles of lithovit which allow it to be easily to absorb by plant as well as the lithovit contains Mg which induces the total chlorophyll in plant [17]. The highest leaves chlorophyll a, b, total chlorophyll, carotenoids contents were obtained from plants sown in early planting which received the medium level of Potasin-P (5cm^3/l) and CO_2 fertilizer as a spray at the high rate (7.5g/l) [19].

Sweet pepper leaves chemical composition (N, P and K) were increased with increasing potassium fertilization [16]. Lithovit gave the highest increase in nutrient uptake, total sugar, total soluble solids [17]. The highest leaf P content in the first season and K values in both seasons were obtained from plants sown in early planting date (8th April) which received the high level of Potasin-P (7.5cm^3/l) and CO_2 fertilizer as a spray at the high rate (7.5g/l). The highest leaves N, total sugars and total carbohydrates contents were obtained from plants sown in early planting date (8th April) which received the medium level of Potasin-P (5cm^3/l) and CO_2 fertilizer as a spray at the high rate (7.5g/l) [19].

The highest potassium fertilization rate (200kg/fed.) gave the highest total yield, and the fruit length, average fruit weight and vitamin C content were increased with increasing potassium

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fertilization [16]. Pepper plants were affected according to the application of mono potassium phosphate (MKP) recorded plant yield. Foliar spray of K showed an enhancement of fruits number and weight, as well as total acidity and vitamin C concentrations [21]. Lithovit gave the highest increase in some plant traits (fruit diameter, fruit weight, fresh yield, nutrient uptake, total sugar and total soluble solids) [17,18]. Number of fruiting branches/ plant reached its maximum from plants sown on early on 8th April and received the high rate of both Potasin-P (7.5cm^3/l) and CO_2 fertilizer (7.5g/l) [19].

Potassium is one of the most important and essential macro-elements of plant nutrients and is also the most abundant cation in plants. The K fertilizer importance for the formation of crop production and its quality is known. A strong positive relationship between K fertilizer input and grain yield has been shown [22]. Potassium plays essential roles in enzyme activation, protein synthesis, photosynthesis, osmoregulation, stomatal movement, energy transfer, phloem transport, cation-anion balance and stress resistance [23]. So that, the metabolic activities in the plant cell depends entirely with K and that reflex on the plant growth, development and its production (quantity and quality). The importance of potassium (K) in plant nutrition and agricultural crop production has been well documented and foliar spray is being considered and ideal method for its application for improvement of crop production [24]. Moreover K^+ considered to fruit weight, color, dry matter content and final yield of tomatoes [25]. Moreover, foliar K application resulted in improved number of fruits and quality attributes i.e color and ascorbic acid content [26]. An improvement of fruit quality due to appropriates K+ nutrition might be due to improved photosynthesis assimilation, their translocation from leaves to fruit and increase in enzyme activation [27] and increasing in vitamin C concentration [28].

The Foliar fertilizers from the lithovit range are the first foliar fertilizers that enhance the photosynthesis rate by releasing CO_2 inside the leaf, intensifying the plants metabolism, while feeding macro and micro nutrient needed by the plants for healthy growth and development. Due to the direct interference of lithovit in photosynthesis process and the increase in the output of this process, this effect is due to the increase in activity and metabolism of plant cell represented in the composition of chlorophyll, enzymes and plant hormones and its important in the plant growth process and development and this is reflected in the quantity and quality of the crop of treated plants. The micro-size particles of lithovit allow it to be easily absorbed by plant as well as its Mg content which increases total chlorophyll in plant and finally the release of carbon dioxide in plant tissues due to decomposition of calcium carbonate [29-31] leading to increased photosynthesis which could explain the positive effect of lithovit on vegetative growth.

Conclusion

It can be concluded that there is more promise for the use of nano-chemical approaches in crop production instead of using organic farming and growing public concern to minimize the use of chemicals. The results of this study showed that foliar spray of lithovit plus potassium fertilizer enhanced sweet pepper plants growth, yield quality and quantity.

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Conflict of Interest Statement

The author whose name are listed immediately below certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria, educational grants, participation in speakers' bureaus, membership, employment, consultancies, stock ownership, or other equity interest, and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Significant statement

This study confirmed that the use of potassium fertilizer interacted with lithovit application on sweet pepper led to increase the productivity of pepper plants in terms of quantity and quality.

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