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Effect of some Inorganic NPK Fertilization Treatments on Cauliflower

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ABSTRACT

Two successive winter field experiments were performed at 2015/2016 and 2016/2017 seasons at Vegetables Research Station, Faculty of Agric., Mansoura Univ., Egypt to study the effect of different fertilization treatments in terms of NPK fertilizer ratios and rates on growth, yield and quality of cauliflower (cv. Fargo) cultivated under silty clay loam soil conditions by furrow irrigation system. Four NPK fertilizer ratios (1.0:1.0:1.0; 1.0:1.0:0.5; 1.0:0.5:1.0 and1.0:0.5:0.5) with three fertilizer rates (50, 100 and 150 kg fed^{-1}) as a soil application were tested. Each experiment comprised of 12 treatments and were designed as split plots and replicated three times in a randomized complete blocks design. The obtained data of this investigation clearly demonstrated that, all studied parameters such as vegetative growth characters (*i.e.*, plant height and leaves number, plant leaf area, leaves fresh weight and leaves dry matter percentage), leaves chemical composition (*viz.* N, P, K, chlorophyll a, chlorophyll b and carotenoids contents), Curds yield and its components (*i.e.* curd weight, curd diameter, curds yield/fed. and curds dry matter percentage) and curds chemical quality attributes (*namely,* Vitamin C, TSS, N, P and K contents) had significantly been influenced with NPK fertilizer ratios, rates and their interactions in both seasons. Concerning the effect of NPK fertilizer ratios, 1.0:0.5:1.0 ration gave the highest values for all forecited characters, whereas 1.0:1.0:0.5 ratio recorded the lowest values in this respect. Regarding the impact of NPK fertilizer rates, the rate of 150 kg fed^{-1} achieved the maximum records for all mentioned parameters compared with other two fertilizer rates. Respecting the influence of interaction treatments, both commercial inorganic NPK fertilization treatments resulted from whether fertilizer ratio of 1.0:0.5:1.0 or 1.0:1.0:1.0 combined with 150 kg fed^{-1} fertilization rate recorded the best means for all aforementioned studied traits as compared with other all NPK fertilization treatments in this regard. Hence, it could be recommended that fertilization of cauliflower crop (cv. Fargo) with commercial inorganic NPK fertilizers blend resulted from combination of NPK fertilizer ratio 1.0:0.5:1.0 with the fertilization rate of 150 kg fed^{-1} in order to obtain high parameters of vegetative growth, yield and quality under similar research conditions.

Keywords: NPK fertilizer ratios and rates, NPK fertilization treatments, Cauliflower, Growth, Yield and Curds chemical quality.

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis* L) as a queen of the winter cole vegetable crops is one of the members of Brassicaceae or Cruciferae family. It is mostly consumed cooked, fried, boiled and pickled. Cauliflower has numerous nutritional and medicinal values because of its high components of vitamins *i.e.* B_5, B_6, B_9, C, E, K and β-carotene (Kurilich *et al*., 1999) which are necessary and needed for fat, protein and carbohydrate metabolism; dietary fibers which represented approximately 50 % on the basis of total dry matter weight, comprising nearly 40 % non-starch polysaccharides, that is mainly 16 % cellulose and 13 % lignin (Fermenia *et al*., 1999 and Rahn *et al*., 1999) and minerals such as K, Mg, P, Zn and Fe. Also, cauliflower contains polyphenolic components (flavonoids) such as myricetin and quercetin with high antioxidant activity avoid the formation of cancer (Ramarathnam *et al*., 1997; Miean and Mohamed, 2001 and Sousa *et al*., 2008). Moreover, cauliflower as one of the other cruciferous vegetables is the richest source of glucosinolates in the human diet which can protect different human organs against cancer (Verhoeven *et al*., 1996 and World Cancer Research Fund, 1997).

In Egypt, the total cultivated area in 2017 of a cauliflower crop was approximately 10398 fed. The total yield of this cultivated area was 124984 ton, with an average of 12.02 ton/fed. (FAO, 2018).

Soil minerals do not include sufficient and available amounts of N, P and K nutrients. These essential major elements may be lost from the soil-plant system via various paths, containing volatilization, denitrification, leaching (mostly NO_3^--N) and soil erosion (chiefly NH_4^+-N) with nitrogen or in fixed and adsorbed form in the case of P or in fixed form within the layers of some types of clay minerals or in unavailable form inside the crystalline construction of soil minerals with K (Gianquinto *et al*., 2013). Therefore, deficient or excessive or imbalanced quantities of NPK nutrients will result in numerous physiological disorders and some biotic stresses which lead to unsatisfactory growth, yield and quality of most vegetable crops (Elahi *et al*., 2015).

The amount of applied fertilizers in optimal limits for vegetable crops may differ throughout a wide range depending on climate, soil, methods of cultivation and plant density. The proper plant nutrition which containing typical NPK fertilizer quantities, appropriate forms and suitable application times throughout the growing season are considered one of the most important ingredients affecting plant growth, yield and quality of different vegetable crops.

Nitrogen (N) is necessary for all plant metabolic processes. It is essential major component of many important organic compounds such as amino acids, amino enzymes, purine bases, nucleotides, nucleic acids (DNA and RNA), proteins, hormones, some B complex vitamins (e.g. thiamine, riboflavin, niacin, pantothenic acid and folic acid) and chlorophyll molecules, which are very needed components for high plant growth, development and health. In addition to its vital role in amelioration of plant growth characteristics, it enhances the formation of great plant flowering and set fruiting as well as assimilation inflow into edible plant parts (Jones *et al*., 1991; Marschner, 2012 and Gianquinto *et al*., 2013). Phosphorus (P) is an essential major component of certain enzymes and proteins, nucleic acids (DNA and RNA), phytin and adenosine triphosphate (ATP). ATP molecules are involved in diverse energy transfer reactions. Phosphorus is necessary for energy transfer and storage into plant metabolism. Also, P is combined with nucleotides, coenzymes, phospholipids, carbohydrates and storage compounds. Referring to its necessary role into energy

metabolism; P is needed for respiration, photosynthesis and biosynthesis of various organic compounds, containing nucleic acids and sugars. In addition, P is required for formation of strong and efficient plant root system (Jones *et al.*, 1991; Marschner, 2012 and Gianquinto *et al*., 2013). Hence, adequate availability of phosphorus in the growing medium is decisive for high vegetable yield and quality.

Potassium (K) is an essential element for plant life, since the content of plant tissues of K is higher than of other major cations. In despite of that K is omnipresent, very mobile in the plant and considered the most important cation in numerous physiological and biochemical processes, it is not a constituent of organic compounds. K has different substantial regulatory roles in plant development including; synthesis of cellulose and lignin that required for production of cellular structural ingredients, promotion of photosynthesis, synthesis of carbohydrates and proteins needed for several plant metabolic purposes, speeding up translocation of assimilates from the leaves to plant roots and enhancement of its accumulation in storage tissues, which in turn improves quality parameters. As well, K regulates water loss from plants, maintains the turgor pressure of its cells and the closing and opening of its stomata, thus it improves water-use efficiency. Moreover, potassium also participates in the activation of more than important 50 enzymatic reactions (Jones *et al.*, 1991; Marschner, 2012 and Gianquinto *et al*., 2013). Therefore, application of appropriate quantities of K is a prerequisite for high vegetables productivity and quality.

Many investigators studied the effect of N, P and K either alone or in combinations with each other from recommendation doses of them or with some micro-nutrients especially boron on vegetative growth and productivity of some cruciferous vegetables and stated that increasing NPK fertilizer rates or doses increased plant growth, yield and quality (Cutcliffe and Munro, 1976; Csizinszky, 1996; Wenqiang *et al.,* 2004; Dhakal *et al.,* 2009; Li *et al.,* 2011; Elahi, 2015; Filho *et al.,* 2015; Sharma, 2016 and Metwaly, 2017) on cauliflower, (Islam *et al.,* 2010; El-Helaly, 2012; Neethu *et al.,* 2015; Singh *et al.,* 2015; Doklega and Abd El-Hady, 2017) on broccoli. On the other hand, very few investigations have been made to study the influence of different blends of commercial inorganic NPK fertilizers resulting from combinations between NPK fertilizer ratio and rates on growth and field performance of either current or recent cauliflower cultivars.

Consequently, the objective of this investigation was to study the effect of different inorganic NPK fertilizer ratio, rates and their interactions on cauliflower growth, productivity and quality and determination of commercial NPK fertilizers blend that is effective in this connection.

MATERIALS AND METHODS

Two successive field experiments were conducted in 2015/2016 and 2016/2017 seasons at Vegetables Research Station, Faculty of Agric., Mansoura Univ., Egypt to investigate the impact of different fertilization treatments in terms of NPK fertilizer ratio, rates and their combinations on growth, yield and quality of cauliflower (cv. Fargo) cultured under silty clay loam soil conditions with furrow irrigation system. Some physical and chemical properties of the used agricultural soil are presented in Table (1).

Table 1. Some physical and chemical properties of the experimental soil during 2015/2016 (1st) and 2016/2017 (2nd) seasons

Soil characters	Clay %	Silt %	Sand %	Texture	pH	EC (dSm^{-1})	Organic matter %	$CaCO_3$ %	Available (mg kg^{-1})		
									N	P	K
1st season	24.07	39.23	36.70	Silty clay loam	8.21	1.51	1.94	3.39	49.7	5.95	168.4
2nd season	24.17	39.29	36.54	Silty clay loam	8.17	1.63	1.97	3.48	51.4	6.14	173.8

Commercial inorganic NPK fertilizers *viz*, ammonium sulphate (20.5 % N), granulated single calcium superphosphate (12.5 % P_2O_5) and potassium sulphate (50 % K_2O) were used. The applied quantities of fertilizers for all fertilization treatments were accurately computed and listed in Table (2). The total amounts of granulated single calcium superphosphate and farmyard manure at 20 m^3/fed. were completely added for each experimental unit during soil preparation. Potassium sulphate fertilizer was applied in two equal doses, the first one was at transplanting date and the second one was 30 days after transplanting. Ammonium sulphate fertilizer was also added into two equal batches at 30 and 60 days of transplanting date. Four inorganic NPK fertilizer ratios, namely 1.0:1.0:1.0; 1.0:1.0:0.5, 1.0:0.5:1.0 and 1.0:0.5:0.5 were used at the rates of 50, 100 and 150 kg/fed. of each.

Transplants of cauliflower (cv. Fargo) of 45 days old were transplanted on 4th and 7th of November in the first and second seasons, respectively, on one side of each ridge 50 cm apart. The plot area was 10.5 m^2, containing 5 ridges of 70 cm width and 3 m length. The other cultural practices and crop protection were done according to Ministry of Agriculture Recommendations, except to the variables under study.

Experimental design:

The experiments were performed as split-plots in a randomized complete blocks design with three replications. Whereat, NPK fertilizer ratio were arranged in the main plots, whereas NPK fertilizer rates were ranked in the sub-plots.

Recorded parameters:

In both seasons, at 105 days old from transplanting date, five plants were taken randomly from each experimental unit to measure the following parameters:

1- Vegetative growth characters:

The measured vegetative growth parameters were plant height, plant leaves No., leaf area/plant, leaves fresh weight/plant and leaves dry matter percentage.

2- Leaves chemical components:

The content of chlorophyll a, chlorophyll b and total carotenoids on the basis of fresh weight and

percentage of nitrogen, phosphorus and potassium on the basis of dry matter weight were estimated in leaves according to AOAC (1990).

Table 2. Inorganic commercial NPK fertilizers (kg fed^{-1}) used for each fertilization treatment.

Fertilization treatments		commercial fertilizers		
Fertilizer ratio	Fertilizer rates (kg fed^{-1})	Ammonium sulphate (20.5 % N)	Calcium superphosphate (12.5 % P_2O_5)	Potassium sulphate (50 % K_2O)
1 :1 :1	50	81	133	33
	100	163	267	67
	150	244	400	100
1:1:0.5	50	98	160	20
	100	195	320	40
	150	293	480	60
1:0.5:1	50	98	80	40
	100	195	160	80
	150	293	240	120
1:0.5:0.5	50	122	100	25
	100	244	200	50
	150	366	300	75

3- Curds yield and its components:

The curd of each cauliflower plant was cut, trimmed to marketable form, and used to determine curd fresh weight; curd diameter which was measured across the widest part of the curd, curds yield/fed., which was computed by multiply average curd weight by no. of curds/fed. and curd dry matter percentage, by drying 100 g of curd samples at 70 ^{0}C in a drying oven until a constant weight.

4- Curds chemical quality:

Vitamin C and total soluble (TSS) content of fresh curd samples and percentage of N, P and K of dry curd samples were estimated according to AOAC (1990).

Small portions of cauliflower leaves and curds were washed carefully by diluted HCl (0.001 N), followed by a tap water and finally two successive times with distilled water. The leaves and curd pieces were dried at 70 ^{o}C for constant weight, and grounded in stainless steel mill to pass through 0.5 mm sieve. Based on Jones *et al*., (1991) method, the leaves and curd samples (0.2 g) was subjected to wet ashing, then filtered through filter paper and thereafter transferred quantitatively into 100 ml volumetric flask and completed to mark with distilled water. The digestive product was transferred to a dark glass container with sealed cover and kept refrigerated for the minerals analysis. Nitrogen (N) concentration; was determined using the micro-Kjeldahl method (AOAC, 1990).

Phosphorus (P) concentration; was estimated using Spectrophotometer (Spectro UV-VIS AUTO UV-2602). Potassium (K) concentration was determined using Flame photometer (Jenway, PFP7).

Statistical analysis:

The obtained data were subjected to statistical analysis using the analysis of variance (ANOVA) procedure as reported by Gomez and Gomez (1984). Least significant difference (LSD) test at probability of 5 % level was used to compare the differences among treatment means as described by Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

1-Vegetative growth characters:

Data of Table 3 reveal that each of plant height, average leaves No. and leaves area/plant, plant leaves fresh weight and leaves dry matter % were significantly influenced by different fertilizer ratio of inorganic NPK fertilizers, without significant differences between the fertilizer ratio of 1:0.5:1 and 1:1:1 one in both seasons, respectively. In this connection, the highest values of all previous parameters were obtained by 1:0.5:1 fertilizers ratio, whereas the lowest values of these parameters recorded with fertilizer ratio of 1:1:0.5 in the 1st and 2nd seasons, consecutively. These results are in agreement with those of Warncke *et al*. (1992); they stated that the removal N, P_2O_5 and K_2O ratio by cauliflower is 1:0.4:1.

Regarding the effect of applied NPK fertilizer rate, data also presented in Table 3 declare that the same mentioned characters were significantly increased with increasing applied NPK fertilizer rate from 50 Kg/fed. up to the highest rate (150 kg/fed.) in both growing seasons, successively. In this respect, the maximum values of all former parameters were achieved with the fertilizer rate of 150 Kg/fed., while 50 Kg/fed. fertilizer rate gave the minimum values of all previous ones in both seasons, successively. These results are in the same line with those obtained by Warncke *et al*. (1992); they concluded that the requirement of cauliflower plant of N is 140 lb/acre. Also, Kodithuwakku and Kirthisinghe (2009) reported that cauliflower plant height and leaf area/plant increased with increasing NPK fertilizer rates from 50 % up to 125 % of recommended dose. In addition, Sharma (2016) stated that highest stalk length and leaves per cauliflower plant were achieved when plants treated with either 125% NPK or 150% NPK comparing other NPK rates (50%, 75% and 100% of NPK recommended dose).

The various interaction treatments between all NPK fertilizer ratios and all NPK fertilizer rates had significant effects on all forecited characters as compared with the interaction treatment between NPK fertilizer ratio of 1.0:1.0:0.5 and fertilization rate of 50 kg/fed., with no significant differences between the interaction treatment of 1.0:0.5:1.0 NPK fertilizer ratio with the rate of 150 kg/fed. and the interaction one of 1.0:1.0:1.0 at 150 kg/fed. in two seasons, respectively as shown in Table (3). The highest means in this regard were obtained with the cauliflower plants fertilized with commercial inorganic NPK fertilizers blend which resulted from the combination treatment of 1.0:0.5:1.0 NPK fertilizer ratio with fertilization rate of 150 kg/fed. On the other hand, the lowest means were recorded with the cauliflower plants treated with commercial inorganic NPK fertilizers blend produced from the interaction treatment of NPK fertilizer ratio of 1.0:1.0:0.5 at the rate of 50 kg/fed. These obtained results for vegetative growth characters due to the best interaction treatment may be attributed to that such treatment achieved balanced and adequate levels of inorganic NPK fertilizers which represented the actual and optimum requirements of cauliflower plants needed for high plant growth traits.

Also, the obtained stimulatory effect of this treatment may be ascribed to the most important roles of

nitrogen, phosphorus and potassium in promotion of several physiological and biochemical processes including photosynthesis and biosynthesis of various organic compounds such as nucleic acids, proteins, vitamins, hormones, chlorophyll molecules and carbohydrates which are considered very essential components for high plant growth and development. Moreover, P is required for formation of strong and efficient plant root system and K is an essential major element for water- plant relations. These results are in harmony with the obtained results by Wenqiang *et al.* (2004), Kodithuwakku and Kirthisinghe (2009), Elahi *et al.* (2015), Sharma (2016) and Metwaly (2017) on cauliflower; Neethu *et al.* (2015), Singh *et al.* (2015) and Doklega and Abd El-Hady (2017) on broccoli.

Table 3. Effect of NPK fertilizer ratios, rates and their interactions on cauliflower vegetative growth characters during 2015/2016 (S1) and 2016/2017 (S2) seasons.

Parameters		Plant height (cm)		Leaves number/plant		Leaves area (cm^2/plant)		Leaves FW* (g/plant)		Leaves dry matter (%)	
Treatments		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
NPK Fertilizer ratios											
1.0 - 1.0 - 1.0		62.6	63.7	24.1	24.7	13496	13730	1745	1806	12.21	12.42
1.0 - 1.0 - 0.5		54.1	55.1	21.1	21.6	11660	11865	1508	1561	10.55	10.74
1.0 - 0.5 - 1.0		62.9	64.0	24.4	25.0	13560	13795	1754	1815	12.27	12.48
1.0 - 0.5 – 0.5		58.3	59.3	22.8	23.2	12564	12780	1625	1681	11.37	11.56
LSD 5%		0.6	0.6	0.4	1.3	133	135	17	18	0.12	0.14
NPK Fertilizer rates (kg fed^{-1})											
50		51.1	51.6	19.8	20.3	11019	11129	1425	1453	9.97	10.07
100		60.3	61.2	23.5	23.9	12990	13185	1680	1730	11.75	11.93
150		67.1	68.7	26.0	26.6	14451	14813	1869	1963	13.08	13.40
LSD 5%		0.5	0.5	0.3	0.9	114	115	15	15	0.10	0.14
Interaction treatments											
1.0 - 1.0 - 1.0	50	55.3	55.9	21.3	22.0	11923	12042	1542	1573	10.79	10.90
	100	62.0	63.0	24.0	24.3	13372	13573	1729	1781	12.10	12.28
	150	70.5	72.2	27.0	27.7	15194	15574	1964	2064	13.75	14.09
1.0 - 1.0 - 0.5	50	43.5	44.0	17.0	17.3	9381	9475	1213	1237	8.49	8.58
	100	55.7	56.6	22.0	22.3	12016	12197	1554	1601	10.87	11.03
	150	63.0	64.6	24.3	25.0	13583	13923	1756	1845	12.29	12.60
1.0 - 0.5 - 1.0	50	55.6	56.2	21.7	22.3	11992	12112	1551	1582	10.85	10.96
	100	62.2	63.1	24.0	24.7	13403	13604	1733	1785	12.13	12.31
	150	70.9	72.7	27.7	28.0	15286	15669	1977	2077	13.83	14.18
1.0 - 0.5 - 0.5	50	50.0	50.5	19.3	19.7	10780	10887	1394	1422	9.76	9.85
	100	61.1	62.0	24.0	24.3	13170	13367	1703	1754	11.91	12.10
	150	63.8	65.4	25.0	25.7	13743	14086	1777	1867	12.43	12.75
LSD 5%		1.0	1.1	0.7	1.9	227	231	29	30	0.21	0.26

FW*: Fresh weight S1: First season S2: Second season

2- Leaves chemical components:

Data listed in Table (4) indicate the effect of NPK fertilizer ratios on N, P, K, chl. a, chl. b and total carotenoids contents of cauliflower leaves during 2015/2016 and 2016/2017 seasons. Inorganic NPK fertilizer ratios had significant impacts on the all previous parameters as compared with the 1.0:1.0:0.5 fertilizer ratio, without significant differences between both fertilizer ratios of 1.0:0.5:1.0 and 1.0:1.0:1.0 in these two seasons, respectively. The highest records in this respect were achieved with fertilizer ratio of 1.0:0.5:1.0, while the lowest ones were registered with the 1.0:1.0:0.5 one in both seasons. These results are in agreement with those of Filho *et al*. (2015), they reported that in spite of phosphorus is known as one of the most important nutrients influencing growth and productivity of cauliflower and broccoli plants, little accumulated from it by cauliflower and broccoli plants was noticed.

Regarding the fertilizer rate impact, data of Table (4) pointed out that N, P, K, Chl. a, chl. b and total carotenoids contents of leaves at cutting stage had significantly been increased with increasing fertilizer rate up to the highest level used, 150 Kg/fed. This high NPK applying rate (150 kg/fed.) gave significant increases for all preceding parameters compared with 50 Kg/fed. rate in both seasons, consecutively. These results are in accordance with those of Csizinszky (1996) who stated that nitrogen concentrations in leaves and stem were higher with N at 294 than at 98 kg ha^{-1}.

Data shown in Table (4) clearly reveal that NPK fertilizer ratios-rates combination significantly influenced N, P, K, chl. a, chl. b and carotenoids contents of leaves in the 1st and 2nd seasons, consecutively. The best interaction treatment in this connection was 1.0:0.5:1.0 as fertilizer ratio combined with fertilization rate of 150 kg/fed. compared with fertilizer ratio of 1.0:1.0:0.5 at 50 kg/fed., with no significant differences between 1.0:0.5:1.0 fertilizer ratio at 150 kg/fed. combination treatment and fertilizer ratio of 1.0:1.0:1.0 at 150 kg/fed. during two seasons, respectively. While, the rest fertilizer treatments gave values between these two extremes. This increase in cauliflower leaves content of N, P, K, chl. a, chl. b and carotenoids may be due to add sufficient and balanced amounts of mineral NPK fertilizers together with good decomposed farmyard manure to the soil which enhanced physical and chemical properties of the soil resulting in increasing NPK availability for up-taking by strong plant roots, thus increasing cauliflower leaves

content of these essential NPK elements. In addition, increments of chl. a, chl. b and carotenoids contents in cauliflower leaves may be attributed to that nitrogen is considered a structural essential component of chlorophyll molecules, and nitrogen and phosphorus are necessary ingredients for biosynthesis of several organic compounds e.g. nucleic acids, amino acids, proteins and carbohydrates in the case of phosphorus which are important components required for synthesis chlorophyll and carotenoid molecules.

Moreover, potassium plays effective roles in diverse physiological and biochemical processes including stimulation of proteins and carbohydrates synthesis, activation of important enzyme reactions and improvement of water-use efficiency and all of them are needed for integrity of chlorophyll and carotenoid molecules biosynthesis. These results are in harmony with the obtained results by Abdel-Razzak *et al.* (2008) and Metwaly (2017) on cauliflower, Doklega and Abd El-Hady (2017) on broccoli.

Table 4. Effect of NPK fertilizer ratios, rates and their interactions on cauliflower leaves chemical composition during 2015/2016 (S1) and 2016/2017 (S2) seasons.

Parameters		N (%)		P (%)		K (%)		Chl. a[1] (mg/100g FW*)		Chl.b[2] (mg/100g FW*)		Carotenoids (mg/100g FW*)	
Treatments		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
NPK Fertilizer ratios													
1.0 – 1.0 – 1.0		2.67	2.72	0.360	0.366	3.54	3.61	50.89	51.77	26.24	26.69	16.77	17.08
1.0 - 1.0 - 0.5		2.31	2.35	0.311	0.316	3.06	3.12	43.97	44.73	22.67	23.08	14.52	14.76
1.0 - 0.5 - 1.0		2.68	2.73	0.362	0.368	3.56	3.63	51.13	52.01	26.37	26.82	16.86	17.16
1.0 – 0.5 - 0.5		2.49	2.53	0.335	0.341	3.30	3.36	47.38	48.19	24.42	24.86	15.62	15.89
LSD 5%		0.02	0.07	0.004	0.007	0.04	0.04	0.48	0.56	0.26	0.38	0.17	0.30
NPK Fertilizer rates (kg fed^{-1})													
50		2.18	2.20	0.294	0.297	2.89	2.92	41.54	41.96	21.43	21.64	13.70	13.85
100		2.57	2.61	0.346	0.352	3.41	3.47	48.99	49.71	25.26	25.64	16.17	16.39
150		2.86	2.93	0.385	0.395	3.80	3.89	54.49	55.86	28.09	28.80	17.96	18.42
LSD 5%		0.02	0.06	0.002	0.005	0.03	0.04	0.43	0.58	0.23	0.39	0.13	0.30
Interaction treatments													
1.0 - 1.0 – 1.0	50	2.36	2.38	0.318	0.321	3.13	3.16	44.93	45.41	23.20	23.41	14.80	14.97
	100	2.64	2.68	0.356	0.362	3.51	3.56	50.43	51.17	26.00	26.40	16.63	16.90
	150	3.00	3.08	0.405	0.415	3.99	4.09	57.30	58.73	29.53	30.27	18.87	19.37
1.0 - 1.0 - 0.5	50	1.86	1.88	0.250	0.253	2.47	2.49	35.37	35.73	18.23	18.43	11.70	11.80
	100	2.38	2.41	0.321	0.325	3.16	3.21	45.33	45.97	23.37	23.70	14.97	15.17
	150	2.69	2.75	0.362	0.371	3.57	3.66	51.20	52.50	26.40	27.10	16.90	17.30
1.0 - 0.5 - 1.0	50	2.37	2.40	0.320	0.323	3.15	3.18	45.23	45.67	23.30	23.57	14.90	15.10
	100	2.65	2.69	0.357	0.363	3.52	3.59	50.53	51.30	26.07	26.47	16.67	16.90
	150	3.02	3.10	0.408	0.418	4.01	4.12	57.63	59.07	29.73	30.43	19.00	19.47
1.0 - 0.5 - 0.5	50	2.13	2.15	0.288	0.290	2.83	2.86	40.63	41.03	20.97	21.17	13.40	13.53
	100	2.60	2.64	0.351	0.356	3.46	3.51	49.67	50.40	25.60	26.00	16.40	16.60
	150	2.72	2.79	0.366	0.376	3.61	3.70	51.83	53.13	26.70	27.40	17.07	17.53
LSD 5%		0.05	0.12	0.006	0.013	0.06	0.09	0.85	1.10	0.45	0.74	0.27	0.59

FW*: Fresh weight Chl. a[1]: Chlorophyll a Chl. b[2]: Chlorophyll b

3- Curds yield and its components:

The impact of NPK fertilizer ratios, rates and their interactions on cauliflower curds yield and its components in terms of curd fresh weight, curd diameter, curds yield and curd dry matter percentage in both seasons are listed in Table (5). Data of the same Table state that all preceding traits had been affected significantly by NPK fertilizer ratios during both seasons. Where, the NPK fertilizer ratio of 1:0.5:1 gave significant increases for these traits compared with 1.0:1.0:0.5 one, but there were no significant differences between 1.0:0.5:1.0 ratio and 1.0:1.0:1.0 ratio in two growing seasons, successively.

These results are in agreement with those obtained by Kage *et.al*. (2002) and Kirthisinghe (2006) on cauliflower.

Concerning the fertilization rate effect, data of Table (5) outline that the forecited traits had significantly been increased with increasing NPK fertilization rate from the lowest level (50 kg/fed.) up to the highest level used (150 kg/fed.) in both seasons, respectively. These results are in agreement with those of Kodithuwakku and Kirthisinghe (2009); they concluded that increasing N dosage from 50 % up to 125 % of recommended dose gave larger curds and a higher curd yield of cauliflower. Also, Sharma (2016) reported that higher stalk length; leaves per plant, curd weight and size of cauliflower were obtained when plants fertilized by 125% or 150% of NPK fertilizers as compared with other NPK levels (50%, 75% and 100% of NPK recommended dose).

Data presented in Table (5) clearly indicate that fertilizer ratios-rates interaction significantly influenced the aforementioned traits in both season, without significant differences between treatment of 1.0:0.5:1.0 ratio at rate of 150 kg/fed. and treatment of 1.0:1.0:1.0 ratio with the same fertilization rate. The highest values in this respect were achieved with fertilizers ratio (1.0:0.5:1.0) in accompanied with fertilization rate of 150 kg/fed. treatment. On the contrary, the lowest values of the same parameters were recorded with fertilizers ratio (1.0:1.0:0.5) in combined with fertilization rate of 50 kg/fed. treatment in these two seasons, respectively. The increases in yield of cauliflower and its components due to supplementation with the best fertilization treatment may be referred to favorable roles of

NPK nutrients in promotion of photosynthesis and formation of carbohydrates, proteins and other important organic components which flow and intensify in edible plant parts such as cauliflower curds by the mode of action of these constituents in this connection, and therefore enhancement of cauliflower productivity. These results are in agreement with those of wenqiang *et al.* (2004), Abdel-Razzak *et al.* (2008), Kodithuwakku and Kirthisinghe (2009), Farahzety and Aishah (2013), Elahi *et al.* (2015), Sharma (2016) and Metwaly (2017) on cauliflower; Filho *et al*. (2015) on cauliflower and broccoli; Neethu *et al.* (2015) and Singh *et al.* (2015) and Doklega and Abd El-Hady (2017) on broccoli.

Table 5. Effect of NPK fertilizer ratios, rates and their interactions on cauliflower curds yield during 2015/2016 (S1) and 2016/2017 (S2) seasons.

Parameters		Curd fresh weight (g)		Curd diameter (cm)		Curds yield (ton/fed.)		Curd dry matter (%)	
Treatments		**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
NPK Fertilizer ratios									
1.0 – 1.0 – 1.0		2143	2180	24.8	25.3	25.709	26.153	7.28	7.41
1.0 - 1.0 - 0.5		1851	1883	21.2	21.5	22.211	22.601	6.29	6.40
1.0 - 0.5 - 1.0		2153	2190	25.0	25.4	25.831	26.277	7.31	7.44
1.0 - 0.5 - 0.5		1995	2029	23.2	23.6	23.933	24.345	6.78	6.89
LSD 5%		21	37	0.3	0.3	0.253	0.449	0.07	0.09
NPK Fertilizer rates (kg fed^{-1})									
50		1749	1767	20.3	20.5	20.990	21.200	5.94	6.00
100		2062	2093	23.8	24.2	24.744	25.116	7.01	7.11
150		2295	2351	26.5	27.2	27.528	28.216	7.80	7.99
LSD 5%		18	34	0.5	0.5	0.216	0.405	0.06	0.08
Interaction treatments									
	50	1893	1912	22.1	22.3	22.712	22.939	6.43	6.50
1.0 – 1.0 – 1.0	100	2123	2154	24.6	25.0	25.472	25.854	7.21	7.32
	150	2412	2472	27.8	28.5	28.942	29.666	8.20	8.40
	50	1489	1504	16.9	17.1	17.870	18.048	5.06	5.11
1.0 – 1.0 – 0.5	100	1908	1936	21.6	21.9	22.890	23.233	6.48	6.58
	150	2157	2210	25.0	25.6	25.874	26.521	7.33	7.51
	50	1904	1923	22.2	22.4	22.844	23.073	6.47	6.53
1.0 – 0.5 – 1.0	100	2128	2159	24.8	25.2	25.530	25.913	7.23	7.34
	150	2427	2487	28.0	28.7	29.118	29.846	8.25	8.45
	50	1711	1728	20.0	20.2	20.534	20.739	5.81	5.87
1.0 - 0.5 - 0.5	100	2091	2122	24.2	24.6	25.086	25.462	7.10	7.21
	150	2182	2236	25.3	25.9	26.178	26.833	7.41	7.60
LSD 5%		36	66	0.8	0.9	0.433	0.798	0.12	0.16

4- Curds chemical quality parameters:

Data given in Table (6) indicate the effect of fertilizer ratios, rates and their interactions on cauliflower curds chemical composition *i.e.* vitamin C, TSS, N, P and K contents. All former parameters significantly had been influenced by NPK fertilizer ratios in both seasons. The maximum values of the previous parameters were recorded with 1.0:0.5:1.0 fertilizer ratio, without differing with 1.0:1.0:1.0 one. Whereas, the minimum values of the precedent parameters were registered with 1.0:1.0:0.5 one in two growing seasons, consecutively.

Respecting the impact of fertilization rate used, data shown in the same Table (6) declare that added NPK fertilizer rate of 150 Kg/fed. gave the highest values of above mentioned attributes, while the lowest values were obtained with 50 Kg/fed. in the 1st and 2nd seasons, successively. The obtained results go in line with the findings of Abdel-Razzak *et al.* (2008) and Metwaly (2017) on cauliflower, and Doklega and Abd El-Hady (2017) on broccoli.

Data of Table (6) clearly reveal that the interaction between NPK fertilizer ratios and rates has significant effects on vitamin C, TSS, N, P and K contents of cauliflower curds in both seasons. The highest records of the previous parameters were achieved with fertilizer ratio of 1.0:0.5:1.0 in accompanied with fertilization rate of 150 kg/fed. treatment, followed by the treatment of 1.0:1.0:1.0 with the same rate in two growing seasons, respectively. On the other hand, the lowest records on that score were attained with fertilizer ratio of 1.0:1.0:0.5 in concomitant with fertilization rate of 50 kg/fed. The rest fertilization treatments recorded values between these two extremes. The increments of cauliflower curds chemical quality parameters (vitamin C, TSS, N, P and K contents) that produced from combination between NPK fertilizer ratios and rates may be ascribed to ameliorating influence of this interaction treatment on vegetative growth characters (Table 3) and leaves chemical components (Table 4) which in turn significantly enhanced of curds chemical quality parameters of cauliflower plants. As well, the increases in quality characteristics of cauliflower curds may be due to vital roles of nitrogen, phosphorus and potassium elements in improvement of plant storage and edible organs attributes e.g. cauliflower curds as a consequence of its important and stimulatory roles for speeding up transportation of assimilates from the leaves to plant edible parts and intensifying them within these edible parts and consequently amelioration of quality parameters. These results are in agreement with those of Abdel-Razzak *et al.* (2008) and Metwaly (2017) on cauliflower, Doklega and Abd El-Hady (2017) on broccoli.

Table 6. Effect of NPK fertilizer ratios, rates and their interactions on cauliflower curds chemical composition during 2015/2016 (S1) and 2016/2017 (S2) seasons.

Parameters		Vitamin C (mg/100g FW*)		TSS (%)		N (%)		P (%)		K (%)	
Treatments		S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
NPK Fertilizer ratios											
1.0 - 1.0 – 1.0		63.39	64.50	5.86	5.92	2.87	2.92	0.381	0.388	5.10	5.19
1.0 - 1.0 - 0.5		54.78	55.76	5.07	5.17	2.48	2.52	0.329	0.335	4.40	4.48
1.0 - 0.5 - 1.0		63.70	64.81	5.88	6.03	2.88	2.93	0.383	0.390	5.12	5.21
1.0 - 0.5 - 0.5		59.03	60.04	5.48	5.56	2.67	2.72	0.355	0.361	4.75	4.83
LSD 5%		0.62	0.70	0.07	0.10	0.03	0.04	0.004	0.005	0.05	0.06
NPK Fertilizer rates (kg fed^{-1})											
50		51.77	52.30	4.78	4.80	2.34	2.37	0.311	0.315	4.16	4.20
100		61.02	61.94	5.64	5.77	2.76	2.80	0.367	0.372	4.91	4.98
150		67.89	69.59	6.28	6.44	3.07	3.15	0.408	0.419	5.46	5.60
LSD 5%		0.54	0.67	0.05	0.07	0.02	0.04	0.002	0.004	0.04	0.06
Interaction treatments											
	50	56.00	56.93	5.17	5.09	2.54	2.56	0.337	0.340	4.50	4.55
1.0 - 1.0 – 1.0	100	62.80	63.77	5.80	5.90	2.84	2.89	0.378	0.383	5.05	5.12
	150	71.37	73.17	6.60	6.77	3.23	3.31	0.429	0.440	5.74	5.89
	50	44.07	44.53	4.07	4.10	2.00	2.02	0.265	0.268	3.54	3.58
1.0 - 1.0 - 0.5	100	56.43	57.30	5.23	5.33	2.56	2.59	0.340	0.345	4.54	4.61
	150	63.83	65.43	5.90	6.07	2.89	2.96	0.384	0.393	5.13	5.26
	50	56.33	56.93	5.20	5.27	2.55	2.58	0.339	0.342	4.53	4.57
1.0 - 0.5 - 1.0	100	62.97	63.90	5.80	6.00	2.85	2.89	0.379	0.384	5.06	5.14
	150	71.80	73.60	6.63	6.83	3.25	3.33	0.432	0.443	5.77	5.92
	50	50.67	51.17	4.70	4.73	2.29	2.32	0.305	0.308	4.07	4.11
1.0 - 0.5 - 0.5	100	61.87	62.80	5.73	5.83	2.80	2.84	0.372	0.377	4.97	5.05
	150	64.57	66.17	6.00	6.10	2.92	3.00	0.388	0.398	5.19	5.32
LSD 5%		1.07	1.29	0.10	0.16	0.05	0.08	0.005	0.009	0.09	0.11

FW*: Fresh weight

CONCLUSION

In order to obtain high plant growth, productivity and quality characters of cauliflower crop (cv. Fargo), it could be recommended that fertilization of plants with mineral NPK fertilizers blend (*i.e.,* 293 kg ammonium sulphate + 240 kg calcium superphosphate + 120 kg potassium sulphate) produced from interaction between NPK fertilizer ratio of 1.0:0.5:1.0 and fertilizer rate of 150 Kg/fed. under similar conditions of this investigation.

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تأثير بعض معاملات التسميد النيتروجيني والفوسفاتي والبوتاسي الغير عضوي على القنبيط

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أجريت تجربتان حقليتان فى موسمين شتويين متتاليين لعامي 2015/ 2016 و 2016/ 2017 بمحطة بحوث الخضر، كلية الزراعة، جامعة المنصورة، مصر لدراسة تأثير معاملات تسميد مختلفة (نسب ومعدلات سمادية للنيتروجين والفوسفور والبوتاسيوم) على نمو ومحصول وجودة القنبيط (صنف فارجو) المنزرع تحت ظروف تربة طمبية سلتية طينية تروى بنظام ري سطحي. إختبرت 4 نسب سمادية للنيتروجين والفوسفور والبوتاسيوم هى (1-1-1، 1-1-0,5، 1-0,5-1 و 1-0,5-0,5) بثلاث معدلات سمادية هى (50، 100 و 150 كجم/فدان) كإضافة أرضية. تألفت كل تجربة من 12 معاملة وصُممت كقطع منشقة وكررت ثلاث مرات في تصميم قطاعات كاملة العشوائية. لقد أظهرت البيانات المتحصل عليها من هذه الدراسة بوضوح أن جميع الصفات المدروسة مثل صفات النمو الخضري (إرتفاع النبات، عدد الأوراق/نبات، مساحة النبات الورقية، الوزن الطازج للأوراق والنسبة المئوية للمادة الجافة للأوراق)، المكونات الكيماوية للأوراق (محتوي الأوراق من عناصر النيتروجين، الفوسفور، والبوتاسيوم، وكلوروفيل أ، وكلوروفيل ب والكاروتينيدات)، ومحصول الأقراص ومكوناته (وزن القرص، قطر القرص، محصول الأقراص/فدان والنسبة المئوية للمادة الجافة بالأقراص) وصفات الجودة الكيماوية للأقراص (محتوي الأقراص من كل من فيتامين ج، المواد الصلبة الذائبة الكلية، والنيتروجين، الفوسفور والبوتاسيوم) قد تأثرت معنوياً بكل من نسب ومعدلات أسمدة النيتروجين والفوسفور والبوتاسيوم وتفاعلاتهما في كلا الموسمين. فيما يتعلق بتأثير النسب السمادية لكل من النيتروجين والفوسفور والبوتاسيوم، فإن النسبة 1-0,5-1 قد أعطت أعلى القيم لجميع الصفات سابقة الذكر، في حين سجلت النسبة 1-1-0,5 أقل القيم في هذا الشأن. وفيما يتعلق بتأثير المعدلات السمادية لكل من النيتروجين والفوسفور والبوتاسيوم، فإن معدل الإضافة 150 كجم/فدان حقق أقصى القيم لجميع الصفات المذكورة بعاليه مقارنة بمعدلي الإضافة الآخرين. وفيما يتعلق بتأثير معاملات التفاعل بين النسب والمعدلات السمادية، فإن كلا معاملتي التسميد بأسمدة النيتروجين والفوسفور والبوتاسيوم الغير عضوية التجارية الناتجة سواء من النسبة السمادية 1-0,5-1 أو 1-1-1 بالتداخل مع معدل التسميد 150 كجم/فدان قد سجلت أفضل المتوسطات لجميع الصفات المدروسة سابقة الذكر مقارنة بجميع المعاملات السمادية الأخرى للنيتروجين والفوسفور والبوتاسيوم في هذا الشأن. لذا، فإنه يمكن التوصية بتسميد محصول القنبيط (صنف فارجو) بتوليفة أسمدة النيتروجين والفوسفور والبوتاسيوم الغير عضوية التجارية الناتجة من تداخل النسبة السمادية 1-0,5-1 للنيتروجين والفوسفور والبوتاسيوم مع معدل التسميد 150 كجم/فدان من أجل الحصول على أعلى صفات النمو الخضري، والمحصول والجودة تحت ظروف بحثية مماثلة.