African Journal of Agricultural Research Vol. 6(18), pp. 4362-4369, 12 September, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR11.1104
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Efficiencies of some vitamins in improving yield and quality of flax plant

M. M. Emam[1]*, A. H. El-Sweify[2] and N. M. Helal[1]

[1]Botany Department, Faculty of Science, Ain Shams University, Cairo, Egypt.
[2]Agriculture Research Center, Fiber Crops Research Section, Giza, Egypt.

Accepted 22 August, 2011

Two field experiments were conducted during two successive winter seasons in the experimental farm of the Agriculture Research Center of Giza in Egypt to study the effect of some vitamins (vitamin B_9, vitamin C and vitamin B_{12}) on the yield and quality of flax plant. The results showed that foliar application of these vitamins significantly increased the growth parameters, as well as photosynthetic pigments compared with the control plants. All treatments induced the plants to flower and to produce fruits earlier than the control plants, enhanced fiber yield and quality, and improved the quality of flax seeds that induced oil yield per feddan. The vitamin treatments did not only stimulate oil production, but also activated the antioxidative properties of flax seeds in terms of increasing the endogenous contents of glutathione, ascorbic acid and total phenols. However, the observed stimulation of oil production was found to be at the expense of carbohydrate and protein accumulation in vitamin - treated flax plants.

Key words: Flax, vitamins, antioxidants, fiber yield and quality, omega-3 fatty acid.

INTRODUCTION

Flax (*Linum usitatissimum*) seeds shows a very high antioxidant activity and is increasingly proposed as an important source for oil and antioxidants. The main compound responsible for the antioxidant activity is ascorbic acid which is the most abundant antioxidant in flax seeds (Westscott and Muir, 2003; Morris, 2005). Flax plays a prominent role in the national economy by its large possibilities of exportation and fabrication. There is no doubt that the need of traditional edible oils will be increased due to the growth of population over the world and increase in the demand of the plant. Therefore, current work on renewable resources of oils is required. Flax seeds produce a vegetable oil known as flaxseed or linseed oil. The oil quality is usually valued according to the content of essential fatty acids (EFAs) (Johnson et al., 2008). The omega 3, 6, 9 groups of fatty acids all contains essential fatty acids necessary for good health. The high level of omega-3 fatty acids consumed by the Eskimos reduced triglycerides, heart rate, blood pressure and atherosclerosis (Morris, 2004). Omega-3 and omega-6 fatty acids are used to create cell membranes and hormones that regulate the hormonal cycles (Okuyama et al., 2007; Johnson et al., 2008). Flax seed has a high ratio of α-linolenic (omega-3) to linoleic (omega-6) fatty acids, and it is one of the richest sources of omega-3 fatty acid. Treatment with 1 g per day of omega-3 fatty acid reduced the occurrence of cardio-vascular diseases and sudden cardiac death (Okuyama et al., 2007). It is possible to alter the percentage of various fatty acids by physiological and / or agronomic methods (Ratledge, 1988; Kene et al., 1990; Tamer et al., 1996; Bharambe et al., 1997; Vasudevan et al., 1997; El-Lateef et al., 1998; Joshi et al., 1998; Raju and Sreemannarayana, 1998; Scheiner and Lavado, 1999; El-Bassiouny et al., 2005).

In addition, flax seeds contain over a hundred times more of a phytonutrient known as lignan than any of its closest competitors such as wheat, rye, oats and soybeans (Thompson et al., 2005). Lignan has received a lot of attention lately because of possible anticancer properties, especially in relation to breast and colon cancers. Lignan seem to flush excess estrogen out of the body, thereby reducing the incidence of estrogen-linked cancer. Besides anti-tumor properties, lignan also seems to have antibacterial, antifungal and antiviral properties (Thompson et al., 2005). Plant lignans are polyphenolic substances derived from phenylalanine. They have weak

*Corresponding author. E-mail: dr. manal_emam@hotmail.com.

estrogenic or antiestrogenic activity in human. These substances are termed phytoestrogens. In fact, improvement of crops in both quantity and quality is among the goals of the modern applied science and technology. In this respect vitamins are known to improve plant growth and development. Beneficial effects of vitamins on yield quantity and quality have been reported for various crops by Samiullah and Khan (1997), Ghourab and Wahdan (2000), El Bassiouny et al. (2005), El-Tohamy and El-Gready (2007), Malhi et al. (2007), and El-Tohamy et al. (2008).

Ascorbic acid (vitamin C) has a regulatory role in promoting productivity in many plants such as pepper (Shehata et al., 2002), pea plants (Helal et al., 2005) and potato (El-Banna et al., 2006). On the other hand, folic acid (vitamin B_9) has become the most prominent of B-complex vitamins despite its essential biochemical function in amino acids metabolism and nucleic acids synthesis (Andrew et al., 2000). Cobalamin (vitamin B_{12}) is necessary for the regulation of DNA synthesis during cell division (Smith et al., 2007). However, responses of plants to cobalamin or folic acid treatments in terms of growth and yield parameters have not been investigated to date. So, the present work was conducted to evaluate the efficiency of foliar application of folic acid, ascorbic acid or cobalamin on improving the growth, yield quantity and quality of flax plants.

MATERIALS AND METHODS

This experiment was conducted in the Agriculture Research Center, Giza in Egypt during two successive seasons 2007/2008 and 2008/2009. The area used was divided into four plots, each of which was divided into three subplots, each of 6 m^2 each. *Linum usitatissimum* seeds var. Sakha 2 were sown on 25/11/2007.The relative humidity ranged between 52 and 80%. Maximum day temperature was 23.4°C, while minimum night temperature was 13.9°C. Seeding rate was 70 kg/feddan. After sowing, spraying was carried out in triplicate when the plants were 45, 60 and 95 days old. The plants of the first three plots were sprayed with 20 µM folic acid, 0.5 mM ascorbic acid or 2 µM cobalamin respectively, while the plants of the fourth plot were sprayed with pure water to serve as controls. The plants were left to grow under the various treatments for 5 months. At full maturity (5 months after sowing), the experiment was terminated and ten plants were harvested at random from each treatment to carry out the yield component measurements. Quantity and quality of fiber yield were investigated as follows: The seeds were collected from each treatment for estimation of seed quality in terms of carbohydrate contents, nitrogenous constituents, oil percentage and oil yield (kg/feddan) and some antioxidants as total phenols, ascorbic acid and glutathione contents. Physical and chemical analyses of the soil were carried out according to the method of Jackson (1965) (Table 7).

Chemical analysis

Extraction and estimation of soluble sugars

Soluble sugars were extracted following the method adopted by Homme et al. (1992). Sugar-free residues were extracted with 1.5 N H_2SO_4 following the method adopted by Naguib (1963). Soluble sugars, which were obtained after polysaccharides hydrolysis, were estimated using the anthrone reagent (Fairbairn, 1953).

Extraction and estimation of soluble proteins

Soluble proteins were extracted according to the method described by Hassanein (1977). Water insoluble residue remaining after extraction of soluble proteins was extracted with 1 N NaOH. Soluble proteins and those resulting after insoluble residue hydrolysis were measured using BIO-RAD protein assay dye reagent, according to the method adopted by Bradford (1976). Free amino acids were extracted according to the method described by Vartanian et al. (1992) and estimated using Ninhydrin reagent (Yemm and Cocking, 1955).

Extraction and estimation of some antioxidants

Water soluble antioxidants such as glutathione and ascorbic acid were determined by the methods of Scupp and Rennenperg (1988) and Kampfenkel et al. (1995) respectively. Total phenols were extracted and estimated following the method described by Malik and Singh (1980).

Retting process

Fifty defoliated and deseeded flax plants from each treatment were taken for water retting process as described by Radwan and Momtaz (1966). Thereafter the retted straw was cleaned with water and air dried for 1 week. Fiber length was measured in cm, while fiber fineness was calculated in (N.m).

Determination of cellulose content

Jenkins method (1930) was used to determine the cellulose content.

Determination of pectin content

The method used was that described by Nanji and Norman (1928).

Determination of lignin content

The method used was that described by Rittler et al. (1932).

Extraction and determination of oil content

The extraction of oil was carried out according to the method described by Meara (1955). The lipid samples were methylated according to Harborne (1984). Thereafter, fatty acids composition was determined by gas liquid chromatography (GLC). The fractionation of fatty acid methyl esters was conducted using a coiled glass column; HP5 (Cross-linked 5% phenyl methyl silicon) 30 m x 0.35 mm x 0.88 µm films (HP part No. 19095 J-0.23). Peaks identification and quantification was carried out by using UP 4810 computing integrator. The percentage of each fatty acid was calculated by the following equation:

$$\% \text{ fatty acid} = \frac{\text{Peak area of each individual fatty acid methyl ester}}{\text{Total peak area of fatty acid methyl esters}} \times 100$$

Table 1. Effects of folic acid, ascorbic acid or cobalamin on time of flowering and fruiting of *Linum usitatissimum* plants.

Treatments	Time of flowering	Time of fruiting
Control (H_2O)	10/3/2008	6/4/2008
Folic acid	26/2/2008	18/3/2008
Ascorbic acid	2/3/2008	27/3/2008
Cobalamin	27/2/2008	21/3/2008

Table 2. Effects of folic acid, ascorbic acid or coalmen on growth and seed yield of *Linum usitatissimum* plants.

Parameter	Treatment			
	Control (H_2O)	Folic acid	Ascorbic acid	Cobalamin
Plant height (cm)	82.8 ±3.6	105.9 ±2.6^{c}	94.1 ±2.6^{b}	89.4 ±3.0^{a}
Technical length (cm)	78.6 ±3.5	86.8 ±4.1	84.6 ±4.0	73.5 ±2.6
Straw yield g / plant	1.9 ±0.1	4.2 ±0.3^{c}	2.5 ±0.2	3.3 ±0.3^{b}
Straw yield (Ton) / fed.	1.49 ±0.2	3.03 ±0.9^{b}	2.27 ±0.9^{a}	2.46 ±0.8^{b}
Fruit branches / plant	3.9 ±0.4	11.0 ±0.8^{c}	7.9 ±0.4^{b}	7.6 ±0.2^{b}
No. of capsules / plant	14.2 ±2.0	22.9 ±3.5^{a}	16.4 ±2.0	20.2 ±1.9
No. of seeds / capsule	5.8 ±0.3	8.7 ±0.2^{c}	6.5 ±0.2	6.4 ±0.1
Seed yield g / plant	1.1 ±0.5	2.1 ±0.1^{b}	1.2 ±0.3	1.2 ±0.1
Seed yield Kg / feddan	270.0 ±1.4	398.2 ±2.1^{c}	307.6 ±9.2^{b}	385.6 ±3.6^{c}
Seed index (weight of 1000 seeds, g)	6.6 ±0.3	8.4 ±0.6^{a}	8.0 ±0.5^{a}	8.3 ±0.4^{a}

Values with a superscript are significant different from the control. Letter a =* at P > 0.05, b =** at P < 0.01, c =*** at P < 0.001, and absence of letter = non significant.

Statistical analysis of variance was conducted using ANOVA one way variance test, using Microsoft Excel 2000. Statistical probability values were calculated to quantify the levels of significance for each treatment type.

RESULTS

Changes in yield components

Data presented in Table 1 showed that folic acid-treated plants started to produce flowers 13 days earlier and fruits 19 days earlier than the control plants. Moreover, all treatments caused increases in plant height and technical length of flax plants as compared with those of the control. The increase in plant height due to vitamin treatments ranged between 7.9 and 27.8% (Table 2). It was also noticed that the straw yield per feddan significantly increased in response to folic acid, ascorbic acid or cobalamin treatment. The maximum increase in straw yield per feddan in response to folic acid treatment was about 103.3% over the control value. Moreover, the results in Table 2 revealed that vitamins increased the number of capsules per plant above the control value. Such stimulatory effect was more pronounced in folic acid-treated plants, where the number of capsules per plant was augmented by 61.2% over the control value. Foliar application of folic acid, ascorbic acid or cobalamin induced significant increase in seed yield as well as seed index was up to 27.3, 21.2 and 25.8% respectively compared with the untreated plants (Table 2).

Changes in chemical composition of seeds

Table 3 showed the seed quality of untreated and differently treated flax plants in terms of carbohydrate contents, nitrogenous constituents, total phenols, ascorbic acid, glutathione as well as oil yield per feddan. All treatments improved the quality of flax seeds as they induced oil yield per feddan at the expense of carbohydrate and protein accumulation. On the other hand, all treatments increased the oil yield per feddan particularly in cobalamin-treated plants to about 192.9%; 31.5% of ascorbic acid and 70.2% of folic acid treated plants above the control value. It is also interesting to mention that an increase in total phenols of flax seeds was estimated after the foliar application of folic acid, ascorbic acid or cobalamin (Table 3). Total phenols content was maximized in seeds of folic acid- treated plants up to 17.4, 14.3 and 5.7% respectively, above the control value in ascorbic acid and cobalamin-treated plants. GSH level significantly increased in all treated samples. The greatest increase of about 3-fold increase in GSH content was induced by folic acid treatment

Table 3. Effects of folic acid, ascorbic acid or cobalamin on quality of *Linum usitatissimum* seeds. Each value is a mean of three replicates ± SD.

Treatments	Parameters											
	Carbohydrate contents (mg/g F.W.)			Nitrogenous constituents (mg/g F.W.)				Total phenols (mg/g F.W.)	Ascorbic acid (mg/g F.W.)	Glutathione (µmol/gF.W.)	Oil content (g%)	Oil yield (kg / fed.)
	Soluble	Insoluble	Total	Soluble	Insoluble	Total	Free amino acids					
Control (H_2O)	9.6±0.5	6.8±0.3	16.4±0.2	17.9±0.3	26.4±0.3	44.3±0.4	0.78±0.01	419 ±7.5	7.2±0.7	8.3 ±0.4	32±2.3	84.20±7.3
Folic acid	8.5±0.2^a	5.5±0.6^a	14.0±0.3^b	17.6±0.6^c	19.7±0.9^c	37.3±1.4^c	0.61±0.2^a	492±8.5^a	20.8±0.9^c	28.9±2.3^c	36±4.2	143.35±8.9^c
Ascorbic acid	8.7±0.2	5.7±0.4	14.4±0.3^b	14.1±0.3^b	16.8±0.4^c	30.9±0.4^c	0.53±0.2^a	479±9.0	21.2±0.5^c	22.1±1.8^c	36±3.5	110.73±6.3^b
Cobalamin	9.1±0.4	4.8±0.3^a	13.9±0.2^b	12.9±0.2	19.9±0.5^c	32.8±0.8^b	0.56±0.1^a	443±1.0	22.0±1.3^c	23.7±1.9^b	64±6.4^c	246.78±7.9^c

Values with a superscript are significant different from the control. Letter a =* at P>0.05, b =** at P<0.01, c =*** at P <0.001, and absence of letter = non significant.

Table 4. Effects of folic acid, ascorbic acid or cobalamin on fatty acids composition of *Linum usitatissimum* oil.

Fatty acids composition	Control (H_2O)	Folic acid	Ascorbic acid	Cobalamin
C 16:0	7.89	6.31	5.77	5.92
C 18:0	6.75	6.20	5.48	5.60
C 18:1, ω-9	26.29	23.53	20.75	20.61
C 18:2, ω-6	15.37	14.15	15.66	12.99
C 18:3, ω-3	43.67	49.78	52.32	54.84

compared with the control.

Changes in fatty acid composition

Data presented in Table 4 showed that the used vitamins markedly decreased the saturated fatty acids. Either folic acid, ascorbic acid or cobalamin treatment reduced palmitic acid level (C 16:0). The percentage of reduction was found to be 20.0, 26.9 and 24.9% respectively below the control level. Stearic acid (C 18:0) showed a similar trend of 8.1, 18.8 and 17.0% respectively below the control. On the other hand, vitamin treatments stimulated linolenic acid (18:3, ω-3) production. The percentage of increase due to folic acid, ascorbic acid or cobalamin treatment was augmented by 13.9, 19.8 and 25.5% respectively above that estimated in the control plants. Table 4 showed that application of either folic acid, ascorbic acid or cobalamin caused a marked decrease in linoleic acid (18:2, ω-6) and oleic acid (18:1, ω-9) contents. Such effect was more pronounced in cobalamin-treated plants, where the percentage of decrease was 15.4 and 21.6% respectively below the control value.

Changes in fiber yield and quality

The data in Table 5 showed that fibers yield per feddan was increased in response to either folic acid (90.9%), ascorbic acid (58.4%) or cobalamin (134.7%) above the control. In addition, foliar application of either folic acid or ascorbic acid significantly increased the fiber length as compared with the control. However, cobalamin treatment showed significant decrease in fiber length (about 5.3% below the control value). Fiber fineness was significantly reduced by about 14.3, 8.2 and 13.4% respectively below the control value.

Changes in chemical composition of the fiber

The increase in cellulose content of flax plants in response to folic acid, ascorbic acid or cobalamin

Table 5. Effects of folic acid, ascorbic acid or cobalamin on fiber yield and quality of *Linum usitatissmum* plants.

Treatment	Parameter			
	Fiber (%)	Fiber yield (kg / fed.)	Fiber length (cm)	Fiber fineness (N.m)
Control (H_2O)	14.3 ± 1.0	156.2 ± 7.0	78.0 ± 1.2	230 ± 5.0
Folic acid	16.3 ± 3.7	298.2 ± 6.4^b	84.9 ± 4.4^a	197 ± 1.0^b
Ascorbic acid	17.7 ± 2.0	247.5 ± 4.9^b	83.3 ± 0.7^a	211 ± 4.9^c
Cobalamin	18.6 ± 4.2^a	366.7 ± 8.6^c	73.9 ± 3.0^a	199 ± 1.0^c

Values with a superscript are significant different from the control. Letter a =* at P > 0.05, b =** at P < 0.01, c =*** at P < 0.001, and absence of letter = non significant.

Table 6. Effects of folic acid, ascorbic acid or cobalamin on the chemical composition of *Linum usitatissimum* fibers. The values listed are expressed as g/100 g fibers. Each value is a mean of three replicates ±SE.

Treatment	Parameter		
	Cellulose	Pectin	Lignin
Control (H_2O)	10.1 ± 1.2	19.6 ± 2.0	21.7 ± 0.9
Folic acid	26.0 ± 1.4^b	72.3 ± 5.8^c	24.5 ± 0.9^a
Ascorbic acid	35.4 ± 1.8^c	74.2 ± 7.9^c	27.8 ± 1.7^b
Cobalamin	40.8 ± 3.4^c	74.5 ± 1.2^c	30.3 ± 0.4^b

Values with a superscript are significant different from the control. Letter a =* at P > 0.05, b =** at P < 0.01, c =*** at P < 0.001, and absence of letter = non significant.

Table 7. Chemical and physical analyses of soil used in the present investigation.

Analyses	Values
Chemical analysis	
Organic carbon %	2.7
Total carbonate %	1.2
SO_4 (mg / 100 g)	0.28
P (mg / 100 g)	0.64
K (mg / 100 g)	9.65
Ca (mg / 100 g)	16.7
Salinity (%)	0.1
pH	8.1
Physical analysis	
EC (m mohs cm^{-1})	1.49
Water Holding Capacity %	56.1
Moisture content %	27.4

treatment was found to be about 2.5, 3.5 and 4 folds respectively when compared with the control. Moreover, cobalamin is the most effective vitamin used in the present investigation which increased cellulose, pectin and lignin contents of flax fibers (Table 6). Similarly, the used vitamins significantly stimulated lignin accumulation to 12.9, 28.1 and 39.6% in folic acid, ascorbic acid or cobalamin-treated plants respectively compared with the control.

DISCUSSION

Among the many biochemical effects of vitamins, one that has attracted much recent attention is the improvement of yield and quality of many crops. In fact, enhancing growth productivity will be of a great importance to maximize the yield (Khan and Srivastava, 1998; Al-Hakimi and Hamada, 2001; El-Tohamy and El-Gready, 2007, 2008). The results obtained showed that foliar application of flax plants with either folic acid, ascorbic acid or cobalamin significantly stimulated growth and development throughout the experimental period. The variation in vitamin requirements of most plants for optimum performance seems to be the result of the difference in the native vitamin content in the seed (Samiullah and Khan, 1997). This is the case in our study, since the productivity of flax plants were stimulated by foliar application of ascorbic acid, which was already *de novo* synthesized (Table 3). Ascorbic acid plays an important role in the regulation of cell division, cell cycle progression from G_1 to S phase (Liso et al., 1988; Smirnoff, 1996) and cell elongation (De-Tullio et al., 1999). All vitamins used in the present work significantly increased the yield components of flax plants in terms of number of capsules/plant, number of seeds/capsule, seed yield/plant, seed yield/feddan as well as seed index compared with the control (Table 2). This result is consistent with that obtained by Samiullah and Khan (1997) who improved the performance of *Brassica juncea* cultivars by seed treatment with pyridoxine (vitamin B_6). Such stimulatory effect was more pronounced in folic acid-treated plants which might be attributed to its effect on regulation of protein and nucleic acid biosynthesis (Andrew et al., 2000).

Flax has recently received registration as a new oil seed due to the high percentage of omega-3 fatty acids. Considerable effort has been carried out to change the fatty acid composition of edible oils to improve the oil stability and nutritional value. In the present work, the percentages of various fatty acids detected in flax seeds varied considerably by different vitamin treatments. The

results of the gas chromatographic analysis of methyl esters of fatty acids revealed that either folic acid, ascorbic acid or cobalamin treatment caused marked decrease in saturated fatty acids (palmitic and stearic) (Table 4) which are reported to be hyperchlosteremic (Holub, 1991). Moreover, diets high in saturated fats are correlated with an increased incidence of atherosclerosis and coronary heart disease (Hu et al., 2000). The observed decrease in the percentage of palmitic, stearic, oleic and linoleic acids and the resultant increase in linolenic acid with vitamin treatments might be attributed to the acceleration of the biosynthetic pathway of linolenic acid (Joshi et al., 1998).

Moreover, the rapid conversion of (18:1, ω-9) to (18:2, ω-6) to (18:3, ω-3) was reported by Wynn and Ratledge (2000). In fact, flax and its oil are the most widely available botanical source of omega-3; it is six times richer than most fish oils in omega-3 (Bartram, 1998). The increase of linolenic acid production in vitamin-treated flax plants is considered as desirable characteristic for flax oil. Consequently, the goal now is about the production of special products such as oils rich in linolenic acid (Ratledge, 1988), this request is true in the present work (Table 4). Table 3 showed that the increase in total oil contents was accompanied by a sharp decrease in total protein and carbohydrate contents. Their metabolism might have shifted toward oil biosynthesis. This result is in agreement with the results obtained by Tamak et al. (1997), Samiullah and Khan (1997), Joshi (1998) and Emam (2001). Vitamin treatments not only stimulated the oil production but also activated the antioxidative properties of vitamin-treated flax seeds irrespective of the vitamin used. In this respect, all vitamins used in the present investigation increased this property in terms of stimulating the accumulation of some antioxidants as ascorbic acid, glutathione and total phenols (lignans) (Table 3). Antioxidants are molecules that act as free radical scavengers. Most of them are electron donors and react with free radicals to form innocuous end products such as water. Free radicals are formed during a variety of biochemical reactions and cellular functions in human body and their formation increase during inflammation, ischemia, infection and cancer.

In the human body, the formation of free radicals and their injurious effects are collectively called oxidative stress. The reactions between cellular components and free radicals lead to DNA damage, cell membrane damage and eventually cell death. Consequently, interest is considerably increasing in finding naturally occurring antioxidants from botanical sources for use in food industry and in preventive medicine to replace synthetic antioxidants that are being restricted due to their carcinogenicity (Velioglu et al., 1998; Hu et al., 2000). In addition, natural compounds have been reported to have stronger antioxidant activity than synthetic ones (Maisuthisakul et al., 2007). Flax is a good source of antioxidants as ascorbic acid, glutathione, and total phenols. Amino acid metabolism (Table 3) has shifted toward glutathione (GSH) biosynthesis (Rosen, 2002). Glutathione is a very important molecule for protecting all cells from oxidative stress (Hu et al., 2000). The central role of GSH in the antioxidative defense is due to its ability to regenerate another powerful water-soluble antioxidant ascorbic acid via ascorbate/glutathione cycle (Noctor and Foyer, 1998). Ascorbic acid was significantly increased in seeds of all vitamin-treated flax plants. The observed decrease in soluble sugar and the subsequent increase in ascorbic acid might be due to the fact that glucose is known to be the initial precursor of ascorbic acid (Smirnoff et al., 2001). Moreover, total phenols content was maximized in seeds of vitamin-treated plants compared with that of the control plants (Table 3). The presence of phenolic compounds in any plant reflects the anti-microbial effect of this plant (Ofokansi et al., 2005).

The biphasic action of vitamin treatments which was generally reflected in attenuated saturated fatty acids level and augmented omega-3, as well as some antioxidants (ascorbic acid, glutathione and total phenols) could be a successful step in improving the quality of flax seeds. Although improving seed quantity and quality have been reported by many investigators. However, little information is available on the effect of vitamins on fiber quality of plants, particularly flax plants. Consequently, the potential effects of vitamins on yield quantity and quality of flax fibers make this study a significant subject for research. Fiber length markedly increased in flax plants treated with either folic acid or ascorbic acid compared with those of the control (Table 5). However, cobalamin treatment caused a reduction in fiber length. It is worthy to note that fiber length followed the same trend of technical stem length (Tables 2 and 5). Foliar application of either folic acid, ascorbic acid or cobalamin significantly increased the fiber yield of flax plants / feddan. Increase in fiber yield could be attributed to the increase in nutrient uptake and / or assimilation due to vitamin treatments (Samiullah et al., 1991). Similar results were obtained by El-Bassiouny et al. (2005) and Shukry et al. (2007).

It is worthy to note that increase in fiber length of treated flax plants was concomitant with a decrease in fiber fineness. Thus, there was a trend of coarseness of fibers in all vitamin-treated plants. It is of interest to mention here that the observed increase in fiber yield in vitamin-treated plants was accompanied by high percentage of cellulose, pectin and lignin which in turn was concomitant with a sharp decrease in total sugar contents in the yielded seeds of treated flax plants (Tables 3 and 6). The carbohydrate metabolism might be shifted toward the formation of fibers, so plant directed the excess amount of organic compounds toward different components of the yielded fiber and oil. During lignifications, a wide range of phenolic compounds can be oxidized by peroxidase using extra cellular H_2O_2.

Ascorbic acid can completely inhibit these oxidation reactions resulting in lignin accumulation (Noctor and Foyer, 1998). Therefore, the goal of the present work is achieved through improving the growth vigor and the quality of flax plant by foliar application of folic acid, ascorbic acid or cobalamin and consequently maximizing the endogenous metabolites in flax seeds necessary for human health.

REFERENCES

Al-Hakimi AMA, Hamada AM (2001). Counteraction of salinity stress on wheat plants by grain soaking in ascorbic acid, thiamin or sodium salicylate. Biol. Plant., 44: 253-261.

Andrew WJ, Youngkoo C, Chen X, Pandalai SG (2000). Vicissitudes of a vitamin. Recent Res. Dev. Phytochem., 4: 89-98.

Bartram T (1998). Bartram's Encyclopedia of herbal medicine. London, Constable and Robinson.

Bharambe PR, Bhalerao JB, Oza SR (1997). Effect of nitrogen and soil water regimes on soil-plant-water relationship, yield and water use efficiency of summer sunflower. J. Indian Soc. Soil Sci., 45(4): 701.

Bradford MM (1976). A rapid and sensitive method for the quantization of microgram quantities of protein utilizing the principle of protein-dye binding. Anal. Biochem., 72: 248-254.

De Tullio MC, Paciollac Dalla Vecchia F, Rascio ND, Emerico S, Dé Gara L, Liso R, Arrigoni O (1999). Changes in onion root development induced by the inhibition of peptidyl-prolyl hydroxylase and influence of the ascorbate system on cell division and elongation. Planta, 209: 424-434.

El-Banna EN, Ashour SA, Abd El-Salam HZ (2006). Effect of foliar application with organic compounds on growth, yield and tubers quality of potato (*Solanum tuberosum* L.). J. Agric. Sci., Mansoura Univ., 31(2): 1165-1173.

El-Bassiouny HMS, Gobarah ME, Ramadan AA (2005). Effect of antioxidants on growth, yield and Favism Causative Agents in seeds of *Vicia faba* L. plants grown under reclaimed sandy soil. J. Agron., 4(4): 281-287.

El-Lateef EMA, Selim MM, Benairy TG (1998). Response of some oil crops to bio-fertilization with phosphate dissolving bacteria associated with different levels of phosphatic fertilization. Bulletin of the National- Research Center, Cairo, 32(2): 193-202.

El-Tohamy WA, El-Gready NHM (2007). Physiological responses, growth, yield and quality of snap beans in response to foliar application of yeast, vitamin E and zinc under sandy soil conditions. Aust. J. Basic Appl. Sci., 1(3): 294-299.

El-Tohamy WA, El-Abugy HM, El-Gready NHM (2008). Studies on the effect putrescine, yeast and vitamin C on growth, yield and physiological responses of eggplant (*Solanum melongena* L.) under sandy soil conditions. Aust. J. Basic Appl. Sci., 2(2): 296-300.

Emam MM (2001). Effect of seed pre-treatment on the yield and quality of sunflower oil. Egypt J. Food Sci., 29(1): 49-61.

Fairbairn N (1953). A modified anthrone reagent. Chem. Ind., 4: 285-313.

Ghourab MHH, Wahdan GA (2000). Response of cotton plants to foliar application of ascobine and ascorbic acid. Egypt J. Agric. Res., 78: 1195-1205.

Harborne JB (1984). Phytochemical methods: A guide to modern techniques of plant analysis. Second edition. Chapman and Hall, London, New York, p. 288.

Hassanein RA (1977). Effect of certain growth regulators on plant growth and development. Ph.D. Thesis, Fac. Of Sci, Ain Shams Univ., Cairo, Egypt.

Helal FA, Farag ST, El-Sayed SA (2005). Studies on growth, yield and its components and chemical composition under effect of vitamin C, vitamin B_1, boric acid and sulphur on pea (*Pisum sativum* L.) plants. J. Agric. Sci. Mansoura Univ., 30(6): 3343-3353.

Holub BJ (1991). Chollesterol-free foods: where's the trans? Can. Med. Assoc. J., 144: 330.

Homme PM, Gonalez B, Billard J (1992). Carbohydrate content, fructane and sucrose enzyme activities in roots, stubble and leaves of rye grass (*Lolium perenne* L.) as affected by source/sink modification after cutting. J. Plant Physiol., 140: 282-291.

Hu C, Zhang Y, Kitts DD (2000). Evaluation of antioxidant and pro-oxidant activities of bamboo *Phyllostachys nigra* var. *Henonis* leaf extract *in vitro*. J. Agric. Food Chem., 48: 3170-3176.

Jackson ML (1965). Soil chemical analysis constable and co. LTD. London.

Jenkins SH (1930). Determination of cellulose in straw. Biochem. J., 24: 1428.

Johnson M, Ostlund S, Fransson G, Kadesjö B, Gillberg C (2008). Omega-3/omega-6 fatty acids for attention deficit hyperactivity disorder: A randomized placebo-controlled trial in children and adolescents. J. Atten. Disord. PMID, pp. 1844-8859.

Joshi NL, Mali PC, Anurag S (1998). Effect of nitrogen and sulphur application on yield and fatty acid composition of mustard (*Brassica juncea* L.) oil J. Agron. Crop Sci., 180: 59-63.

Kampfenkel K, Van Montagu M, De InŸe (1995). Extraction and determination of ascorbate and dehydroascorbate from plant tissue. Anal. Biochem., 225: 165-167.

Kene HK, Wankhade ST, Sagare BN (1990). Influence of nutrients spray on yield and oil content of sunflower. Ann. Plant Physiol., 4(2): 246-248.

Khan MG, Srivastava HS (1998). Changes in growth and nitrogen assimilation in maize plants induced by NaCl and growth regulators. Biol. Plant., 41: 93-99.

Liso R, Innocenti AM, Bitonti MB, Arrigoni O (1988). Ascorbic acid induced progression of quiescent center cells from G1 to S phase. New Physiologist, 110: 469-471.

Maisuthisakul P, Suttajit M, Pongsawatmanit R (2007). Assessment of phenolic content and free radical-scavenging capacity of some Thai indigenous plants. Food Chem., 100: 1409-1418.

Malhi SS, Gan Y, Raney JP (2007). Yield, seed quality, and sulfur uptake of *Brassica* oil seed crops in response to sulfur fertilization. Am. Soc. Agron. J., 99: 570-577.

Malik CP Singh MB (1980). Plant Enzymology of Histo-enzymology. Kalyani Publishers. New Delhi, pp. 124-160.

Meara ML (1955). Fats and other lipids. In: Modern methods of plant analysis (peach, K and Tracey, M. R.), Springer-Verlag Berlin, 2: 317.

Morris DH (2004). Flax reduces inflammation leading to atherosclerosis. New Flax Facts. Flax Council of Canada, pp. 86-90.

Morris DH (2005). Flax-A smart choice. New Flax Facts. Flax Council of Canada.

Naguib MI (1963). Colourimetric estimation of plant polysaccharides. Zeit. Zucher., 16: 15.

Nanji DR, Norman AG (1928). Pectin estimation of the individual pectic substances in nature. Biochem. J., 22: 599.

Noctor G, Foyer CH (1998). Ascorbate and glutathione: Keeping active oxygen under control. Annu. Rev. Plant Physiol. Plant Mol. Biol., 49: 249-279.

Ofokansi KC, Esimone CO, Anele CK (2005). Evaluation of the in Vitro combined anti bacterial effects of the leaf extracts of *Bryophyllum pinnatum*. (Fam: crassulaceae) and *Ocimum gratissium* (Fam: Labiate). Plant Prod. Res. J., 9: 23-27.

Okuyama H, Ichikawa Y, Sun Y, Hamazaki T, Lands WEM (2007). Three fatty acids effectively prevent coronary heart disease and other late-onset diseases: the excessive linoleic acid syndrome. World Rev. Nutr. Dietetics, 96:(Prevention of Coronary Heart Disease), 83-103.

Radwan SRH, Momtaz A (1966). The technological properties of flax fibers and method of their estimation. El-Felaha J., 46: 466 (In Arabic).

Raju AS, Sreemannarayana B (1998). Sulphur in crop production in Southern Telangana zone of Andhra Pradesh. Fertil.-News, 43 (3): 47-56.

Ratledge C (1988). Lipid biotechnology: a wander land for microbial physiologist, in proceeding of the world conference on biotechnology for the fats and oils Industry, ed. T. H. Apple. White. American oil Chemists Society, Champaign, IL, pp. 153-171.

Rittler GJ, Seborg R, Mitchell RI (1932). Factors affecting determination of lignin by 72 percent sulphuric acid method. Ind. Eng. Chem. Ann.,

4: 202.
Rosen BP (2002). Biochemistry of arsenic detoxification. FEBS Lett., 529: 86-92.
Samiullah, Khan NA (1997). Improving performance of *Brassica juncea* cultivars by seed treatment with pyridoxine. New Zealand J. Crop Hortic. Sci., 25: 43-47.
Samiullah, Khan NA, Ansari SA, Afridi MMRK (1991). Pyridoxine augments growth, yield and quality of mustard through efficient utilization of soil applied NP-fertilizers. Acta Agron. Hung., 40(1-2): 111-116.
Scheiner JD, Lavado RS (1999). Oil water content, absorption of nutrient elements and responses to fertilization of sunflower: A case study. J. Plant Nutr., 22(2): 369-377.
Schupp R, Rennenperg H (1988). Duirnal changes in the glutathione content of spurce needle (*Picea abiec* L.). Plant Sci., 27: 113-117.
Shehata SM, Helmy YI, El-Tohamy WA (2002). Pepper plants as affected by foliar application with some chemical treatments under later summer conditions. Egypt J. Appl. Sci., 17 (7): 236-248.
Shukry WM, Khattab HKI, El-Bassiouny HMS (2007). Physiological and biochemical studies on flax plant grew in calcareous soil amended with water Hyacinth dry manure. J. Appl. Sci. Res., 3(1): 64-72.
Smirnoff N (1996). The function and metabolism of ascorbic acid in plants. Ann. Bot., 78: 661-669.
Smirnoff N, Conklin P, Loewus FA (2001). Biosynthesis of ascorbic acid in plants: Arenaissance. Ann. Rev. Plant Physiol. Plant Mol. Biol., 52: 437-467.
Smith AG, Croft MT, Moulin M, Webb ME (2007). Plants need their vitamins too. Physiol. Metab., 10(3): 266-275.
Tamak JC, Sharma HC, Singh KP (1997). Effect of phosphorus, sulphur and boron on seed yield and quality of sunflower. Indian J. Agron., 42: 173-176.
Tamar HPS, Dadhwal KS, Singh HP (1996). Oil content, oil and cake yield and protein content of sunflower (*Helianthus annuus* L) as influenced by irrigation, nitrogen and phosphorus levels. Indian J. Soil Conserv., 24(3): 512-220.
Thompson LU, Chen JM, Li T, Strasser-Weippl K, Goss PE (2005). Dietary flaxseed alters tumor biological markers in postmenopausal breast cancer. Clin. Cancer Res., 11(10): 3828-3835.
Vartainan N, Hervochon P, Marcotte L, Larher F (1992). Proline accumulation during drought rhizogenesis in *Brassica napus* var. Oleifera. Plant Physiol., 140: 623-628.
Vasudevan SN, Virupak-Shappa K, Venugopal N, Bhaskar S (1997). Response of sunflower (*Helianthus annuus*) to phosphorus, sulphur, micronutrients and humic acid under irrigated conditions on red-sand-loam soil. Indian J. Agric. Sci., 67(3): 116-112.
Velioglu YS, Massa G, Gao L, Oomah BD (1998). Antioxidant activity and total phenolics in selected fruits, vegetables, and grain products, J. Agric. Food Chem., 46: 4113-4117.
Westscott ND, Muir AD (2003). Chemical studies on the constituents of *Linum* spp. In Muir, A. D. and Westscott, N. D. (ed.) flax, the genus *Linum*. Taylor and Francis, London, pp. 55-73.
Wynn JP, Ratledge C (2000). Evidence the rate-limiting step for the biosynthesis of arachidonic acid in *Mortierella alpine* is at the level of the 18:3 to 20:3 elongase. Microbiology, 146: 2325-2331.
Yemn EW, Cocking EC (1955). The determination of amino acids with ninhydrine. Analyst, 80: 209-213.