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Response of *Camelina sativa* Oil to Different Levels of N-P-K and Compost Fertilizers

Abd El-Ghafour A. El-Sayed[1], Ahmed S. El-Liethy[1], Saber F. Hendawy[2*], Omnia G. Hefni[2]

[1] Faculty of Agriculture, Cairo University, Rd, Oula, Giza District, Giza Governorate, Egypt
[2] National Research Centre, 33 El Buhouth St., Ad Doqi, Dokki, Cairo Governorate, Egypt
* Corresponding author's e-mail: hendawysaber@yahoo.com

ABSTRACT

This study was conducted during the two winter seasons (2018/2019&2019/2020) to investigate the effect of NPK and compost fertilizers on the *Camelina sativa* plant under Egyptian ecology. The fertilizer levels of NPK were 0, 25, 50, 75 and 100%, recommended doses, whereas compost was applied at 6, 8 and 10 m^3/fed to investigate the effect of these fertilizers and the interaction of both chemical and organic fertilizers on the vegetative growth, oil yield and oil components percentage, especially Linolenic acid (ω-3). The obtained results indicated that the application of 100% NPK as well as 10 m^3 of compost produced the highest mean values of all vegetative characteristics compared to unfertilized plants at both samples in the two growing seasons and the other treatments. On the other hand, the results showed that all NPK treatments, i.e. 25, 50, 75, and 100% NPK significantly increased seed yield (g/plant) as compared to control, the mean values were 3.06, 4.70, 9.09 and 10.20 g/plant compared to 1.84 g/plant, respectively, for the 1st season and 3.11, 4.48, 9.27 & 10.27 g/plant comparing to 1.80 of control for the 2nd season. Compost treatments significantly increased the seed yield; the mean values were 5.10, 5.72, 5.88 and 6.42 g/plant in the 1st season and 5.09, 5.73, 5.99 and 6.32 g/plant in the 2nd season for fertilization with 0, 6, 8 and 10 m^3/Fed., respectively. The maximum mean values were obtained by compost at 10 m^3/fed. The interaction treatment between 100% NPK and 10 m^3/fed showed the maximum mean value of seed yield which recorded 10.51 and 10.78 g/plant for the 1st and 2nd seasons, respectively. In contrast, the lowest values of seed yield were obtained from unfertilized plant which recorded 1.09 and 1.04 g/plant for the 1st and 2nd seasons, respectively. The promising effect of NPK fertilizer on fixed oil % and yield was evident with NPK 100%, 52.53% and 52.83% fixed oil, whereas yield was 408.63 and 413.68 l/fed.), followed by 75% NPK which produced fixed oil percentage and yield 46.82, 46.77% as well as 207.29 and 208.06 l/fed for the first and second season, respectively, compared with other treatments and control. The highest fixed oil percentages and yield (l/fed) were recorded with NPK at 100% and compost at 10 m^3/fed during both seasons.

Keywords: NPK, *Camelina sativa*, compost fertilizers

INTRODUCTION

Camelina (*Camelina sativa L.*Crantz) is an oil-seeded crop belonging to the Brassicaceae family. This crop has attracted the interest of scientific centers and industry in many countries (Zanetti et al., 2017). Zubr (2003) reported that the main product of this crop is seed oil, which constitutes unsaturated fatty acids (15%), linoleic acid (15%) and α-linolenic acid (38%). Its seed oil is used in human nutrition, cosmetics and other industrial applications (Zubr 2003). In many regions of the world this crop has great potential as a low-cost feedstock for biodiesel production as mentioned by Punam et al., (1993) and Solis et al., (2009). Camelina seed oil has potential to be a renewable, low emission component of jet fuel (Shonnard et al. 2010).

Compost is used for plant nutrition, which considers as the cornerstone of nutrient resources for conserving soil fertility. It plays numerous roles in soil fertility and productivity including: providing soils with humus that improves the physical properties of soil, improving the soil capacity to hold water, rebuilding soil structure and increasing the capability of the soil molecules to exchange cation (Akhtar et al. 2016; Medina et al. 2015; Mtui 2009). The addition of compost to agricultural soils supplies organic matter and nutrients as well as improves soil physical structure and decreases leaching of mineral elements from the soil (Rantala et al., 1999). Compost is also used to provide biological control against various plant pathogens (Hoitink and Grebus, 1994). Compost has already been established as suitable fertilizer for improving the productivity of several aromatic and medicinal plants, such as *Dracocephalum moldavica* (Hussein et al., 2006 and Horia et al. 2019) and *Tageteserecta* (Khalil et al. 2002).

Nitrogen is an important element for the formation of amino acids. It is essential for cell division of plant, vitamins and protein biosyntheses, nucleic acids, coenzymes and production of carbohydrates. Moreover, it plays an important role in photosynthesis. Generally, N supply favors increased vegetative growth (Argyropoulou et al. 2015). Camelina has small leaves, greenish yellow color, the crop matures become earlier, it does not form many silicles, and the seeds are small when deficient in nitrogen. Zubr (1997) found that the nutrient requirements for Camelina were moderate to low, approximately 100 kg N ha^{-1} and recommended to apply fertilizer at the beginning of spring for winter crops. Moreover, the application of the N fertilizer at the 4 to 6 leaves stage in spring-seeded crops was recommended to avoid leaching, as well as about 30 kg ha^{-1} P_2O_5 and 50 kg K_2O ha^{-1} added to the soil before or at planting (Zubr, 1997). Some studies were carried out to determine the nitrogen requirements of camelina crop where seed yields have been found to maximize at about 100 kg N ha^{-1} in Europe (Zubr 2003), 90 kg N ha^{-1} in USA (Budin et al. 1995) and 75 kg N ha^{-1} in Ireland (Crowley and Frohlich 1998). Zadernowski et al. (1999) found that the N fertilizer affected seed quality, oil yield and fatty acid composition of camelina under Polish conditions. In Austria, Agegnehu and Honermeier (1997) reported that increasing the N level from 60 to 130 kg N ha^{-1} increased seed yield by 30%, against significant decline in seed oil content. In Romania, Bugnarug and Borcean (2000) noticed that N fertilizer at 100 kg N ha^{-1} resulted in a 58% increase in seed yield, while decreasing seed oil concentration. On the other hand, in Ireland, Crowley and Frohlich (1998) observed a significant increment in the Camelina seed yield from applied N, but found no effect of the N fertilizer on seed oil content (%). Recently, the studies in Chile indicated that N at 150 kg N ha^{-1} resulted in maximum camelina yields and oil content declined with increasing N rate (Solis et al. 2013).

The phosphorus fertilizer will promote reproductive yields and inflorescence production (Egle et al., 1999, Besmer and Koide 1999). Many researchers reported that the P fertilizer can increase seed yield, dry matter, photosynthesis (Fleisher et al., 2013, Rogério et al., 2013; Xie et al., 2014). Xie et al., (2014) found that P increased the seed yield by enhancing dry matter translocation to the seed. Furthermore, Hocking and Pinkerton, (1993) and Pande et al., (1970) observed that P improved the seed yield by increasing the number of capsules per plant and seeds per capsule. Some studies have also reported effect of P supply on yield and yield components such as Abbadi and Gerendás (2011) for safflower and sunflower, Fageria and Baligar (1997) for upland rice.

K plays a vital role in photosynthesis, translocation of photosynthates, protein synthesis, control of ionic balance, regulation of plant stomata and water use, activation of plant enzymes as well as many other processes (Marschner, 1995; Reddya et al. 2004). It is not only an essential macronutrient for plant growth and development, but also is a primary osmoticum in maintaining low water potential of plant tissues. According to Fageria (2009), K deficiency resulted in poor root system development, weak stalks, poor and shriveled seeds and fruits in addition to susceptibility to diseases. Amanullah et al. (2011) reported that elevation in the rates of potassium resulted in significant increment of yield and yield components.

MATERIALS AND METHODS:

Two field experiments were carried out in a private organic farm belonging to Heliopolis University, Sharqia Governorate, Egypt. During two successive seasons(2018 and 2019), to study the effects of the NPK fertilization rate (0, 100, 75, 50 and 25% of recommended dose), compost (0,6, 8, and 10 m^3/fed) as well as their interaction treatments on Camelina growth, yield, and some chemical constituents. The recommended rate of NPK was 200 kg ammonium sulfate (20.5% N), 150 kg calcium super phosphate (15.5% P_2O_5) and 60 kg potassium sulfate (48% K_2O)/fed. The seeds of *Camelina sativa* were imported from Gross University, Germany. The seeds of Camelina were sown on 1st of October during both seasons and immediately irrigated.

After soil preparation and before sowing, the complete dose of the organic manure (compost) was added with the rate of (0, 6, 8 and 10 m^3/fed) and added the whole dose of phosphatic fertilizer as calcium super phosphate ($Ca(H_2PO_4)$,$2CaSO_4$), 15.5%, at different rates. After fertilizers addition, the seeds were sown. On 1st November, thirty days after sowing, the half dose of both Ammonium sulfate and potassium sulfate were added, in addition to patching the missing holes. One month later, in 1st December, the second dose of nitrogenous and potash fertilizers (before flowering) was added and the first samples were collected to record data (plant height, branches number, fresh weight and dry weight). On 1st January, the second batch of samples was collected for recording the same data, in addition to capsules numbers and seed weight/plant.

Data recorded

Three plants from each treatment in each replication were randomly selected for recording the growth and yield parameters during both seasons. The recorded growth parameters were plant height (cm) measured as the main plant stem for three times in growing seasons at (30,60 and 90 days) from the sowing date, number of branches/plant (the main lateral branches were counted) at (30, 60 and 90 days) from the sowing date, number of capsules/plant, herb fresh and dry weight (g/plant) and seeds weight (g/plant and kg/fed)

Table 1. Main characteristics of soil

Specification	Value
1-Mechanical analysis	
Sand %	81.8
Silt %	16.79
Clay %	1.23
Texture	Sand
2-Chemical analysis	
PH 1:2.5ext.	7.56
Electrical Conductivity 1:2.5ext	2.22
Soluble cations meq/L	
Na^+	5.5
Ca^{++}	4.55
Mg^{++}	1.65
Soluble anions meq/ L	
CO_3^{-1}	0.00
HCO_3^{-1}	3.49
Cl^{-1}	6.54
SO_4^{-2}	3.2
Available (mg·g^{-2})	
P	8.6
K	18
Total (mg g^{-2}) N	55

The samples of aerial parts of *Camelina sativa L.* plants of each treatment were dried naturally and then at 40°C until recording constant weights. The dried herb was powdered and kept in dissector for chemical analyses.

The following chemical constituents were recorded during both seasons; chlorophyll (A,B), carotenoids, herb nitrogen, phosphor and potassium contents (%), herb total carbohydrates (%), herb protein (%), herb total flavonoids, seeds fixed oil percentage (%), fixed oil yield (ml/ plant and L/fed) and fatty acids. In parallel, the yield per feddan was obtained according to the equation; the mean value of treatment × number of plants/fedas well as number of plants/fed.

Statistical analysis

All obtained data of the present study were statically analyzed as a split plot system in randomized complete blocks design by Duncan`s multiple-range test (DMR) **(**Duncan 1955; Snedecor and Cochran 1967) using the General Linear Models procedure of the Costat program (version 6.4; CoHort Company, Birmingham, UK, 1998–2008) BY (Cardinali and Nason 2013).

Chemical analyses

Total chlorophyll was determined as (SPAD units) using chlorophyll meter (SPAD-502 Plus--Minolta, Osaka, Japan). It was carried out according to Yadava (1986). Total carbohydrates percentage was performed according to a modified version of Dubois assay (Dubois et al., 1956). The carbohydrate content was calculated using the equation from glucose standard curve using the same method.

At the beginning, 0.5 g of each sample was digested according to the method outlined by Black et al. (1965). Nitrogen is determined after steam distillation by capture in an excess of boric acid on titration with HCl by modified Kjeldahl method using Kjeldahl apparatus (Gerhardt),quote results as N%. Regarding phosphorus, assessment was conducted using fresh vanadate-molybdate reagent by spectrophotometer (JENWAY 6315) at 430 nm according to (Cottnie et al. 1982). Additionally, flame photometer was used to determine the concentration of K in diluted solution (1:5) then the K-emission was measured at 768 nm according to (Cottnie et al. 1982).

Protein concentration in the dried herb was estimated from Nitrogen concentration of dry herb according to the following formula:

$$\text{Protein (\%)} = \text{Nitrogen (\%)} \times 6.25$$

The flavonoids content (mg/g) of each treatment were determined in the represented dry herb samples according Quettier et al. (2000). The samples were prepared in triplicate. Standard solution of rutin and the calibration line was construed. The concentration of flavonoids in extracts was expressed in terms of rutin equivalent (mg of RU/g herb).

Fixed oil percentage in seed samples was performed as described in A.O.A.C. (1970). Fixed oil percentage was determined, while fixed oil content and yield were calculated. Preparation of fatty acid methyl esters was conducted according to Christie (1993) and Khan and Scheinmann (1978) to produce the fatty acid methyl esters for the GC--MS analyses instrument, a TRACE GC ULTRA GAS Chromatographs (THERMO Scientific crop., USA), coupled with a thermo mass spectrometer detector (ISQ Single Quadrupole Mass Spectrometer). The GC-MS system was equipped with a TG-5MS column (30 m × 0.25 mm i.d., 0.25 μm film thickness) using Helium as a carrier gas in flow rate 1.0 Ml/min and a split ratio of 1:10 with temperature program; 80°C for 1 min; rising at 4.0°C/min to 300°C and held for 5 min. The injector and detector were held at 240°C. Diluted samples (1:10 hexane, v/v) of 0.3μL of the mixtures were injected. Mass spectra were obtained by electron ionization (EI) at 70EV, using a spectral range of m/z 35-500. Most of the compounds were identified using the analytical method: mass spectra (authentic chemicals, Wiley spectral library collection and NSIT library) and were confirmed with the published data (Adams 2001).

RESULTS AND DISCUSSION

Vegetative growth and yield components

Plant height

Data in Tables 2 and 3 show the effect of NPK, compost, and their interactions with the height of the Camelina plants during two seasons. Generally, NPK fertilization significantly increased plant height in a dose dependent manner in both seasons, compared with control plants; accordingly, NPK (100%) presented the highest mean values followed with 50% NPK.

Concerning compost application, the results in Tables 2 and 3 reveal that all compost levels (6, 8 and 10 m^3) resulted in significant increment in plant height, comparing to unfertilized plants. The highest mean values were obtained from the maximum compost application rate (10 m^3) during both seasons.

Regarding the interaction between NPK and compost on plant height (Tables 2–3), significant differences were recorded for the samples of both seasons. Plants reached 122.67 and 110.67 cm for the 1st & 2nd seasons, respectively in a response to fertilization with 100% NPK + compost (10 m^3), whereas the shortest plants (73.67 and 73.67 cm for 1st & 2nd seasons, respectively) resulted from the lack of fertilization. It could be noticed that 100% NPK + compost at 10 m^3 and 100% NPK + compost at 8 m^3/fed exhibited the same value for the 2nd sample of 2nd season.

Fresh and dry weights of plant

The fresh and dry weights of the *Camelina sativa* plant (g/plant) in a response to NPK, compost and their interactions were presented in Tables 4–7, in the two growing seasons. All NPK fertilization levels significantly increased fresh and dry weights (g/plant) compared to unfertilized plants at both samples in the two growing

Table 2. Effect of NPK, compost and their interaction on plant height (cm) of the *Camelina sativa* plants (1st season)

NPK	Compost				
	0	6 m3	8 m3	10 m	Mean
1st Sample					
0 NPK	67 j	75.67 i	77.67 i	88.67 h	77.25 E
25% NPK	90.33 gh	92 fgh	94 fgh	95.94 fgh	93.07 D
50% NPK	93.33 fgh	98.67 fg	100 efg	101 def	98.25 C
75% NPK	102 def	108.67 cde	108.67 cde	109.67 cd	107.25 B
100% NPK	112.33 bc	113.67 bc	118.33 ab	122.67 a	116.75 A
Mean	93.00 C	97.74 B	99.73 B	103.59 A	
2nd Sample					
0 NPK	73.67 g	82.67 f	83.67 ef	87.67 def	81.92 E
25% NPK	89 cdef	90 cdef	90.33 cdef	90.67 cdef	90.00 D
50% NPK	91.67 cde	95.33 cd	97.33 bc	105 ab	97.33 C
75% NPK	95.33 cd	103.67 ab	104.67 ab	102.67 ab	101.59 B
100% NPK	105.67 a	109 a	109.33 a	110.67 a	108.67 A
Mean	91.07 B	96.13 A	97.07 A	99.34 A	

Table 3. Effect of NPK, compost and their interaction on plant height(cm) of the *Camelina sativa* plants (2nd season)

NPK	Compost				
	0	6 m3	8 m3	10 m	Mean
1st Sample					
0 NPK	66 i	75 h	75.67 h	90 g	76.67 E
25% NPK	90.67 g	93 fg	95.33 ef	98 e	94.25 D
50% NPK	94 efg	97.33 ef	102.33 d	102 d	98.92 C
75% NPK	103.67 d	105.67 cd	105.67 cd	108.67 c	105.92 B
100% NPK	109.33 c	115.67 b	119 b	127 a	117.75 A
Mean	92.73 C	97.33 B	99.60 B	105.13 A	
2nd Sample					
0 NPK	65.67 j	82 i	83 i	86.67 h	79.34 E
25% NPK	90.67 g	93 fg	90.33 g	90.67 g	91.17 D
50% NPK	92.67 fg	95.33 ef	97 e	103.67 bcd	97.17 C
75% NPK	100.67 d	103 cd	104 bcd	104 bcd	102.92 B
100% NPK	106.33 bc	107.67 b	112 a	112 a	109.50 A
Mean	91.20 C	96.20 B	97.27 B	99.40 A	

seasons. Maximum increase on both weights was obtained with NPK at 100% produced as compared to other treatments. In parallel, compost treatments presented significant increment for plant fresh and dry weights during both seasons, 10 m^3 produced the highest mean values of fresh weight followed by compost at 8 m^3.

Regarding the interaction between NPK fertilization and compost on the fresh and dry weights/ plant, significant differences were obtained between these two factors at both samples in the two seasons (Tables 4–7). In both seasons, the highest plant fresh and dry weights (g/plant) were obtained from the plants fertilized with high levels of both NPK and compost, as compared to unfertilized plants.

Fixed oil percentage and yield

The effect of NPK application at different levels on fixed oil percentage and yield of the *Camelina sativa* plants during both seasons presented in Tables 8 and 9. Increasing the NPK fertilizer dose exhibited a gradual steady increase in the fixed oil and yield in both seasons. The promising effect on fixed oil and yield was particularly evident at NPK 100%, which significantly increased fixed oil accumulation (52.53%, 52.83%)

Table 4. Effect of NPK, compost and their interaction on fresh weight (g/plant} of the *Camelina sativa* plants (1st season)

NPK	Compost				
	0	6 m³	8 m³	10 m	Mean
1st Sample					
0 NPK	21.46 i	28.23 hi	35.7 gh	43.47 g	32.22E
25% NPK	36.97 gh	48.53 fg	57.8 ef	58.5 ef	50.45D
50% NPK	59.87 ef	64.8 de	62.93 def	74.93 d	65.63C
75% NPK	76.3 d	99.5 c	100.47 c	101 c	94.32B
100% NPK	110.13 c	128.7 b	173.97 a	174.07 a	146.72A
Mean	60.95C	73.95B	86.17A	90.39A	
2nd Sample					
0 NPK	20.93 f	27.53 ef	28.2 ef	30 e	26.67E
25% NPK	31.43 e	35.43 de	35.63 de	37.37 de	34.97D
50% NPK	36.17 de	42.87 d	43.13 d	45.3 d	41.87C
75% NPK	57.07 c	64.67 bc	65.57 bc	65.6 bc	63.23B
100% NPK	66.3 bc	70.2 b	80 a	84.53 a	75.26A
Mean	42.38D	48.14C	50.51B	52.56A	

Table 5. Effect of NPK, compost and their interaction on fresh weight (g/plant} of the *Camelina sativa* plants (2nd season)

NPK	Compost				
	0	6 m³	8 m³	10 m	Mean
1st Sample					
0 NPK	21.83 h	29.07 gh	36.1 fg	43.93 ef	32.73E
25% NPK	38.6 efg	48.1 e	58.8 d	59.27 d	51.19D
50% NPK	61.37 d	65.1 d	67.8 cd	76.8 c	67.69C
75% NPK	78.17 c	100.5 b	101 b	102.3 b	95.49B
100% NPK	105.7 b	108.53 b	125.97 a	132 a	118.05A
Mean	61.13D	70.26C	77.93B	82.86A	
	2nd Sample				
0 NPK	19.83 h	23.97 g	25.13 g	28.17 f	24.28E
25% NPK	29.03 f	33.53 e	34.63 e	34.33 e	32.88D
50% NPK	35.23 e	39.63 d	40.13 d	42.33 d	39.33C
75% NPK	67.4 c	84.8 b	85.5 b	86.1 b	80.95B
100% NPK	86.13 b	91.1 a	91.37 a	93.13 a	90.43A
Mean	47.52C	54.61B	55.35AB	56.81A	

Table 6. Effect of NPK, compost and their interaction on dry weight (g/ plant} of the *Camelina sativa* plants (1st season)

NPK	Compost				
	0	6 m³	8 m³	10 m	Mean
1st sample					
0 NPK	10.83 h	12.78 gh	13.42 gh	15.22 fg	13.06E
25% NPK	15.13 fg	15.53 fg	17.8 ef	16.3 fg	16.19D
50% NPK	19.8 e	20.77 e	26.13 d	34.67 c	25.34C
75% NPK	36.18 c	42.17 b	46.1 a	46.57 a	42.76B
100% NPK	47.2 a	47.7 a	47.73 a	48.83 a	47.87A
0 NPK	10.83 h	12.78 gh	13.42 gh	15.22 fg	13.06E
2nd sample					
0 NPK	8.3 b	13.7 b	14.77 b	14 b	12.69D
25% NPK	14.2 b	22.23 a	22.33 a	23 a	20.44C
50% NPK	23.57 a	23.87 a	25.7 a	25.5 a	24.66B
75% NPK	24.53 a	25.5 a	25.63 a	27.23 a	25.72AB
100% NPK	27.83 a	28.4 a	28.53 a	28.67 a	28.36A
Mean	19.69B	22.74A	23.39A	23.68A	

Table 7. Effect of NPK, compost and their interaction on dry weight (g/plant} of the *Camelina sativa* plants (2nd season)

NPK	Compost				
	0	6 m^3	8 m^3	10 m	Mean
1st sample					
0 NPK	8.9 ^{h}	11.97 ^{g}	13.5 ^{fg}	14.03 ^{fg}	12.10^{E}
25% NPK	16.23 ^{ef}	16.63 ^{ef}	18 ^{de}	18.33 ^{de}	17.30^{D}
50% NPK	19.7 ^{de}	20.57 ^{de}	21.43 ^{d}	24.43 ^{c}	21.53^{C}
75% NPK	29.6 ^{b}	34.87 ^{a}	34.97 ^{a}	34.93 ^{a}	33.59^{B}
100% NPK	36.17 ^{a}	36.2 ^{a}	36.47 ^{a}	37.2 ^{a}	36.51^{A}
0 NPK	22.12^{B}	24.04^{A}	24.87^{A}	25.68^{A}	
2nd sample					
0 NPK	10.62 ^{e}	14.33 ^{cde}	14.54 ^{cde}	15.53 ^{cde}	13.76^{D}
25% NPK	13.43 ^{de}	15.87 ^{cde}	17.77 ^{bcd}	19.68 ^{abcd}	16.69^{C}
50% NPK	20.97 ^{abc}	22.47 ^{ab}	23.23 ^{ab}	24.83 ^{a}	22.88^{B}
75% NPK	25.17 ^{a}	25.87 ^{a}	26.73 ^{a}	26.17 ^{a}	25.99^{A}
100% NPK	26.37 ^{a}	26.63 ^{a}	26.73 ^{a}	27.27 ^{a}	26.75^{A}
Mean	19.31^{B}	21.03^{AB}	21.80^{AB}	22.70^{A}	

Table 8. Effect of NPK, compost and their interaction on oil percentage of the *Camelina sativa* plants during both growing seasons

Column1	0	6 m^3	8 m^3	10 m	Mean
0 NPK	27.6 ^{f}	27.6 ^{f}	28.3 ^{f}	28.6 ^{f}	28.03
25% NPK	28.3 ^{f}	28.8 ^{f}	31.2 ^{ef}	32.7 ^{e}	30.25
50% NPK	32.9 ^{e}	33.6 ^{e}	37.4 ^{d}	38.2 ^{d}	35.53
75% NPK	38.8 ^{d}	46.87 ^{c}	51.6 ^{ab}	51.6 ^{ab}	47.90
100% NPK	50 ^{bc}	52.5 ^{ab}	53.2 ^{ab}	54.4 ^{a}	52.53
Mean	35.52	38.50	40.26	41.10	
2nd sample					
Column1	0	6 m^3	8 m^3	10 m	Mean
0 NPK	26 ^{e}	27.5 ^{e}	28.1 ^{e}	28.6 ^{e}	27.55
25% NPK	28.5 ^{e}	28.3 ^{e}	30.2 ^{de}	32.9 ^{d}	29.98
50% NPK	32.6 ^{d}	33.7 ^{d}	37.4 ^{c}	38 ^{c}	35.43
75% NPK	38.9 ^{c}	50.3 ^{a}	51 ^{a}	51.2 ^{a}	47.85
100% NPK	51.4 ^{a}	52.3 ^{a}	53.4 ^{a}	54.2 ^{a}	52.83
Mean	35.48	38.42	40.02	40.98	

Table 9. Effect of NPK, compost and their interaction on oil yield/feddan of the *Camelina sativa* plants during both growing seasons

Column1	0	6 m3	8 m3	10 m	Mean
0 NPK	22.91^{i}	40.9 ^{hi}	43.76 ^{hi}	50.04 ^{h}	39.40
25% NPK	52.6 ^{h}	57.12 ^{h}	88.11 ^{g}	93.92 ^{g}	72.94
50% NPK	99.51 ^{g}	112.89 ^{fg}	123.66 ^{f}	177.14 ^{e}	128.30
75% NPK	241.51 ^{d}	357.71 ^{c}	365.77 c ^{a}	370.07 ^{c}	333.77
100% NPK	373.58 ^{c}	409.99 ^{b}	415.05 ^{b}	435.74 ^{a}	408.59
Mean	158.02	195.72	207.27	225.38	
2nd sample					
Column1	0	6 m3	8 m^3	10 m	Mean
0 NPK	20.66 ^{d}	39.94 ^{d}	42.46 ^{d}	49.6 ^{d}	38.17
25% NPK	50.23 ^{d}	59.22 ^{d}	90.58 ^{cd}	86.31 ^{cd}	71.59
50% NPK	94.38 ^{cd}	110.23 ^{cd}	126.61 ^{cd}	155.76 ^{c}	121.75
75% NPK	251.03 ^{b}	362.79 ^{a}	365.25 ^{a}	379.69 ^{a}	339.69
100% NPK	385.61 ^{a}	408.57 ^{a}	415.39 ^{a}	445.16 ^{a}	413.68
Mean	160.38	196.15	208.06	223.30	

and consequently increased the yield (408.63 and 413.68 l/fed), followed by 75% NPK (46.82%, 46.77% as well as 207.29 and 208.06 l/fed. for the first and the second seasons, respectively) compared with the two other treatments and control.

The values of fixed oil percentage and yield for *Camelina sativa* seeds in the two seasons (Tables 8 and 9) show variation with different compost levels during both seasons. The plants fertilized with compost at 10 m^3/fed produced the highest significant fixed oil percentage (41.10 & 40.11%) and yield (225.39 & 207.29l/fed.) in comparison with other treatments and control during both seasons. Lower mean values for fixed oil and yield were 35.52% and 35.48% as well as 158.02 and 160.38 l/fed. for unfertilized plants during the first and second seasons, respectively.

The combination treatments between NPK and compost significantly induced fixed oil percentage and yield as shown in Tables (8 and 9). The highest fixed oil percentages and yield (l/Fed.) were recorded when the plants were treated with the maximum level of NPK (100% NPK) and compost (10 m^3/fed) during both seasons, the mean values of fixed oil were 54.4% and 45.2%, while the mean values of fixed oil yield were 435.74 and 445.16 l/fed for the first and second seasons, respectively. Lower values of fixed oil percentage and yield were obtained from untreated plants. The effect of compost on oil content was in agreement with the studies obtained by Bilalis *et al*., (2010) and Joshi *et al*., (2017) which also studied the effect of organic fertilization on flax and Camelina plant, respectively. Generally, application of compost on soil improved its properties, water holding capacity, air and heat balance, plant water and nutrients availability, decrease of nutrients leaching and reducing erosion and evaporation which lead to the highest yield safety compared to pure mineral fertilization as mentioned by Adugna (2016).

Relative percentage of fatty acids

As shown in Table 10, eight fatty acids were identified. Total fatty acids percentages ranged from 98.54 to 100%. It could be noticed that this oil is rich in unsaturated fatty acids

Table 10. Influence of NPK and compost fertilizers on fatty acids of the *Camelina sativa* plants during the 2nd season

Treatments	Palmitic (16:0)	Stearic (18:0)	Oleic (18:1)	Linoleic (18:2n-6)	γ-linoleinic (18:3n-3)	Arachidic (20:0)	Eicosenoic (20:3n-6)	Docosenoate (22:1)	Saturated fatty acids	Un-saturated fatty acids	C18 un-saturated fatty acids	Total identified
Control	1.76	0.15	3.87	16.59	71.34	0.05	6.04	0.2	1.96	98.04	91.8	100
25% NPK	0.36	0.1	2.07	13.1	75.64	0.04	7.1	0.13	0.5	98.04	90.81	98.54
25% NPK+6 m^3 compost	1.55	0.09	5.43	18.58	60.37	0.03	13.53	0.13	1.67	98.04	84.38	99.71
25% NPK+8 m^3	1.87	0.2	6.00	18.53	58.41	0.03	14.83	0.13	2.1	97.9	82.94	100
25% NPK+10m^3	1.61	0.09	6.32	18.98	58.18	0.03	14.43	0.13	1.73	98.04	83.48	99.77
50% NPK	1.59	0.1	7.26	19.63	57.48	0.03	13.54	0.13	1.72	98.04	84.37	99.76
50% NPK+6m^3	1.06	0.11	5.28	15.62	69.36	0.04	7.67	0.11	1.21	98.04	90.26	99.25
50% NPK+8m^3	1.61	0.1	4.15	18.69	61.17	0.04	13.87	0.16	1.75	98.04	84.01	99.79
50% NPK+10m^3	1.49	0.5	5.05	18.03	64.91	0.04	9.84	0.14	2.03	97.97	87.99	100
75% NPK	1.45	0.17	4.14	18.41	66.16	0.04	9.18	0.15	1.66	98.04	88.71	99.7
75% NPK+6 m^3	1.48	0.46	2.77	14.06	73.85	0.05	7.16	0.17	1.99	98.01	90.68	100
75% NPK+8m^3	1.38	0.12	4.02	13.2	75.09	0.04	5.56	0.17	1.54	98.04	92.31	99.58
75% NPK+10 m^3	1.53	0.17	4.13	12.02	73.09	0.1	8.71	0.09	1.8	98.04	89.24	99.84
100% NPK	1.97	0.53	7.35	16.13	64.32	0.2	8.95	0.55	2.7	97.3	87.8	100
100% NPK+6m^3	1.39	0.19	3.4	13.2	76.21	0.06	5	0.23	1.64	98.04	92.81	99.68
100% NPK+8m^3	1.49	0.2	3.75	8.26	81.55	0.06	4.22	0.26	1.75	98.04	93.56	99.79
100% NPK+10m^3	1.29	0.19	4.02	7.55	79.26	0.07	7	0.21	1.55	98.04	90.83	99.59
6 m^3 compost	1.53	0.17	4.11	10.04	78.58	0.06	5.04	0.27	1.76	98.04	92.73	99.8
8 m^3 compost	1.33	0.16	4.09	10.1	79.41	0.04	4.21	0.23	1.53	98.04	93.6	99.57
10 m^3 compost	2.03	0.33	4.63	19.8	63.69	0.04	9.27	0.21	2.4	97.6	88.12	100

(97.30- 98.04%) such as linoleic (7.55-19.63%), α-linolenic (58.41-81.55%), oleic (2.07-7.35%) and eicosadienoic (4.21-14.83%). The 2nd rank of fatty acids group was saturated fatty acids (0.50-2.70%) such as palmitic (0.36-2.03%), stearic (0.09-0.53%) and arachidic (0.03-0.20%). The maximum percentage of unsaturated fatty acids was obtained by 25% NPK + compost at 6 m^3 while 100% NPK without compost exhibited the highest percentage of saturated fatty acids.

Calculation of the ratio between PUFA ω−6/ PUFA ω−3 showed that it ranged from 0.15 to 0.58. This ratio proved that Camelina oil is a good source of omega-3 fatty acid (α-Linolenic acid). In this connection, α-Linolenic can produce eicosapentaenoic acid and docosahexaenoic acid which depends on the ratio between linoleic acid and α-Linolenic in the food consumed (Gebarer *et al*., 2006). High values of the PUFA ω−6/ PUFA ω−3 (10:1–20:1) may stimulate inflammations (Tapiero *et al*., 1999). Therefore, using Camelina oil in the diet can help to decrease the PUFA ω−6/ PUFA ω−3 ratio.

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