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Influence of different levels of phosphorus supply on growth, yield and quality of some broccoli varieties under sandy soil

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Cultivating broccoli in the newly reclaimed soils faces various problems, such as cultivars, fertilization, low amounts of available nutrients. Phosphorus fertilization can influence the curd initiation and development of broccoli. Phosphorus deficiency causes important nutritional problems; therefore, the heavy application of phosphate fertilizers is a routine work necessary to supply the plant with the required amount of phosphorus. A field experiment was conducted in two successive seasons of (2014/2015 and 2015/2016) at Nubaria (Behira Governorate) Egypt, to study the response of vegetative growth, yield and quality of seven broccoli varieties (Centauro, Southern star, Decathlon H, Calabrais, Green sprouting, Condi and BRπ) to three levels of super phosphate fertilizer (15.5% P₂O₅) (50, 75 and 100 Kg P₂O₅/fed). Results indicated that, the highest vegetative growth of broccoli plants was recorded by Calabrais variety which was supplied by 75 Kg P₂O₅/fed. Furthermore, the highest total yield and quality of broccoli were recorded by Decathlon H variety supplied by 75 Kg P₂O₅/fed in the two seasons.

Keywords: Broccoli, Growth, Phosphorus fertilizer, Varieties, Yield

INTRODUCTION

Broccoli (*Brassica oleracea* L.) belongs to family Brassicaceae and considers a number of cole vegetable crops; which includes Cabbage, Cauliflower, Chinese cabbage, Broccoli, Brussels sprouts and Kohlrabi. It well known that, broccoli has enormous nutritional and medicinal values due to its high contents of vitamins (A, B1, B2, B5, B6 and E), minerals (Ca, Mg, Zn and Fe) and antioxidant substances which prevent the formation of cancer causing agents (Beecher, 1994; Aboul-Nasr and Ragab, 2000). Broccoli and other brassica vegetables have high content of glucosinolates (Zhao et al. 2007) which has cancer-fighting properties. Broccoli buds are rich source of minerals especially K, S, P, Mg and

micro-elements (Aboul-Nasr and Ragab, 2000). In Egypt, broccoli still grown in a very limited scattered areas and the total cultivated area is not exactly known.

Growing broccoli in the newly reclaimed soils is faced by various problems, such as cultivars, fertilization, low amounts of available nutrients and low organic matter content as well as poor hydrophilic, chemical and biological properties of the sandy soil (Hassan et al. 2013)

Many investigators evaluated broccoli varieties under the different environmental conditions (Cong et al. 1995; Grevsen, 1998; Aboul-Nasr and Ragab, 2000, Abou El-Magd et al. 2005 and 2006, El-Helaly, 2006; Hanaa et al. 2010).

Growing broccoli in the newly reclaimed soils is

faced by various problems, such as cultivars, fertilization, low amounts of available nutrients and low organic matter content as well as poor hydrophilic, chemical and biological properties of the sandy soil.

Some investigators dealt with broccoli varieties under different environmental conditions (Liu and Shelp, 1993; Santamaria et al. 1994; Cong et al. 1995; Sanchez et al. 1996; Karitonas and Viskelis, 1999).

Although, phosphorus (P) being one of the most important nutrients, it is influencing growth, productivity and little accumulated by cauliflower and broccoli plants.

Many investigators reported that increasing phosphorus levels improved the plant growth, yield and head quality of broccoli (Brahma and Phookan, 2006 and Islam et al. 2010). Most of the areas that have been put under reclamation and planned to be cultivated in Egypt are sandy and calcareous soils with alkaline pH. Under such conditions, considerable amounts of the available forms of phosphorus are usually subjected to rapid transformation to less available or unavailable forms. Therefore, the heavy application of phosphate fertilizer is a routine work necessary to supply the plant with the required amount of phosphorus (Mehana and Abdul Wahid, 2000).

Phosphorus deficiency causes important nutritional problems in newly reclaimed soils (Abd El-Salam et al., 2005). Phosphorus fertilization can influence the curd initiation and development of broccoli.

Mineral fertilizer improves growth and yield of broccoli due to the role of nitrogen, phosphorus and potassium on the meristematic activity. Many investigators found that using phosphorus fertilizer increased vegetative growth, yield and quality (Sharma et al. 2002; Abou El-Magd et al. 2005 and 2006).

Phosphorus at different levels influenced the yield and yield contributing characters of broccoli, (Brahma and Phookan, 2006 and Islam et al., 2010).

The aim of this investigation is to evaluate and to improve the productivity also the head quality of some cultivars of broccoli under three different levels of phosphorus fertilizer.

MATERIALS AND METHODS

Experimental site location and characterization:

The field experiment was carried out at the experimental station of National Research Centre, at Nubaria district western of Nile Delta, Egypt during the two successive seasons of 2014/2015 and 2015/2016 to study the response of vegetative growth, chemical composition, yield and quality of some broccoli cultivars to apply phosphorus fertilizer different levels.

To identify the initial characteristics of the experimental soil, a surface soil sample (0-30 cm depth) was collected before the beginning of the experiment and subjected to some physical and chemical analyses according to Jackson (1973), Page et al. (1982) and Gee and Bauder (1986), as well as some soil essential nutrients status. The obtained results are presented in Table, 1.

Table 1: Physico-chemical parameters of the investigated soil:

Soil property	Value	Soil property	Value		
Particle size distribution %		pH (1:2.5 soil suspension)	7.78		
		EC (dS m ⁻¹)	9.10		
Sand %	57.72	Soluble ions (meq L⁻¹)			
Silt %	38.56	Ca ⁺⁺	2.37		
Clay %	3.72	Mg ⁺⁺	1.70		
Texture	Sandy	Na ⁺	3.84		
Available Nutrients (mg kg ⁻¹ soil)		K ⁺	1.13		
		HCO ³⁻	1.40		
		Cl ⁻	1.60		
		SO ⁴⁻⁻	8.74		
		N	25.4		
		P	4.21		
K	64.5				
Fe	4.66				
Zn	0.14				
Mn	2.97				

Cultivation and Treatments:

Seeds of broccoli (*Brassica oleracea* L.) were drilled in foam trays of 209 holes in a media consisting of peat moss and vermiculite 1:1. Trays were wetted and warmed under plastic sheets for three days, then kept under plastic tunnel. Normal

nursery treatments were followed till transplants become suitable for transplanting. After 45 days, trays were brought and transplants were planted one besides every dripper through drip irrigation system.

The experiment included twenty one treatments, which were the combination of seven cultivars of broccoli and three different levels of super phosphate fertilizer (15.5% P₂O₅) (50, 75 and 100 Kg P₂O₅ /fed) in a split plot system with three replicates. Varieties were allotted in the main plots and phosphorus fertilizer treatments were arranged in sub plots. The plot area was 9 m² (75 cm. width and 12 meter long). The normal agricultural treatments of growing broccoli were practiced as usually followed in the commercial production.

Treatments were as follows:

Broccoli cultivars:

Centauro	Southern star	Decathlon	H
Calabrai	Green sprouting Condi		BRπ

Phosphorus levels:

50 Kg P₂O₅/fed 75 Kg P₂O₅/fed 100 Kg P₂O₅/fed.

Treatments of three different levels of super phosphate fertilizer (15.5% P₂O₅) were added immediately one time before planting of the transplants of the seven cultivars of broccoli plants.

Samples and analysis:

During the vegetative growth period, samples of five plants were taken at 90 days after transplanting and the following data were recorded:

Vegetative growth (plant height (cm), number of leaves/ plant, leaves fresh weight (g), stem fresh weight (g), plant fresh weight (g) and leaves dry weight(%) = (leaves dry weight (g)/leaves fresh weight (g))x100 and head dry weight(%) = (head dry weight (g)/head fresh weight (g))x100). At harvest time, broccoli heads were harvested and the yield and the quality parameters were recorded: Head weight (g), head diameter (cm.) and total yield (ton/fed.). Samples of leaves and head were oven dried at 70 C^o, and then fine grounded and wet digested for chemical analysis. N, P and K- content were determined according to the methods mentioned by Black (1983), Troug and Mayer (1939) and Brown and Lilleland (1946), respectively.

Phosphorus use efficiency was calculated according to Dobermann (2005);

Phosphorus Use Efficiency = (Y_P-Y₀)/F_P.

Where, Y_P: Crop yield with applied P (Kg fed⁻¹), Y₀: crop yield (Kg fed⁻¹) in a control treatment with no P and F_P: amount of applied P fertilizer (Kg fed⁻¹).

Statistical analysis:

Data of the experiment were subjected to statistical analysis of Least-significant-differences test (LSD) at the confidence level of 5% conducted on means of treatments to measure the considered significantly different according to the procedures of the procedure outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Vegetative growth characteristics:

Cultivars effect:

Data in Table (2) show clearly as a result of the two successive seasons that, the highest plant height (54.42 and 54.43 cm) was recorded by Calabrai cultivar, whereas the highest leaves number (21.67 and 22.45) and fresh weight of leaves (552.47 and 572.78 g) were recorded by Decathlon H.. While, the highest stem (267.45 and 276.93 g) and total plant fresh weight (814.01 and 842.68 g) were recorded by Centauro and BRπ of broccoli plants, respectively. Meanwhile, the lowest vegetative growth characters were recorded by Green sprouting and Southern star varieties. These results were true and similar in the two seasons of study. The wide variation in vegetative growth of the different varieties was also recorded by earlier investigators (Aboul-Nasr and Ragab 2000; Abou El- Magd et al. 2005, 2006 and El-Helaly 2006). Similar results were also recorded by Damato (2000); Damato and Trotta (2000); Sharma (2003); Sterret et al. (2004) and Siomos et al. (2004). These results might be correlated with the gene action of the tested cultivars. Many investigators dealt with broccoli cultivars. These results might be correlated with the gene action of the tested cultivars. Many investigators dealt with broccoli cultivars (Liu and Shelp, 1993), (Sanchez et al. (1996), McCall et al. (1996), Rekowska (1999) and Real Rosas et al. (2002)) of broccoli plants.

Phosphorus fertilizer different levels effect:

Results in Table (2) showed that, the phosphorus fertilizer have a significant effect on vegetative growth characters in the two seasons.

Table (2): Vegetative growth parameters of some broccoli cultivars as affected by different levels of super phosphate fertilizer.

Characters	2014/2015					2015/2016				
	Plant height (cm)	Leaves number	Leaves fresh weight (g)	Stem fresh weight (g)	Plant fresh weight (g)	Plant height (cm)	Leaves number	Leaves fresh weight (g)	Stem fresh weight (g)	Plant fresh weight (g)
Treatments	Effect of cultivars									
Centauro	50.50	13.50	472.14	267.45	739.58	49.77	13.74	477.18	276.93	754.11
Southern star	43.17	12.83	249.71	141.62	660.54	41.04	12.94	239.16	137.19	663.38
DecathlonH	47.27	21.67	552.47	261.54	514.12	45.92	22.45	572.78	269.90	502.48
Calabrais	54.42	21.00	455.81	208.35	391.33	54.43	20.66	457.75	213.27	376.36
Green sprouting	43.33	12.17	257.86	159.34	547.70	41.24	12.15	235.52	151.62	545.77
Condi	45.92	12.33	411.90	184.69	692.04	44.31	12.35	405.49	178.46	717.53
BRπ	45.00	12.83	347.63	185.21	814.01	43.22	12.94	342.35	179.07	842.68
LSD at 5%	0.89	1.75	26.05	28.01	35.34	3.47	1.55	49.15	29.67	32.87
	Effect of phosphorus fertilizers									
100	47.82	14.29	428.19	204.85	633.04	46.58	14.67	426.79	203.87	630.66
75	49.82	16.57	450.77	233.72	684.49	48.96	16.53	453.66	238.23	691.88
50	43.61	14.71	298.55	164.94	463.49	41.57	14.75	289.65	160.66	450.32
LSD at 5%	1.83	0.79	29.11	12.36	24.45	2.35	1.53	62.34	28.97	41.89

The highest vegetative growth characters were recorded by plants which supplied with 75 Kg P₂O₅ /fed of phosphorus fertilizer. These findings were similar and true in both seasons of study. On the contrary, the lowest values of vegetative growth characters were recorded by 50 Kg P₂O₅ /fed treatment. These results held well in the two experimental seasons. This result may be due to the role of Phosphorus in which converted the unavailable form of phosphorus to available form for plant absorption, which in turn reflected in increasing the vegetative growth of broccoli plants. This result are in harmony with those reported by EL-Gamal (1996), on potato, Saber and Gomaa (1993) and Barkat and Gabr (1998), on tomato, Abd-EL-Fattah and Sorial (1998), on lettuce and Brahma and Phookan (2006) and Islam et al. (2010), on broccoli, which mentioned that, adding Phosphorus led to a significant increase in the vegetative growth of plants.

Interaction effect:

The obtained data revealed that, the interaction between treatments (Table 3) significantly affected all growth parameters. These results held well in the two experimental seasons. Generally, it could be summarized that, the highest vegetative growth was obtained by the treatment of Decathlon H and Calabrais with 75 Kg P₂O₅ /fed of phosphorus fertilizer. On the contrary, the lowest amount of vegetative growth characterizes was found by using Southern star variety with 50 Kg P₂O₅ /fed of phosphorus fertilizer.

Nitrogen, Phosphorus and Potassium content in leaves and head of broccoli plants:

Cultivars effect:

Data in Table (4) show clearly that, the different varieties have a significant effect on N, P and K amount in leaves and head of broccoli plants except for K content in head of broccoli in the first season. The highest N content in leaves (2.24 and 2.30%), respectively, of broccoli plants was recorded by Southern star cultivar in the two seasons, whereas, the highest P content in leaves (0.18 and 0.19 %), respectively, of broccoli plants was recorded by Condi variety, furthermore, the highest amount of K content in leaves (0.97 and 1.00 %) respectively, of broccoli plant was found by Calabrais varieties in the both growing seasons. Furthermore, the highest values of N, P and K content in head (2.16 and 2.19%), (0.25 and 0.28%) and (1.17 and 1.24%), respectively, of broccoli plants were found by Decathlon H in both seasons of study. Meanwhile, the lowest values of N and P content in leaves (1.48 and 1.53%) and (0.05%) respectively, of broccoli were found by Green sprouting in both seasons and the lowest value of K in leaves (0.62 and 0.58%) was reported by Centauro variety. On other hand, the lowest amount of N, P and K content in heads of broccoli were found by using Centauro in both seasons. Except for N content in head (1.72 %) was recorded by Calabrais variety in the second season. These results might be correlated with the gene action of the tested cultivars. Many investigators dealt with broccoli Rekowska (1999)

Table (3): Interaction between phosphorus fertilizer levels and cultivars effect on vegetative growth parameters of some broccoli cultivars.

Characters		2014/2015					2015/2016				
		Plant height (cm)	Leaves number	Leaves fresh weight (g)	Stem fresh weight (g)	Plant fresh weight (g)	Plant height (cm)	Leaves number	Leaves fresh weight (g)	Stem fresh weight (g)	Plant fresh weight (g)
Effect of the interaction											
Centauro	100	50.00	13.50	385.48	248.61	634.09	49.17	13.74	387.39	254.52	641.91
	75	55.00	14.00	606.47	331.39	937.86	55.12	14.33	610.37	353.02	963.39
	50	46.50	13.00	424.46	222.34	646.80	45.01	13.14	433.77	223.25	657.03
Southern star	100	47.00	13.00	257.62	139.34	396.96	45.60	13.14	235.23	134.48	369.72
	75	44.00	13.00	321.97	176.65	498.62	42.03	13.14	311.81	168.88	480.69
	50	38.50	12.50	169.56	108.86	278.42	35.49	12.55	170.45	108.21	278.66
Decathlon H	100	47.75	19.50	614.47	251.59	866.06	46.49	20.88	619.89	258.06	877.95
	75	52.00	25.50	618.40	313.25	931.65	51.55	25.02	664.56	331.44	996.00
	50	42.05	20.00	424.55	219.78	644.33	39.71	21.47	433.88	220.21	654.09
Calabrais	100	51.75	16.50	435.18	214.38	649.56	51.25	17.31	446.53	213.78	660.31
	75	62.50	24.00	606.19	276.19	882.38	64.05	23.23	610.04	287.34	897.37
	50	49.00	22.50	326.08	134.47	460.54	47.98	21.45	316.70	138.68	455.38
Green sprouting	100	44.75	12.00	307.35	183.03	490.38	42.92	11.95	294.42	176.48	470.89
	75	42.75	12.50	228.82	139.85	368.67	40.54	12.55	200.97	135.09	336.05
	50	42.50	12.00	237.40	155.16	392.55	40.25	11.95	211.17	143.30	354.47
Condi	100	46.00	11.50	576.14	168.99	745.12	44.41	11.36	574.27	159.76	734.03
	75	48.00	14.00	419.93	224.90	644.83	46.79	14.33	428.39	226.30	654.69
	50	43.75	11.50	239.62	160.20	399.82	41.73	11.36	213.82	149.30	363.12
BRπ	100	47.50	14.00	421.11	228.01	649.12	46.20	14.33	429.78	230.00	659.79
	75	44.50	13.00	353.61	173.82	527.43	42.63	13.14	349.47	165.52	514.98
	50	43.00	11.50	268.18	153.80	421.97	40.84	11.36	247.80	141.69	389.48
LSD at 5%		4.84	2.09	77.03	32.69	23.15	5.17	3.88	83.36	65.12	31.12

Table (4): Phosphorus fertilizer treatments effect on chemical composition of some broccoli cultivars.

Characters	2014/2015						2015/2016					
	Leaves			Head			Leaves			Head		
	N%	P%	K%	N%	P%	K%	N%	P%	K%	N%	P%	K%
Treatments	Effect of cultivars											
Centauro	2.07	0.06	0.62	1.71	0.07	0.95	2.23	0.07	0.58	1.80	0.09	0.98
Southern star	2.24	0.07	0.95	1.80	0.12	1.10	2.30	0.08	0.95	1.91	0.13	1.16
Decathlon H	1.86	0.09	0.76	2.16	0.25	1.17	1.99	0.10	0.75	2.19	0.28	1.24
Calabrais	2.00	0.15	0.97	1.76	0.21	0.97	2.09	0.16	1.00	1.72	0.24	1.01
Green sprouting	1.48	0.05	0.78	1.74	0.10	0.98	1.53	0.05	0.77	1.84	0.11	1.01
Condi	2.13	0.18	0.87	2.01	0.25	1.08	2.30	0.19	0.88	2.04	0.27	1.13
BRπ	1.89	0.11	0.85	2.08	0.09	0.97	2.02	0.12	0.86	2.16	0.11	1.00
LSD at 5%	0.12	0.03	0.09	0.08	0.02	0.06	0.09	0.03	0.07	0.19	0.03	NS
	Effect of phosphorus fertilizers											
100	1.80	0.11	0.82	1.86	0.15	1.02	1.92	0.10	0.83	1.96	0.17	1.07
75	2.10	0.10	0.84	2.02	0.16	1.03	2.19	0.11	0.83	2.05	0.18	1.08
50	1.95	0.11	0.82	1.80	0.17	1.04	2.09	0.12	0.83	1.85	0.19	1.08
LSD at 5%	0.11	NS	NS	0.08	NS	NS	0.06	NS	NS	0.05	NS	NS

and Real Rosas et al. (2002), of broccoli plants.

Phosphorus fertilizer different levels effect:

Results in Table (4) showed that, the phosphorus fertilizer have a non-significant effect on N, P and K content in the two seasons except for N content in leaves and heads of broccoli plants of both two seasons of study. Actually, the highest values of N and K contents were found by using 75 Kg P₂O₅ /fed of phosphorus fertilizer in both seasons. Furthermore, the highest value of P content of leaves of broccoli was reported by treatment of 50 Kg P₂O₅ /fed of phosphorus fertilizer. Moreover, the highest value of N content was found by 75 Kg P₂O₅ /fed of phosphorus fertilizer and the highest values of P and K contents in heads of broccoli plants were recorded by using 50 Kg P₂O₅ /fed of phosphorus fertilizer. These results held well in the two experimental seasons. These results are in harmony with those reported by Abd-EL-Fattah and Mervat (1998), on lettuce and Brahma and Phookan (2006) and Islam et al. (2010) on broccoli.

Interaction effect:

The obtained data in Table (5) showed that the interaction treatments had no significant effected on all N, P and K contents. These results held well in the two experimental seasons. Generally, it could be summarized that, the

highest amount of N content was found by using Southern star variety with 75 Kg P₂O₅ /fed of phosphorus fertilizer in both seasons. Moreover, the highest value of P content was recorded by using Conde variety with 100 Kg P₂O₅ /fed. Furthermore, the highest value of K content was found by using Southern star with 75 Kg P₂O₅ /fed. These results held well in the two seasons of study. On the other hand, the highest value of N content was found by BRπ variety with 75 Kg P₂O₅ /fed in both seasons. Moreover, the highest value of P content was recorded by Conde variety with 50 Kg P₂O₅ /fed and the highest value of K content was found by Decathlon H with 75 Kg P₂O₅ /fed in both seasons. On the contrary, the lowest value N content of leaves of broccoli plants was found by Green sprouting variety with 75 Kg P₂O₅ /fed and the lowest values of P and K contents of leaves of broccoli plants were recorded by Centauro variety with 100 Kg P₂O₅ /fed in both seasons. Furthermore, the lowest value of N content of head of broccoli was found by Calabrais with 50 Kg P₂O₅ /fed, meanwhile, the lowest values of K content were found by using BRπ variety with 50 Kg P₂O₅ /fed. These results held well in the two seasons of study.

Yield and its quality:

Cultivars effect:

Data in Table (6) show clearly that, the

highest head diameter (14.20 and 14.57 cm), respectively in the two seasons, of broccoli plants was recorded by Green sprouting cultivar. Whereas, the highest head fresh weight (363.20

and 370.87 g) and total yield of broccoli plants (4.36 and 4.45 ton fed⁻¹) were recorded by Centauro cultivar.

Table (5): Interaction between phosphorus fertilizer levels and cultivars effect on chemical composition of some broccoli cultivars.

Characters		2014/2015						2015/2016					
		Leaves			Head			Leaves			Head		
		N%	P%	K%	N%	P%	K%	N%	P%	K%	N%	P%	K%
Effect of the interaction													
Centauro	100	1.58	0.02	0.48	1.61	0.06	0.93	1.65	0.01	0.42	1.69	0.07	0.96
	75	2.02	0.07	0.65	1.64	0.06	0.93	2.17	0.07	0.62	1.72	0.09	0.96
	50	2.60	0.10	0.72	1.89	0.10	0.99	2.86	0.11	0.71	1.99	0.11	1.03
Southern star	100	1.59	0.09	0.90	1.89	0.16	1.10	1.66	0.10	0.92	2.02	0.18	1.16
	75	3.48	0.04	1.14	1.69	0.10	1.05	3.51	0.04	1.12	1.78	0.11	1.10
	50	1.64	0.09	0.81	1.81	0.10	1.15	1.72	0.10	0.81	1.92	0.11	1.22
Decathlon H	100	2.14	0.07	0.81	2.02	0.23	1.16	2.32	0.07	0.81	2.17	0.26	1.23
	75	1.64	0.13	0.71	2.29	0.30	1.23	1.72	0.14	0.69	2.26	0.31	1.31
	50	1.81	0.08	0.76	2.17	0.23	1.12	1.92	0.09	0.75	2.15	0.26	1.18
Calabrais	100	1.79	0.21	0.99	2.12	0.21	1.01	1.90	0.20	1.03	2.11	0.24	1.05
	75	2.27	0.14	0.99	2.22	0.18	0.94	2.29	0.16	1.03	2.17	0.20	0.97
	50	1.94	0.11	0.93	0.93	0.25	0.97	2.08	0.12	0.96	0.88	0.29	1.00
Green sprouting	100	1.61	0.07	0.85	1.74	0.12	1.00	1.69	0.07	0.86	1.84	0.13	1.04
	75	1.34	0.03	0.69	1.84	0.11	0.99	1.36	0.03	0.67	1.96	0.12	1.03
	50	1.49	0.06	0.79	1.64	0.06	0.94	1.54	0.06	0.79	1.72	0.09	0.97
Condi	100	2.09	0.22	0.92	1.61	0.13	0.95	2.26	0.21	0.94	1.69	0.14	0.98
	75	2.02	0.15	0.85	2.14	0.25	1.10	2.17	0.17	0.86	2.15	0.29	1.16
	50	2.27	0.18	0.83	2.29	0.38	1.18	2.47	0.20	0.84	2.27	0.39	1.25
BRπ	100	1.82	0.06	0.81	2.03	0.12	1.00	1.94	0.06	0.81	2.19	0.13	1.04
	75	1.96	0.12	0.82	2.31	0.11	1.00	2.10	0.13	0.83	2.29	0.12	1.04
	50	1.89	0.16	0.91	1.89	0.04	0.91	2.02	0.18	0.93	2.02	0.07	0.93
LSD at 5%		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table (6): Effect of phosphorus fertilizers on yield and its quality of some broccoli cultivars.

Characters	2014/2015					2015/2016				
	Head diameter (cm)	Head fresh weight (g)	Total yield (ton/fed)	Leaves dry weight %	Head dry weight %	Head diameter (cm)	Head fresh weight (g)	Total yield (ton/fed)	Leaves dry weight %	Head dry weight %
Treatments	Effect of cultivars									
Centauro	13.62	363.20	4.36	12.03	5.17	13.87	370.87	4.45	11.98	5.22
Southern star	13.07	241.61	2.90	11.29	4.95	13.22	226.18	2.71	11.10	4.96
Decathlon H	12.55	305.24	3.66	11.97	5.54	12.60	301.91	3.62	11.91	5.67
Calabrais	7.97	166.12	1.99	12.11	6.50	7.15	153.02	1.84	12.08	6.80
Green sprouting	14.20	295.83	3.55	11.92	5.42	14.57	290.71	3.49	11.85	5.52
Condi	12.78	233.12	2.80	11.69	5.11	12.88	229.42	2.75	11.58	5.15
BRπ	14.03	275.69	3.31	10.74	5.42	14.37	266.74	3.20	10.45	5.52
LSD at 5%	1.18	47.37	0.56	0.52	0.35	1.65	33.87	0.69	0.97	0.66
	Effect of phosphorus fertilizers									
100	13.69	304.09	3.65	11.57	5.52	13.96	300.53	3.61	11.44	5.64
75	13.24	304.55	3.65	11.89	5.50	13.43	301.08	3.61	11.81	5.62
50	10.87	197.43	2.37	11.57	5.31	10.61	186.46	2.24	11.44	5.39
LSD at 5%	0.92	28.47	0.34	NS	0.14	0.37	36.34	0.17	NS	NS

Furthermore, the highest amount of dry weight of leaves (%) and heads (%) of broccoli plant was found by Centauro and Calabrais varieties. Meanwhile, the lowest head fresh weight (166.12 and 153.02 g), diameter (7.97 and 7.15 cm) and total yield (1.99 and 1.84 ton fed⁻¹) of broccoli plants were recorded by Calabrais cv.. However, in the two seasons results showed that, the lowest amount of leaves dry weight (%) (10.74 and 10.45) was found by BRπ variety and the lowest value of head dry weight (%) (4.95 and 5.22) was recorded by Southern star variety. These results were true and similar in the two seasons of study. These results might be correlated with the gene action of the tested cultivars. Many investigators dealt with broccoli Rekowska (1999) and Real Rosas et al.(2002), of broccoli plants.

Phosphorus fertilizer different levels effect:

Results in Table (6) showed that, the phosphorus fertilizer have a significant effect on yields and its quality characters in the two seasons except for leaves dry weight (%) in the first season and dry weight of head and leaves

(%) in the second one. The highest total yield and its quality (head fresh weight (g) and diameter (cm)) as well as dry weight of head and leaves (%) of broccoli plants characters were recorded by plants which supplied with 75 and 100 Kg P₂O₅ /fed of phosphorus fertilizer application. These findings were similar and true in both seasons of study. On the other hand, the lowest values of yield and its quality characters were recorded by 50 Kg P₂O₅ /fed treatment. These results held well in the two experimental seasons. This result may be due to the role of Phosphorus in which converted the unavailable form of phosphorus to available form for plant absorption, which in turn reflected in increasing the vegetative growth of broccoli plants. This result are in harmony with those reported by Abd-EL-Fattah and Sorial (1998), on lettuce and Brahma and Phookan (2006) and Islam et al. (2010), on broccoli, which mentioned that, adding Phosphorus led to a significant increase in the yield characters of plants.

Table (7): Effect of the interaction between phosphorus fertilizers and cultivars on yield and its quality of some broccoli cultivars.

Characters		2014/2015					2015/2016				
		Head diameter (cm)	Head fresh weight (g)	Total yield (ton/fed)	Leaves dry weight %	Head dry Weight %	Head diameter (cm)	Head fresh weight (g)	Total yield (ton/fed)	Leaves dry weight %	Head dry weight %
Effect of the interaction											
Centauro	100	15.80	440.27	5.28	12.24	5.51	16.47	462.59	5.55	12.23	5.62
	75	15.20	466.39	5.60	12.28	4.85	15.76	493.67	5.92	12.28	4.84
	50	9.85	182.94	2.20	11.57	5.16	9.39	156.36	1.88	11.43	5.20
Southern star	100	13.80	250.87	3.01	11.19	5.07	14.09	237.20	2.85	10.99	5.10
	75	13.35	275.13	3.30	12.24	4.89	13.56	266.07	3.19	12.23	4.88
	50	12.05	198.82	2.39	10.44	4.90	12.01	175.27	2.10	10.09	4.90
Decathlon H	100	11.25	232.88	2.79	11.92	5.61	11.06	215.80	2.59	11.85	5.74
	75	15.30	473.40	5.68	12.25	5.22	15.88	502.02	6.02	12.24	5.28
	50	11.10	209.45	2.51	11.73	5.81	10.88	187.91	2.25	11.63	5.98
Calabrais	100	8.85	165.50	1.99	11.12	6.81	8.20	135.62	1.63	10.90	7.17
	75	8.55	189.20	2.27	12.50	6.84	7.84	163.82	1.97	12.54	7.21
	50	6.50	143.67	1.72	12.71	5.85	5.41	159.64	1.92	12.79	6.03
Green sprouting	100	16.20	424.36	5.09	11.97	5.50	16.95	443.66	5.32	11.91	5.61
	75	12.80	228.08	2.74	12.24	5.60	12.90	210.09	2.52	12.24	5.73
	50	13.60	235.06	2.82	11.55	5.18	13.85	218.39	2.62	11.41	5.23
Condi	100	15.55	284.36	3.41	11.79	4.89	16.17	277.05	3.32	11.69	4.89
	75	13.50	264.17	3.17	11.19	5.33	13.74	253.03	3.04	10.99	5.41
	50	9.30	150.84	1.81	12.10	5.12	8.74	158.17	1.90	12.06	5.16
BRπ	100	14.40	330.38	3.96	10.79	5.27	14.81	331.82	3.98	10.50	5.34
	75	14.00	235.46	2.83	10.52	5.80	14.33	218.86	2.63	10.19	5.97
	50	13.70	261.22	3.13	10.91	5.19	13.97	249.52	2.99	10.65	5.25
LSD at 5%		2.42	75.33	0.9	0.85	0.37	1.69	52.14	0.63	0.62	0.29

Table (8): Means of yield (Kg/fed) of some broccoli cultivars and phosphorus utilization efficiency (PUE) as influenced by interaction between cultivars and different P fertilization rates

Characters		2014/2015		2015/2016	
		Biomass yield ton/fed	PUE Kg yield/Kg P ₂ O ₅	Biomass yield ton/fed	PUE Kg yield/Kg P ₂ O ₅
Effect of the interaction					
Centauro	100	12.57	9.17	13.21	9.62
	75	13.33	13.24	14.10	14.00
	50	5.24	3.67	4.48	1.76
Southern star	100	7.17	2.71	6.79	2.24
	75	7.86	4.53	7.60	4.06
	50	5.69	2.46	5.00	0.90
Decathlon H	100	6.64	1.12	6.17	0.87
	75	13.52	10.67	14.33	12.04
	50	5.98	0.91	5.36	0.11
Calabrais	100	4.74	0.74	3.88	0.52
	75	5.40	1.87	4.69	1.77
	50	4.10	0.19	4.57	2.42
Green sprouting	100	12.12	6.91	12.67	6.97
	75	6.52	1.75	6.00	0.40
	50	6.71	3.01	6.24	1.08
Condi	100	8.12	3.96	7.90	3.90
	75	7.55	4.52	7.24	4.32
	50	4.31	0.30	4.52	1.05
BRπ	100	9.43	3.09	9.48	3.31
	75	6.74	0.53	6.26	0.12
	50	7.45	2.23	7.12	1.90
LSD at 5%		2.14	1.89	1.50	1.32

Interaction effect:

The obtained data in Table (7) showed that the interaction between cultivars and phosphorus application significantly affected all yield parameters. These results held well in the two experimental seasons. Generally, it could be summarized that, the highest head diameter (cm) was obtained by Green sprouting variety with 100 Kg P₂O₅ /fed of phosphorus application and the highest amount of total yield (ton /fed) and head diameter (cm) was reported by using Decathlon H variety with 75 Kg P₂O₅ /fed of phosphorus application. Furthermore, the highest amount of dry weight of leaves and heads (%) was found by treatment of Calabrais variety with 50 and 75 Kg P₂O₅ /fed of phosphorus in the two seasons. On the contrary, the lowest amount of head fresh weight (g) and diameter (cm) as well as total yield (ton/fed) was found by using Calabrais variety with 50 and 75 Kg P₂O₅ /fed of phosphorus

application. Moreover, the lowest amount of leaves dry weight (%) was recorded by using Southern star variety with 50 Kg P₂O₅ /fed of phosphorus and the lowest amount of head dry weight (%) of broccoli was reported by treatment of Centauro variety with 75 Kg P₂O₅ /fed of phosphorus. These results held well in the two seasons of study.

Phosphorus fertilizer-use efficiency (PUE):

The highest mean value of fertilizer use efficiency was 13.24 kg yield occurred with Decathlon H with 75 Kg P₂O₅ /fed, while the lowest mean value was found with Calabrais cultivar and 50 Kg P₂O₅ /fed. Based on the presented data in Table (8), it can be noticed that Decathlon H achieved highly significant values for yield and its components and it is followed by Centauro compared with the other cultivars of broccoli plants. This increase in yield may be referred to the fact that phosphorus is a constituent of many compounds in plants, i.e.

phospholipids, nucleotides and Co-enzymes as reported by Russell (1988).

CONCLUSION

Phosphorus (P) is an essential plant nutrient required for optimum crop production. Plants need phosphorus for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division. Adequate phosphorus results in rapid growth and early maturity. Frequently, phosphorus will enhance the quality of vegetative growth. On the basis of obtained results, it can be concluded that the application of phosphorus at 75 Kg P₂O₅ /fed shows the best result with Calabrais and Decathlon H variety for there for it is recommended for off-season broccoli production under the climatic conditions of Nubaria district western of Nile Delta, Egypt

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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