Effect of Nitrogen Fertilizer and Fulvic Acid Application on the Growth, Productivity and Nutritional Quality of Cabbage

Ashraf Mahmoud[1], Ali H. Abdel- Razik[1], Sanaa M. El-Araby[1] and Shimaa M. Hassan[1*]

ABSTRACT

Two field experiments were conducted at the Agricultural Experimental Station, Alexandria University, at Abis during the two growing seasons of 2017-2018 and 2018-2019. The objective of these experiments was clarifying the response of cabbage plants to nitrogen fertilizer and soil application of fulvic acid as well as exploring its effect on the growth, yield and chemical components. Four levels of nitrogen fertilizer were tested (control treatment 0, 40, 60 and 80 kg N /fed and three concentrations of fulvic acid (0, 100 and 200 ppm as a soil drench), were studied in a split plots system in a randomized complete blocks design, with three replications, in both seasons. Results indicated that raising N applied level from 0 up to 80 kg N /fed was associated with progressive increments of the unfolded leaves plant^{-1} characters, marketable head characters, inner head stem characters, dry matter content (%), total yield of cabbage fed.$^{-1}$ and marketable yield. Soil application of fulvic acid did not significantly reflect any effect on the tested parameters of vegetative growth characters and cabbage yield and quality characters. The obtained and discussed results of the present study showed that fertilizing cabbage plants with N at a rate of 80 kg N/fed with 100 ppm fulvic acid might be considered as an adequate and effecient treatment combination for the production of high yield of the marketable head with good quality suitable for local consumption, in the two growing seasons.

Key words: Cabbage, Nitrogen fertilizers, Fulvic acid, growth, yield.

INTRODUCTION

Cabbage (*Brassica* oleracea L.) is an important cole crops belonging to the family *Cruciferae* and the winter leafy vegetable in Egypt. It has good nutritional value of many vitamins (A, B1, B2 and C). It is rich in minerals like Ca, Mg, P, K, Na and S (Verma and Nawange, 2015). It's, also, an important source of antioxidant such as carotenoids, polyphenols and ascorbic acid (Riad *et al.*, 2009). The area and the production of cabbage in Egypt was about 38900 fed, and 485700 ton respectively (FAO, 2018). Cabbage is a heavy feeder crop, requiring a high rate of chemical fertilizer for growth and head yield development. Heavy application of commercial organic fertilizer as a liquid humic acid eliminates the necessity for N side-dressings and reduces the amount of chemical fertilizer that must be applied. It could be beneficial to reduce the use of chemical fertilizers and find alternative ways to improve yield quality and quantity (Manea, 2017).

To achieve marketable cabbage with high nutritional quality, the agronomic practices which highly dependent on N fertilizer is required. Lack of N causes stunted growth or leaves discoloration in green cabbage. However, excessive applied of N fertilizer contributes to nitrate build up in soil and vegetables (Manchali *et al.,* 2012). Imbalanced and poor strategy of nitrogen addition limits yields and induces large losses of reactive nitrogen to the environment; as well as could lead to increase physiological disorders of crops after harvest (Hewett, 2006). Cabbage has high nitrogen uptake rates and high N contents, which is required for higher yield (Riad et al., 2009; Din et al., 2007). An adequate supply of nitrogen is essential for vegetative growth, head formation and desirable yield (Yshiwas, 2017).

Fulvic acid (FA) is a mixture of weak aliphatic and aromatic organic acid as well as a part of humic substances (HS) that soluble in water at all pH conditions (acidic, neutral and alkaline). The fulvic acid is an important fraction of soil organic matter (Van-Hees et al., 2005).Several hypotheses interpretiate how humic substances may function in plants to produce changes in growth. Some possible mechanisms are direct and indirect effects (Selim and Mossa, 2012). Concerning the direct effects, it has been demonstrated that HS could induce an increase in the root surface by affecting root morphology (Schmidt et al., 2007).The growth and yield of cabbage crop are remarkably influenced by organic and inorganic nutrients .It is an established fact that use of inorganic fertilizer for the crops is not so good for health because of its residual effect ,but in the case of organic fertilizer such as problem dose not arise ,whearas; it increase the productivity of soil as well as crop quality and yield (Tindall, 1983 and 2000). Excess application of inorganic fertilizer causes a hazard to the environment. Unfortunately, the application of both organic and

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[1]Department of Vegetable, Faculty of Agriculture,
Alexandria University, 21545- El Shatby, Alexandria, Egypt.
[*]Corresponding author: shaymaa.hassan@alexu.edu.eg

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inorganic fertilizer combined can increase the yield as well as keep the environment sound (Hsieh et al., 1995). The current study was conducted to investigate effect of various nitrogen concentrations and fulvic acid on growth, productivity and nutritional quality characteristics of cabbage.

MATERIALS AND METHODS

Soil Analysis of Experimental Sites

Prior to the initiation of each experiment, soil samples to 20-25 cm depth from the experimental sites were collected and analyzed for some chemical and physical properties, according to the published and standard procedures described by (A.O.A.C., 1992). The values of these analyses are shown in Table (1).

Two field experiments were carried out during the autumn seasons of 2017/2018 and 2018/2019, at the Experimental Station Farm of the Faculty of Agriculture, at Abies, Alexandria University, Egypt. Main plots were assigned to the four nitrogen levels (0, 40, 60 and 80 kg N/feddan), denoted as N_0,N_1,N_2 and N_3, respectively) . The sub-plots was allocated to three concentrations of fulvic acid; 0, 100, 200 ppm, will be denoted as F_0, F_1, and F_2, respectively. Ammonium sulphate (20% N) and ammonium nitrate (33.5% N) were the respective source of nitrogen fertilizer. Application of N levels was side banded.

Fulvic acid treatments were applied as a drenching methods to each plant root area three times during the vegetative growth period at three weeks intervals. The first one was carried after four weeks fom transplanting, in both studied seasons. The volume of the tested concentrations of fulvic acid is (0.2 Liter) using a hand sprayer previously modified and calibrated.Cabbage transplants (c.v. Balady); were transplanted on October 22, 2017 and October 10, 2018 at interow spacing of 40 cm; in the first and second seasons, respectively. A full dose of P2O5 (90 kg P2O5/fed.) as a calcium super phosphate (15% P2O5) and K2O (60 kg K2O /fed.) as a potassium sulphate (48-50% K2O) were applied during soil preparation. Regular standard agricultural practices such irrigation (surface system), cultivation, control of disease and pest were carried out as recommended by the Egyptian Ministry of Agriculture. The first hoeing and weeding were carried out 3 weeks after transplanting and two more weedings carried out at one month interval.

Data Recorded.

Vegetative growth characters; a random sample of five cabbage plants was taken throughout the harvesting in growing seasons to measure number of unfolded leaves plant^{-1} characters, marketable head characters, inner head stem characters and dry matter content.

Cabbage yield and quality characters; Harvesting was started after 103 and 120 days after transplanting in the two growing seasons, respectively. Total yield of cabbage fed.$^{-1}$, marketable yield, fresh weight of plant and nitrogen use efficiency (NUE)

Chemical constituents of cabbage leaves; random samples of the cabbage plants, were randomly collected from each sub-plot before planting, then washed with distilled water, weighed, then oven dried at 70 °C till constant weight. The dried leaf materials were ground and homogenized, wet digested; using concentrated sulfuric acid and H_2O_2, and the total nitrogen and phosphorus on leaves of cabbage were determined calorimetrically; using spectrophotometer at 662 and 650 nanometers; according to Evenhuis, (1976) and Murphy and Riley, (1962), respectively. The total chlorophyll of leaves (mg/100 gm fresh weight) was determined using the colorimetric method at wavelength of 660 and 642.5 mm, respectively (Witham et al.,1971) and the total carbohydrate of inedible leaves was determined accordingly (A.O.A.C., 1992).

Table 1. Some physical and chemical properties of the two experimental sites used in the two-growing season.

Properties	Season 2017/2018	Season 2018/2019
Physical properties		
Clay (%)	44.8	42.9
Silt (%)	20.9	24.6
Sand (%)	34.3	32.5
Soil texture	Clay loam	Clay loam
Chemical properties		
PH	7.93	8.12
E.C (dS/m)	3.32	3.41
O.M. (%)	1.05	1.20
Total N (%)	1.05	1.11
Available phosphorus, ppm	3.18	2.75

* These analyses were carried out at the central laboratory, Faculty of Agriculture Alexandria University.

Statistical analysis

Statistical analysis was performed using analysis of variance (ANOVA). All obtained data of the two field experiments were statistically analyzed using Co-state software and Revised L.S.D. test at 0.05 level was used to compare the differences among the means of the various treatment combinations, as illustrated by Snedecor and Cochran (1980).

RESULTS AND DISCUSSION

Vegetative growth characters

Results of the two seasons revealed that increasing the rate of N fertilizer from 0 up to 80 kg/fed was associated with constant increases. The highest mean value was recorded with N at80 kg/fed (Tables 2 - 3). However, the three N levels in the first season and the highest two levels (60 and 80 kg N/fed) in the second season were not significantly differed in their effects on the percentage of unfolded leaves to either head or plant weight. The number of inedible leaves per plant constantly and significantly increased with increments of N rate up to 80 kg/fed in the first season but the differences among the three N levels did not reach to the level of significance, in the second season. The dry matter content of outer leaves was negatively correlated with the applied N rates in the first season, however, the differences among N_1, N_2 and N_3 were not significant. Meanwhile, the differences in the second season were not significant in this respect, compared with control treatment (N_0). The detective positive increments on the studied characters may be attributed to the essential roles of N in the development and differentiation of unfolded leaves since N plays a major role in protein and nucleic acids synthesis and protoplasm formation. Moreover, it stimulates the meristimic activity, which, in turn, resulted in more new tissues and organs (Russel, 1973 and Yagodin, 1984). The importance of N on plant growth may, also, owing to essentially of N as a plant nutrient as well as its importance in the metabolism of many constituents such as chlorophyll, amino acid, auxin, enzymes and general protein synthesis (Singh, 2008). They added, also, that an adequate of N supply generally, stimulates not only photosynthesis but also amino acids and protein. The results of the two seasons revealed that, the characters of inedible leaves of cabbage plant did not significantly respond to applications of fulvic acid, the exception was found with the percentages of outer leaves to head and plant weights in the second season, where plants treated with F_2 (200 ppm) significantly attained the highest values (45.6 and 85.8 %), respectively compared with control treatment F_0 (0 ppm).

Table 2. Unfolded leaves characters of cabbage plant as affected by nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments		**Unfolded leaves plant^{-1}**				
Nitrogen fertilizer rates (kg fed^{-1})	**Fulvic acid (ppm)**	**Number**	**Fresh Wt. (g)**	**% plant Wt.**	**% head Wt.**	**DM content (%)**
		Winter 2017 / 2018				
0 (N_0)		10.6 c	368 b	54.1 a	120.2 a	19.7 a
40 (N_1)		12.3 b	1319 a	43.7 b	73.2 b	15.4 b
60 (N_2)		13.0 ab	1366 a	44.3 b	79.6 b	12.7 b
80 (N_3)		14.1 a	1543 a	43.1 b	78.2 b	13.3 b
	0 (F_0)	12.7 a	1148 a	46.8 a	86.9 a	14.4 a
	100 (F_1)	12.2 a	1156 a	47.3 a	91.4 a	16.4 a
	200 (F_2)	12.6 a	1142 a	45.4 a	85.2 a	15.0 a
		Winter 2018 / 2019				
0 (N_0)		13.6 a	1665 b	49.5 a	99.3 a	12.2 a
40 (N_1)		12.0 a	1929 a	45.1 b	83.7 b	11.9 a
60 (N_2)		11.1 a	1949 a	41.1 c	70.9 c	10.5 a
80 (N_3)		12.7 a	2068 a	41.6 c	72.6 c	10.9 a
	0 (F_0)	12.3 a	1923 a	43.1 b	77.9 b	11.6 a
	100 (F_1)	12.8 a	1866 a	44.3 ab	81.1 ab	11.5 a
	200 (F_2)	12.7 a	1919 a	45.6 a	85.8 a	11.2 a

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

Table 3. Unfolded leaves characters of cabbage plant as affected by the interaction between nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments		**Unfolded leaves plant^{-1}**				
Nitrogen fertilizer (kg fed^{-1})	**Fulvic acid (ppm)**	**Number**	**Fresh Wt. (g)**	**% plant Wt.**	**% head Wt.**	**DM content (%)**
			Winter 2017 /2018			
	0 (F_0)	9.9 d	308 e	52.6 a	113.1 b	19.5 a
0 (N_0)	100 (F_1)	10.9 d	407 e	57.4 a	137.9 a	19.4 a
	200 (F_2)	10.6 d	388 e	52.3 a	109.5 b	20.2 a
	0 (F_0)	12.8 bc	1379 bcd	44.9 b	77.8 c	13.7 c
40 (N_1)	100 (F_1)	11.1 cd	1245 d	44.5 b	68.7 c	18.6 ab
	200 (F_2)	13.1 b	1334 cd	41.7 b	73.2 c	13.7 c
	0 (F_0)	12.9 b	1344 cd	44.6 b	78.6 c	12.3 c
60 (N_2)	100 (F_1)	13.0 b	1348 cd	44.6 b	83.4 c	12.7 c
	200 (F_2)	13.2 b	1407 bcd	43.6 b	76.8 c	13.2 c
	0 (F_0)	15.1 a	1563 ab	44.9 b	77.9 c	12.1 c
80 (N_3)	100 (F_1)	13.9 ab	1626 a	42.9 b	75.6 c	14.7 bc
	200 (F_2)	13.3 b	1441 abc	44.1 b	81.2 c	13.1 c
			Winter 2018 / 2019			
	0 (F_0)	13.1 abc	1707 cd	48.8 ab	97.2 ab	12.2 a
0 (N_0)	100 (F_1)	14.2 a	1643 d	48.2 ab	93.4 b	12.8 a
	200 (F_2)	13.4 ab	1644 d	51.7 a	107.4 a	11.7 a
	0 (F_0)	11.6 cd	1870 bcd	42.0 de	73.4 d	12.5 a
40 (N_1)	100 (F_1)	11.9 bcd	1888 bc	45.9 bc	86.4 bc	11.4 a
	200 (F_2)	12.6 a-d	2029 ab	47.6 b	91.1 b	11.8 a
	0 (F_0)	11.0 d	1881 bc	38.8 e	64.9 d	10.8 a
60 (N_2)	100 (F_1)	12.5 a-d	1929 bc	41.4 de	71.2 d	10.5 a
	200 (F_2)	12.5 a-d	2037 ab	42.9 cd	76.6 cd	10.3 a
	0 (F_0)	13.4 abc	2233 a	42.8 cd	76.2 cd	10.8 a
80 (N_3)	100 (F_1)	12.4 a-d	2003 ab	41.9 de	73.4 d	11.2 a
	200 (F_2)	12.3 bcd	1966 b	40.1 de	68.2 d	10.9 a

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

The detective insignificant effects of the applied fulvic acid on most of the studied characters of the above ground plant organs and the analyzed chemical constituents may be attributed to the relatively high content of the native soil dissolved organic matter (DOM) in the soils of the experimental sites; 1.05 and 1.20 % as shown in Table (1), in the first and second seasons, respectively, which disappeared the improving effects of the applied rates of fulvic acid. This interpretation is in accordance with those of Hartz and Bottoms (2010), who reported that, at typical commercial application rate in representative field soils, humic substances (HS) is unlikely to be significantly improved vegetable crop nutrient uptake or productivity. The vast majority of positive reports have come from hydroponic or sand culture experiments (*Chen et al.*, 2004). US research suggests that under representative field conditions, commercial HA formulations do not reliably provide agronomic benefits for vegetable production. Boyhan *et al.* (2001) found that HS had no effects on onion yield in 3 years of field trials. Similarly Feibert *et al.* (2003) and Duval *et al.* (1998) reflect no benefit from HS application in field production of onions and mustard greens, respectively. Concerning the comparisons among the means of various treatment combinations of N fertilizer and fulvic acid levels (Table 3), the highest mean values were obtained from the unfertilized plots with N and treated with fulvic acid at rate of F_1 or F_2 (100 or 200 ppm).

The results presented in Tables (4- 5) clarify the effects of N fertilization, fulvic acid and their interaction on marketable head characters in the two winter seasons.

The three tested N levels; N_1, N_2 and N_3 (40, 60 and 80 kg/fed) did not significantly differed in their effects on the studied parameters of the marketable head in the two growing seasons. As for the influences of the studied N levels on the compactness of marketable head, the results of the first season showed that fertilizing cabbage plant with N_1, N_2 and N_3 (40, 60 or 80 kg N/fed) ,statistically, produced heads with the highest compactness as compared with those of the unfertilized treatment. The highest compactness was attained with N3 (80 kg N/fed). However, the results of the second season indicated that the three N levels did not affect head compactness as compared with the control treatment (N_0). The results of the present study are agreed to a great extent with those reported by Riad *et al.* (2009) and Haque *et al.* (2015) ,who illustrated that fresh weight, length and diameter of cabbage head were associated with increasing N levels up to 90 and 350 kg N/ha, respectively. Recently, Yshiwas (2017) revealed that the highest length, diameter and weight of cabbage head were obtained from 150 kg N/ha, while the lowest dry weight was attained at 0 Kg N/ha. These findings are also in accordance with those of Patrick et al. (2012), who indicated that head diameter increased from 98 mm to 218 mm with increasing N level from 0 to 120 kg/ha. Concerning the results of the second season , results indicated that application of fulvic acid at rates F_1 and F_2 ,significantly, decreased head fresh weight, head weight percentage to plant weight, number and weight of edible head leaves. Meanwhile, head length, diameter and compactness were not significantly responded to addition of fulvic acid either at F_1, or F_2. Concerning the effect of the present interaction between N fertilization rate and fulvic acid Table (5), the highest mean values of fresh weights of head and edible leaves, were recorded with plants fertilized with N_2 or N_3 combined with any level of applied fulvic acid. On the other hand, the treatment combinations of the three N levels; N_1, N_2 and N_3 combined with the three levels of FA; F_0, $F_1$and F_2, were not significantly differed in their effects on the studied head characters but exceeded those of unfertilized with N fertilizer combined with any tested level of FA.

The results illustrated the effects of N fertilizer rates fulvic acid concentrations and their interactions, on the tested parameters of inner head stem; fresh weight, length and diameter of stem as well as the percentage of stem to head weight and its dry matter content, in the two growing seasons are presented in Tables (6 – 7). Generally, the three N levels; N_1, N_2 and N_3, ,significantly, increased fresh weight, length, and diameter of inner head stem compared with control treatment (N_0).However, increasing N rate up to N_3 (80 kg N/fed.) was associated with progressive and significant decreases in the percentages of the stem to head weight, in the two seasons, and its dry matter content, in the first season, compared with those of unfertilized control (N_0).

Table 4. Marketable head characters of cabbage as affected by nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments		Marketable head characters				
Nitrogen fertilizer rates (kg fed^{-1})	Fulvic acid (ppm)	Fresh Wt.(g)	Length (cm)	Diameter (cm.)	% plant Wt.	Compact-ness (cm^3 g^{-1})
		Winter 2017 / 2018				
0 (N_0)		311 b	14.1 b	13.3 b	45.9 b	2.46 a
40 (N_1)		1717 a	19.9 a	21.2 a	56.3 a	1.68 b
60 (N_2)		1805 a	19.7 a	21.4 a	56.9 a	1.70 b
80 (N_3)		2042 a	18.9 a	21.5 a	57.4 a	1.54 b
	0 (F_0)	1447 a	18.2 a	19.4 a	55.1 a	1.89 a
	100 (F_1)	1440 a	18.4 a	19.2 a	52.7 a	1.88 a
	200 (F_2)	1520 a	17.9 a	19.4 a	54 6 a	1.78 a
		Winter 2018 / 2019				
0 (N_0)		1694 c	22.4 b	22.7 b	50 4 c	2.10 a
40 (N_1)		2341 b	24.4 ab	25.1 a	54.8 b	2.06 a
60 (N_2)		2851 a	26.2 a	25.2 a	58.9 a	1.71 a
80 (N_3)		2911 a	25.9 a	24.9 a	58.0 ab	1.61 a
	0 (F_0)	2603 a	25.3 a	24.8 a	56.9 a	1.83 a
	100 (F_1)	2369 b	24.6 a	24.4 a	55.6 ab	1.91 a
	200 (F_2)	2377 b	24.3 a	24.2 a	54.1 b	1.88 a

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

Table 5. Marketable head characters of cabbage as affected by the interaction between nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments		Marketable head characters				
Nitrogen fertilizer (kg fed^{-1})	Fulvic acid (ppm)	Fresh Wt.(g)	Length (cm)	Diameter (cm.)	% Plant Wt.	Compactness (cm^3 g^{-1})
		Winter 2017 /2018				
	0 (F_0)	266 e	13.7 c	12.5 d	47.3b	2.48 a
0 (N_0)	100 (F_1)	299 e	14.0 c	13.7 d	42.6 b	2.71 a
	200 (F_2)	369 e	14.7 c	13.6 d	47.7b	2.20 ab
	0 (F_0)	1681 cd	20.6 a	21.7 ab	55.1 a	1.81 bc
40 (N_1)	100 (F_1)	1555 d	20.0 a	20.1 c	55.5 a	1.58 c
	200 (F_2)	1917 abc	19.0 ab	21.9 ab	58.3 a	1.64 c
	0 (F_0)	1802 bcd	19.7 ab	21.3 abc	58.7 a	1.70 bc
60 (N_2)	100 (F_1)	1744 bcd	19.6 ab	21.1 abc	55.4 a	1.71 bc
	200 (F_2)	1870 a-d	19.7 ab	21.7 ab	56.4 a	1.69 bc
	0 (F_0)	2038 ab	18.9 ab	22.0 a	59.3 a	1.57 c
80 (N_3)	100 (F_1)	2161 a	19.8 ab	21.9 ab	57.1 a	1.48 c
	200 (F_2)	1926 abc	18.2 b	20.5 bc	55.9 a	1.56 c
		Winter 2018 / 2019				
	0 (F_0)	1781 d	23.6cde	23.5 bcd	51.2 de	2.2 a
0 (N_0)	100 (F_1)	1766 d	22.3de	22.2 d	51.8 de	1.9 abc
	200 (F_2)	1536 d	21.2e	22.5 cd	48.3 e	2.1 ab
	0 (F_0)	2577 b	25.6abc	24.9 ab	57.9 abc	1.9 abc
40 (N_1)	100 (F_1)	2210 c	23.6cde	25.7 a	54.1 cd	2.3 a
	200 (F_2)	2236 c	23.9bcd	24.5 abc	52.4 d	1.9 abc
	0 (F_0)	3051 a	26.4ab	25.5 ab	61.1 a	1.6 c
60 (N_2)	100 (F_1)	2747 ab	26.5a	25.2ab	58.5 ab	1.8 bc
	200 (F_2)	2755 ab	25.6 abc	24.9 ab	57.1 bc	1.8 bc
	0 (F_0)	3003 a	25.4abc	25.4 ab	57.2 bc	1.6 c
80 (N_3)	100 (F_1)	2751 ab	26.0abc	24.6 abc	58.1 ab	1.6 c
	200 (F_2)	2981 a	26.6a	24.9 ab	58.9 ab	1.6 c

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

Table 6. Inner head stem characters of cabbage as affected by nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments		Inner head stem characters				
Nitrogen fertilizer rates (kg fed^{-1})	Fulvic acid (ppm)	Fresh Wt. (g)	Length (cm)	Diameter (cm)	% Head Wt.	DM content (%)
		Winter 2017 / 2018				
0 (N_0)		74.0 b	3.7 b	2.5 b	25.8 a	15.6 a
40 (N_1)		240.0 a	10.9 a	4.5 a	14.2 b	9.6 b
60 (N_2)		246.1 a	11.3 a	4.3 a	14.6 b	9.6 b
80 (N_3)		247.1 a	11.1 a	4.5 a	12.5 b	8.7 b
	0 (F_0)	203.8 a	8.9 a	3.9 a	17.6 a	10.6 a
	100 (F_1)	201.6 a	9.6 a	4.1 a	16.8 a	10.9 a
	200 (F_2)	199.9 a	9.2 a	3.9 a	15.9 a	11.1 a
		Winter 2018 / 2019				
0 (N_0)		212.0 c	11.3 b	3.7 b	12.7 a	11.0 a
40 (N_1)		326.0 a	14. 1 a	4.1 a	14.0 a	10.7 a
60 (N_2)		263.0 b	16.1 a	4.2 a	9.3 b	11.3 a
80 (N_3)		284.4 ab	15.8 a	4.2 a	9.9 b	10.8 a
	0 (F_0)	287.1 a	15.0 a	4.1 a	11.4 a	10.6 a
	100 (F_1)	260.6 b	13.7 b	4.1a	11.3 a	11.3 a
	200 (F_2)	266.4 ab	14.3 ab	3.9 b	11.8 a b	10.9 a

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

Table 7. Inner head stem characters of cabbage as affected by the interaction between nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments		Inner head stem characters				
Nitrogen fertilizer (kg fed^{-1})	**Fulvic acid (ppm)**	**Fresh Wt. (g)**	**Length (cm)**	**Diameter (cm)**	**% Head Wt.**	**DM content (%)**
		Winter 2017 /2018				
	0 (F_0)	72.7 c	3.1 b	2.3 e	28.6 a	14.9 a
0 (N_0)	100 (F_1)	73.8 c	3.8 b	2.6 de	25.2 ab	15.8 a
	200 (F_2)	75.2 c	4.2 b	2.7 d	23.4 b	16.0 a
	0 (F_0)	230.4 ab	10.9 a	4.6 ab	13.5 c	9.3 b
40 (N_1)	100 (F_1)	229.8 ab	11.5 a	4.4 abc	15.2 c	9.8 b
	200 (F_2)	259.8 a	10.4 a	4.3 bc	13.8 c	9.6 b
	0 (F0)	252.6 ab	11.5 a	4.3 bc	15.2 c	9.7 b
60 (N_2)	100 (F_1)	241.6 ab	11.4 a	4.4 abc	14.8 c	9.5 b
	200 (F_2)	244.3 ab	11.2 a	4.3 bc	13.8 c	9.7 b
	0 (F_0)	259.6 a	10.5 a	4.6 abc	12.9 c	8.4 b
80 (N_3)	100 (F_1)	261.3 a	11.8 a	4.8 a	12.0 c	8.7 b
	200 (F_2)	220.4 b	11.1 a	4.2 c	12.6 c	9.2 b
		Winter 2018 / 2019				
	0 (F_0)	227.4 ef	11.1 g	3.8 c	12.8 b	10.9 ab
0 (N_0)	100 (F_1)	204.2 f	11.8fg	3.9 bc	12.0 bc	11.2 ab
	200 (F_2)	204.3 f	11.0 g	3.4 d	13.2 b	10.9 ab
	0 (F_0)	338.2 ab	15.3 bcd	4.2 ab	13.3 b	9.8 b
40 (N_1)	100 (F_1)	297.0bc	13.3 ef	3.4 d	13.4 ab	11.2 ab
	200 (F_2)	342.9 a	13.6 de	3.9 bc	15.4 a	10.9 ab
	0 (F_0)	276.2 cd	17.3 a	4.1 abc	9.1 d	10.5 b
60 (N_2)	100 (F_1)	267.8 cde	15.1 bcd	4.2 ab	9.7 d	12.1 a
	200 (F_2)	245.1 def	15.8 abc	4.1 abc	9.2 d	11.3 ab
	0 (F_0)	306.6 abc	16.1 abc	4.3 a	10.4 cd	10.9 ab
80 (N_3)	100 (F_1)	273.3 cd	14.7 cde	4.1 abc	10.0 cd	10.6 ab
	200 (F_2)	273.3 cd	16.6 ab	4.1 abc	9.3 d	10.6 ab

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

Also, the result indicated that the three FA concentrations (F_0, F_1 and F_2) were not differed in their effects on the studied characters in the first season. However, the results of the second season indicated that F_2, significantly, decreased stem diameter. The results illustrating the effects of the interaction between the levels of N fertilizer and fulvic acid in the two seasons, on the tested characters of the inner head stem, are shown in Table (7). The highest mean values of fresh weight, length and diameter of stem (261.3 gm, 11.8 cm and 4.8 cm), respectively, were attained with N_3F_1 (80 kg N/fed + 100 ppm FA). Meanwhile, the percentages of the stem to head weight and its dry matter content, statistically, decreased with increasing of N application rate, irrespective of the applied level of fulvic acid, the lowest mean values were reported at N_3F_1 treatment combination. Regarding the results of the second season, the comparisons among 12 treatment combinations clarifieded that fresh weight and length of inner head stem ,significantly, increased with the application of N_1, N_2 and N_3 together with any of the studied fulvic acid concentrations as compared with those of unfertilized with N (N_0F_0, N_0F_1 and N_0F_2).In addition, although stem diameter and dry matter contents were significantly affected by the present interaction, the effects of various treatment combinations were neither clear nor constant.

Cabbage yield and quality characters

Concerning the effects of N fertilizer rates, fulvic acid concentrations and their interactions on total and marketable yield as well as fresh weight of the above-ground parts of cabbage plant, the results of the two-growing season (Tables 8-9), generally, revealed that increasing the level of applied N fertilizer from N0 up to N3 (80 kg N/fed.) was associated with consistent increases in these characters. However, the three N levels (N_1, N_2 and N_3) in the first season, and the highest N two levels (N_2 and N_3), in the second season, were not significantly differed in their effects on total and marketable head yield as well as plant fresh weigh. On the contrary, nitrogen use efficiency (NUE) of cabbage plants, either estimated as kg head or kg plant/1 kg N, significantly decreased with increasing N fertilizer rate up to N_3 (80 kg /fed), in the first season. The present results, also in harmony with those obtained by EL-Afifi *et al.* (2002), Haque *et al.* (2015), Riad *et al.* (2009), Hassan and El-Kader. (2016) and Yshiwas (2017), who found that increasing the rate of applied N rate caused statistical increases in total and marketable head yield as well as plant fresh weight until the rate of 80 kg/fed, 350 kg/ha, 90 kg/fed and 150 kg/ha, respectively. Meanwhile, reverse results were obtained, in the second season. The results of the first season indicated that the tested concentrations of fulvic acid (F_0, F_1 and F_2) did not significantly differ in their effects on total and marketable yields and NUE in the first season. On the other hand, the marketable head yield and plant fresh weight, which were significantly decreased with application of FA at rates of F_1 and F_2 (100 and 200 ppm) in the second season. The highest mean values on the total and marketable yields and plant fresh weight were recorded with treatment combinations of N_3F_1 and N_3F_0, in the first and second seasons, respectively. As for the effects of the present interaction on NUE, the obtained results of the first season showed that, cabbage plants fertilized with 40 kg N/fed and treated with fulvic acid at rate 200 ppm recorded the highest significant increase in NUE comparing with the other treatment combinations. Meanwhile, the results of the second season showed that the treatment combinations containing N_1, N_2 or N_3 together with any rate of fulvic acid were not statistically differed in their effects on NUE. Except for N_1F_2 in the first season and (N_1F_2, N_2F_2), in the second season. Regarding the indirect effects of HS in improving yield and quality, it was reported that HS application increased soil enzyme activity and promoted the growth of rhizosphere microorganisms (Sellamuthu and Govindaswamy, 2003). In addition, there is a vital role of HS in enhancing the stability of soil aggregates and in reducing the disaggregating effect of wetting and drying cycles on soil structure. The formation of these aggregates was explained in terms of the formation of clay humic complexes through bridging polyvalent cations adsorbed on clay surfaces (Piccolo and Mbagwu, 1994).

Chemical constituents of cabbage leaves

Concerning the effects of N fertilizer rates on chemical components of cabbage leaves, the results (Table, 10) indicated that increasing the level of applied N fertilizer from 0 up to 80 kg N/fed, did not show any significant effects on the contents of N and P and total carbohydrate in the two seasons and total chlorophyll content in the first one. On the contrary, the leaves content of total chlorophyll, in the second season, constantly and significantly increased with increments of the applied N level up to 80 kg N/fed (N_3).

Table 8. Total and marketable head yield and nitrogen use efficiency (NUE) of cabbage plants as affected by nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019

Treatments		Total yield (ton fed^{-1})	Marketable head yield (ton fed^{-1})	Plant fresh wt. (g)	NUE (kg head kg^{-1} N)	NUE (kg plant kg^{-1} N)
Nitrogen fertilizer rates (kg fed^{-1})	Fulvic acid (ppm)					
		Winter 2017 / 2018				
0 (N_0)		3.515 c	1.700 b	680 b	0.229 c	0.501 c
40 (N_1)		16. 139 b	9.172 a	3037 a	35.141 a	58.889 a
60 (N_2)		18.123 ab	10.502 a	3135 a	24.894 b	40.916 b
80 (N_3)		21.248 a	12.255 a	3549 a	21.625 b	35.862 b
	0 (F_0)	14.424 a	8.320 a	2540 a	20.822 a	34.965 a
	100 (F_1)	14.860 a	8.336 a	2597 a	19.733 a	32.786 a
	200 (F_2)	14.990 a	8.566 a	2663 a	20.862 a	34.373 a
		Winter 2018 / 2019				
0 (N_0)		23.723 c	11.982 c	3360 c	1.140 b	2.263 b
40 (N_1)		27.718 b	15.263 b	4271 b	16.170 a	22.772 a
60 (N_2)		30.325 ab	17.997 a	4800 a	19.275 a	24.011 a
80 (N_3)		31.734 a	18.435 a	4979a	15.979 a	20.250 a
	0 (F_0)	29.705 a	16.989 a	4526 a	14.384 a	18.061 ab
	100 (F_1)	27.369 b	15.328 b	4235 b	10.815 b	14.359 b
	200 (F_2)	28.052 ab	15.441 b	4296 b	14.224 a	19.551 a

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

Table 9. Total and marketable head yield and nitrogen use efficiency (NUE) of cabbage plants as affected by the interaction between nitrogen fertilizer rate and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments		Total yield (ton fed^{-1})	Marketable head yield (ton fed^{-1})	Plant fresh wt. (g)	NUE (kg head kg^{-1} N)	NUE (kg plant kg^{-1} N)
Nitrogen fertilizer (kg fed^{-1})	Fulvic acid (ppm)					
Winter 2017 /2018						
0 (N_0)	0 (F_0)	3.1 f	1.488 e	575 e	0.196 e	0.424 d
	100 (F_1)	3.5 f	1.552 e	706 e	0.220 e	0.520 d
	200 (F_2)	3.9 f	2.058 e	758 e	0.272 e	0.558 d
40 (N_1)	0 (F_0)	16.1 e	8.93 d	3060 cd	35.356 ab	61.995 a
	100 (F_1)	16.1 e	9.025 d	2800 d	31.378 b	52.356 ab
	200 (F_2)	16.2 e	9.563 cd	3251 bc	38.687 a	62.314 a
60 (N_2)	0 (F_0)	17.1 de	10.323 bcd	3035 cd	25.585 c	40.996 c
	100 (F_1)	17.7 cde	10.038 bcd	3092 cd	24.068 cd	39.757 c
	200 (F_2)	19.6 bcd	11.147 abc	3278 bc	25.027 cd	41.996 bc
80 (N_3)	0 (F_0)	21.4 ab	12.54 a	3491 ab	22.15 cd	36.447 c
	100 (F_1)	22.2 a	12.73 a	3787 a	23.265 cd	38.516 c
	200 (F_2)	20.2 abc	11.495 ab	3367 bc	19.462 d	32.624 c
Winter 2018 / 2019						
0 (N_0)	0 (F_0)	24.3 de	12.31 cd	3488 f	1.197 d	2.349 c
	100 (F_1)	25.3 cde	13.14 cd	3410 f	1.188 d	2.297 c
	200 (F_2)	21.6 e	10.48 d	3181 f	1.037 d	2.142 c
40 (N_1)	0 (F_0)	29.9 b	17.29 ab	4447 cde	19.901 ab	23.98 ab
	100 (F_1)	25.5 cde	13.87 c	4099 e	11.112 c	17.216 b
	200 (F_2)	27.7 bcd	14.63 bc	4266 de	17.497 ab	27.121 a
60 (N_2)	0 (F_0)	29.9 b	18.58 a	4933 ab	21.164 a	24.066 ab
	100 (F_1)	29.2 bc	17.16 ab	4677bcd	16.355 abc	21.113 ab
	200 (F_2)	31.7 ab	18.24 a	4792 bc	20.307 ab	26.853 a
80 (N_3)	0 (F_0)	34.6 a	19.76 a	5236 a	15.275 abc	21.852 ab
	100 (F_1)	29.5 bc	17.13 ab	4755 bc	14.606 bc	16.808 b
	200 (F_2)	31.1 ab	18.41 a	4947 ab	18.055 ab	22.087 ab

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

The favorable effect of N on the leaves' chlorophyll content may be caused by delaying senility and break down chlorophyll in cabbage leaves (Barakat, 1987). The obtained results appeared to be in close agreement with those reported by Singh *et al.* (2001) and Freyman *et al.* (1991), who indicated that adequate N is necessary in the formation of chlorophyll and a component of proteins. The present result, also, in accordance with those obtained by Babik et al. (1996) on brussels sprouts, and El-Afifi et al. (2002) on cabbage, who pointed out that increasing N rate up to 600 kg/ha and to 80 kg/fed, respectively, was positively correlated with the leaves chlorophyll content. Likewise, Tanaka and Sato (1997) illustrated that the concentration of phosphorus, potassium and magnesium in plant varied with N rate. The results of FA revealed that the leaves contents of N and P significantly decreased with the application of F_1 and F_2 compared with control treatment (F_0). Meanwhile, the content of total carbohydrate increased in the first season. The obtained results of the second season (Table, 10) revealed that the three levels of FA did not significantly differ in their effects on the leaves content of N, P and total chlorophyll, while the highest significant increase of total carbohydrate was recorded with F_1 (100 ppm FA). The total chlorophyll content was not responded to FA application. The results also, revealed that increasing the level of applied N rate up to 80 kg/fed regardless the used rate of fulvic acid, progressively increased the content of total chlorophyll. The highest significant increase was attained with the treatment combination of N_3F_0 (Table, 11).

CONCLUSION

It is concluded that fertilizing cabbage plants with N at a rate of 80 kg N/fed with 100 ppm FA have the potential to be used for increasing high marketable yield with good quality of cabbage, under the prevailing condition of the present study and other similar regions.

Table 10. Chemical constituents of cabbage leaves as affected by nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments: Nitrogen fertilizer Rate (kg fed^{-1})	Fulvic acid (ppm)	N (%)	P (%)	Total carbohyd-rate (%)	Total chlorophyll (mg/100g fresh wt.)
		Winter 2017 / 2018			
0 (N_0)		1.72 a	0.53 a	10. 43 b	44.24 a
40 (N_1)		1.38 a	0.57 a	11.16ab	35.64 a
60 (N_2)		1.70 a	0.53 a	11.77 a	37.42 a
80 (N_3)		1.38 a	0.58 a	10 .90ab	37.10 a
	0 (F_0)	1.65 a	0.58 a	10.68 b	39.71 a
	100 (F_1)	1.50 b	0.55 b	11.31 a	37.53 a
	200 (F_2)	1.60 b	0.54 b	11.18ab	38.56 a
		Winter 2018/2019			
0 (N_0)		1.82 a	0.65 a	10.60 a	20.18 c
40 (N_1)		1.79 a	0.73 a	11.10 a	25.69 b
60 (N_2)		1.77 a	0.70 a	11.10 a	27.89 b
80 (N_3)		1.71 a	0.67 a	10.51 a	33.62 a
	0 (F_0)	1.75 a	0.69 a	10.72 b	28.05 a
	100 (F_1)	1.78 a	0.68 a	11.29 a	26.10 a
	200 (F_2)	1.79 a	0.69 a	10.46 b	26.32 a

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

Table 11. Chemical constituents of cabbage leaves as affected by the interaction between nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments: Nitrogen fertilizer (kg fed^{-1})	Fulvic acid (ppm)	N (%)	P (%)	Total carbohydr-ate (%)	Total chlorophyll (mg/100g fresh wt.)
		Winter 2017 /2018			
	0 (F_0)	1.787 ab	0.536 def	10.255 c	44.45 a
0 (N_0)	100 (F_1)	1.754 ab	0.548 b-e	10.863 bc	44.94 a
	200 (F_2)	1.622 bcd	0.517 def	10.184 c	43.31 ab
	0 (F_0)	1.465 cde	0.602 abc	10.916 bc	37.78 c
40 (N_1)	100 (F_1)	1.291 e	0.579 a-d	11.600 ab	34.11 c
	200 (F_2)	1.397 e	0.539 def	10.979 bc	35.04 c
	0 (F_0)	1.930 a	0.556 a-e	10.624 bc	37.58 c
60 (N_2)	100 (F_1)	1.504 cde	0.543 c-f	12.248 a	37.03 c
	200 (F_2)	1.640 bc	0.484 f	12.301 a	37.65 c
	0 (F_0)	1.421 cde	0.613 a	10.939 bc	39.01 bc
80 (N_3)	100 (F_1)	1.409 de	0.512 ef	10.521 bc	34.06 c
	200 (F_2)	1.333 e	0.610 ab	11.241 abc	38.21 bc

Cont. Table 11. Chemical constituents of cabbage leaves as affected by the interaction between nitrogen fertilizer rates and fulvic acid concentrations in the winter seasons of 2017/2018 and 2018/2019.

Treatments		N (%)	P (%)	Total carbohydr-ate (%)	Total chlorophyll (mg/100g fresh wt.)
Nitrogen fertilizer (kg fed^{-1})	Fulvic acid (ppm)				
		Winter 2018 / 2019			
0 (N_0)	0 (F_0)	1.760 ab	0.697 abc	10.943 c-f	19.0 g
	100 (F_1)	1.858 a	0.627 c	10.695 def	20.7 efg
	200 (F_2)	1.851 a	0.629 c	10.162 efg	20.5 fg
40 (N_1)	0 (F_0)	1.848 a	0.685 abc	11.773 abc	27.3 bcd
	100 (F_1)	1.726 ab	0.714 abc	12.097 a	23.8 d-g
	200 (F_2)	1.797 ab	0.778 a	9.385 g	25.9 c-f
60 (N_2)	0 (F_0)	1.718 ab	0.742 ab	9.989 fg	27.8 bcd
	100 (F_1)	1.830 ab	0.698 abc	11.960 ab	29.7 bc
	200 (F_2)	1.773 ab	0.664 bc	11.298 a-d	26.2 cde
80 (N_3)	0 (F_0)	1.683 b	0.639 c	10.157 efg	38.1 a
	100 (F_1)	1.720 ab	0.690 abc	10.388 def	30.2 bc
	200 (F_2)	1.742 ab	0.676 bc	10.988b-e	32.6 ab

*values marked with alphabetical letter (s), within a comparable group of means, do not significantly differ, using revised L.S.D test at 0.05 level.

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الملخص العربي

تأثير الأسمدة النيتروجينية وحمض الفولفيك على النمو والإنتاجية والجودة الغذائية للكرنب

أشرف محمود، على حسن عبد الرازق، سناء مرسى العربي، شيماء محمد رجب

إجريت تجريتان حقليتان خلال الموسم الشتوى لأعوام ٢٠١٨/٢٠١٧-٢٠١٨/٢٠١٩ فى محطة البحوث الزراعية بمنطقة أبيس، والتابعة لكلية الزراعة -جامعة الأسكندرية، أشتملت هذه الدراسة على ١٢ معاملة بين أربعة مستويات من النيتروجين (صفر-٤٠ -٦٠-٨٠ كيلو جرام /فدان) وثلاث تركيزات من حمض الفولفيك (صفر -١٠٠-٢٠٠ جزء فى المليون) فى ثلاث مكررات ووزعت مستويات النيتروجين القطع الرئيسية بينما خصصت القطع التحت الرئيسية لحمض الفولفيك وتمت زراعة شتلات الكرنب صنف بلدى فى ١٠ و٢٠ أكتوبر للموسم الأول والثانى على الترتيب. وقد أظهرت النتائج أن زيادة معدلات النيتروجين المضافة حتى ٨٠ كيلوجرام /فدان أدت الى زيادة فى عدد الأوراق الخارجية ووزنها الرطب بينما خفضت النسبة المئوية لوزن الرأس ومحتواها من المادة الجافة بينما لم تحقق مستويات حمض الفولفيك تأثيرا معنويا على الصفات المدروسة للأوراق الخارجية أو على الأوراق الداخلية وعلى صفات الرأس. وأظهرت التأثير المتداخل بين العاملين بأن تسميد الكرنب بمعدل ٨٠ كيلوجرام نيتروجين /فدان مع المعدل ١٠٠ جزء فى المليون من حمض الفولفيك هى أفضل معاملة للحصول على أعلى محصول من رؤوس الكرنب القابلة للتسويق والمناسبة للسوق المحلى وذلك تحت الظروف المماثلة لظروف الدراسة الحالية والمناطق المشابهة.

الكلمات المفتاحية: كرنب، التسميد النيتروجينى، فولفيك اسيد، النمو، محصول.