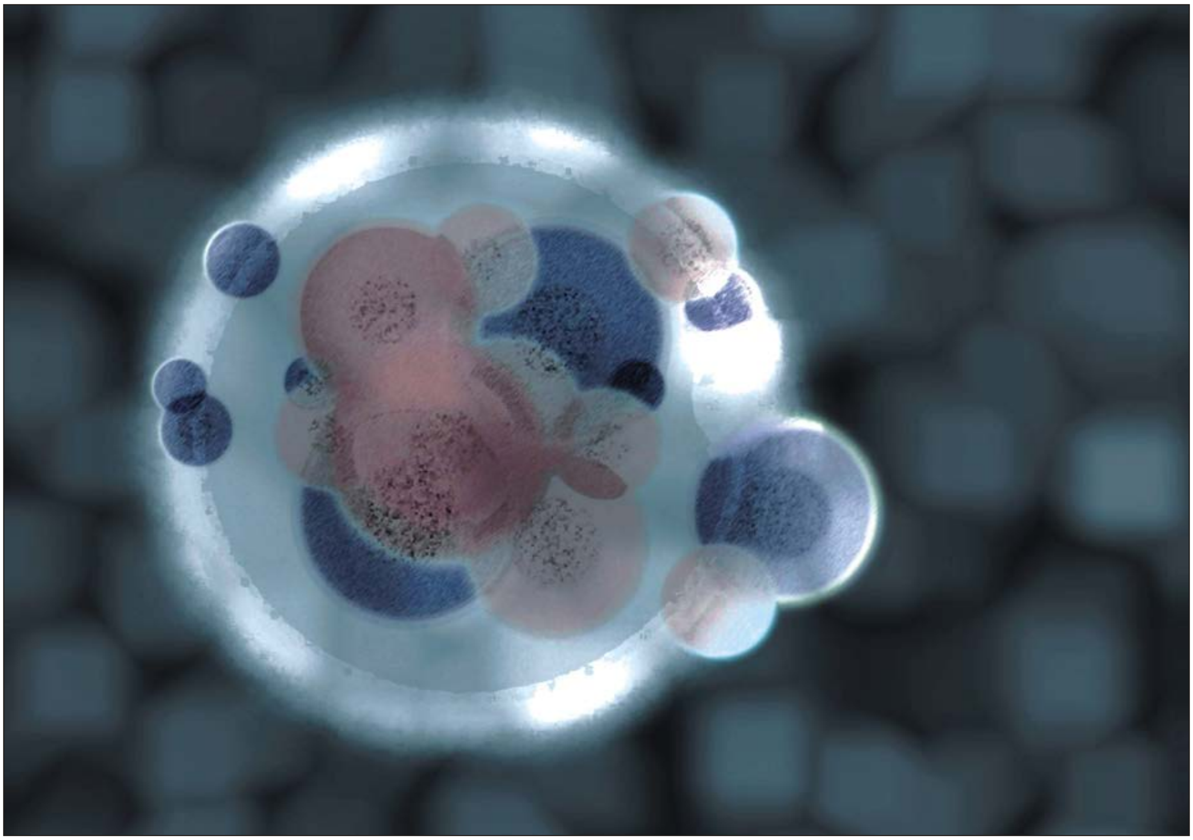

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Effects of Potassium and Zinc Fertilizers on Some Agronomical Traits of Three Spring Canola (*Brassica napus* L.) Cultivars

Shirin Ghazian Tafrishi, Shahin Yazdifar and Iraj Amini
Department of Agronomy, Agricultural College, Mazandaran University, Sari, Iran

Abstract: This study was carried out at Agricultural Station of Dasht-E-Naz in North of Iran during 2003-2004 to evaluate the effects of potassium (K) and zinc (Zn) fertilizer rates on grain yield, gain oil content and some agronomical traits of three spring canola (*Brassica napus* L.) cultivars. Three spring canola cultivars (Hyola 401, Option 501 and PF 7045/9), three rates of potassium sulfate (K_2SO_4) as a potassium fertilizer (0, 50 and 100 kg ha^{-1}) and two rates of zinc sulfate ($ZnSO_4$) as a zinc fertilizer (0 and 10 kg ha^{-1}) were arranged in a factorial design with four replications. The results showed that the application of potassium fertilizer significantly resulted in an increase in number of grains per pod and grain yield in all cultivars while it had no significant effect on grain oil content. However, the application of zinc fertilizer significantly increased grain oil content in all cultivars. Furthermore, the highest number of pods per branches was obtained in hybrid Hyola 401 when the highest amount of potassium (100 kg ha^{-1}) and zinc (10 kg ha^{-1}) fertilizers were applied. Hyola 401 also showed the best performance among cultivars in response to the application of fertilizers, implying its high ability to receive more fertilizer.

Key words: Potassium, zinc, grain yield, oil content, *Brassica napus*

INTRODUCTION

Oilseed rape is now the second largest oilseed crop in the world providing 13% of the world's edible oil supply (Raymer, 2002). Interest in canola is increasing steadily among health-conscious consumers due to its lowest content of saturated fatty acids (<70 g kg^{-1}) among major oil seeds (Starner *et al*., 1996). Therefore, a good understanding of canola nutrient requirements is needed to efficiently manage fertilizers and maximize economic returns. Balanced use of fertilizers, their type and the appropriate time and the method of application are crucially important in sustainable crop production (Jan and Khan, 2000). Spatial nutrient variability in fields creates problems for soil testing and fertilizer application. Besides, the application of single fertilizer rates across variable fields results in over-fertilized and under-fertilized areas within the field. Although, variable fertilization rate is being researched and developed, most fields are still fertilized with a single rate.

The macronutrient potassium (K) is required in large amounts by canola. In spite of the large requirement, numerous fertilizer research studies showed that canola rarely responds consistently or economically to applied K unless the level of K is very low in soil, from 78 to 112 kg ha^{-1}, although the critical amount of K is stated to be around 280 kg ha^{-1} in the top 15 cm of soil (Sheppards and Bates, 1980).

Among the micronutrients, zinc deficiency is the most widespread on a wide range of soil under both cold and warm climates (Cakmak *et al*., 1996; Graham *et al*., 1992; Grewal *et al*., 1997). Zinc deficiency problems severely happens in calcareous soil due to the high pH (>7.0), high amount of free calcium carbonate, low organic matter content and the inter relationships with other elements (Stevens and Mesbah, 2004) particularly in arid and semi-arid regions. Most of the soil in Iran are highly calcareous and deficient in Zn and the excessive application of phosphate fertilizers limits Zn availability. Crops grown under such conditions have low yield and produce seeds with a low Zn amount. In oilseed rape, root growth was impaired and seed yield was severely depressed when Zn was omitted in subsoil (Grewal *et al*., 1997). Many researches and fertilizer trials have provided growers and agronomists with general guidelines for fertilizing canola (Jackson *et al*., 1993; Jackson, 2000; Kidman and Paul, 2001). However, the information on nutrient relationships particularly of macro and micronutrients is not adequate. Canola is recently introduced in Iran, thus, many agronomic aspects of its production needs to be revealed through various and comprehensive studies. The aim of this field experiment is to evaluate the effects of K, Zn and their interactions on yield, yield components and grain oil content of three spring canola cultivars under the Iranian conditions.

Corresponding Author: Shahin Yazdifar, Department of Agronomy, Agricultural College, Mazandaran University, Sari, Iran

MATERIALS AND METHODS

The experiment was carried out at Dasht-E-Naz agricultural research area (lat 36° 37′ E, long 53° 11′ N), Mazandaran, in 2003. Pre-plant soil samples were taken for nutrient analysis and soil texture determination (Table 1). Phosphorus was determined as described by Olsen *et al.* (1954). Potassium was extracted with ammonium acetate and measured by atomic absorption spectroscopy. Zn, Fe, Mn and Cu were extracted by DTPA (Diethylen Triamine Penta Acetic acid) method (Lindsey and Norvell, 1978) and measured by atomic absorption spectroscopy. Organic carbon was measured according to Walkley-Black Method (Walkley, 1947). Soil pH and EC were measured from a saturated paste and soil texture was analyzed and classified by Hydrometer method (Bouyoucos, 1936). The experimental lay-out was a factorial based on randomized complete block design, with 4 replications. Experimental treatments included 3 potassium sulfate rates as K fertilizer (0, 50 and 100 kg ha^{-1}), 2 zinc sulfate rates as Zn fertilizer (0 and 10 kg ha^{-1}) and 3 spring canola cultivars (C) (Hyola 401, Option 501 and PF 7045/91) arranged into 3×2×3 factorial treatments in 4 blocks. These cultivars are extensively planted in the North of Iran, among which Hyola 401 is a famous overseas hybrid and the other ones are open-pollinated genotypes. To prepare the seed bed (field), cultivation practices were conducted in October by ploughing, disk harrowing and rolling. Plot size included 7 rows (30 cm row spacing) and 4.5 m length. Seeds were hand planted in October 21, 2003. Before planting the site received 50 kg ha^{-1} N as urea and 50 kg ha^{-1} P as ammonium phosphate. K and Zn fertilizers treatments were also applied according to surface broadcast method prior to planting for C_1 (Hyola 401), C_2 (Option 501) and C_3 (PF 7045/91) in each block as follow:

- **K_1Zn_1:** 0 kg ha^{-1} potassium sulfate + 0 kg ha^{-1} zinc sulfate (No added K and Zn fertilizer)
- **K_1Zn_2:** 0 kg ha^{-1} potassium sulfate + 10 kg ha^{-1} zinc sulfate
- **K_2Zn_1:** 50 kg ha^{-1} potassium sulfate + 0 kg ha^{-1} zinc sulfate
- **K_2Zn_2:** 50 kg ha^{-1} potassium sulfate + 10 kg ha^{-1} zinc sulfate
- **K_3Zn_1:** 100 kg ha^{-1} potassium sulfate + 0 kg ha^{-1} zinc sulfate
- **K_3Zn_2:** 100 kg ha^{-1} potassium sulfate + 10 kg ha^{-1} zinc sulfate

At 4 leaf stage, plants were thinned to reach the plant population of 140 m^{-2}. During growth stages recommended practices were used for disease and insect control although no damages were observed. Plants were also irrigated regularly and weeds were removed by hand weeding during the growth stages. At the time of harvest, in order to control boarder effects, plants from the sides of each plot were removed. To measure yield components including number of grains per pod, number of pods per main stem, number of pods per branches and 1000 grain weight, 10 plants were harvested from each plot at the time of maturity. To measure grain yield, after removing boarder effects 5 m^2 of each plot were harvested. Evaluated traits were determined as follow:

- Number of pods per main stem, number of pods per branches, number of grains per pod, were determined from the 10 plant sample. The number of these components were counted and then divided by 10
- 1000 gain weight was determined by counting 500 grains from each yield sample. Then grains were dried at 30°C in a forced air dryer, weighted and then multiplied by 2
- To measure grain yield, after removing boarder effects, 5 m^2 of each plot were harvested at the time of maturity. Plot yield samples were forced air-dried at 30°C to a uniform moisture level, cleaned in the seed lab and then weighted
- To determine grain oil content samples were taken from each grain yield sample. They were oven-dried at 130°C for 3 h, cooled in a desiccator and then oil percentages were determined using Nuclear Magnetic Resonance (NMR) system (Robertson and Morrison, 1979)

The obtained data were subjected to variance analysis as a factorial design using the Statistical Analysis System (SAS Institute, 1995). The source of variation, degrees of freedom and expected mean square for evaluated traits shown in Table 2. Comparison of means was performed by Duncan's multiple range test at $p<0.05$.

RESULTS AND DISCUSSION

Number of pods per main stem: The number of pods per plant (per either main stem or branches) is considered a crucial yield component of canola species and contributes

Table 1: Soil analysis of the experimental site (0-30 cm) in 2003

Soil texture	Clay (%)	Silt (%)	Sand (%)	Cu (ppm)	Mn (ppm)	Fe (ppm)	Zn (ppm)	K (ppm)	P (ppm)	Organic carbon (%)	EC (dS m^{-1})	pH
Loam	47	41	12	0.7	8.9	11.6	1.6	129	19.5	1.3	1.59	7.2

Table 2: Variance analysis results of the agronomic traits based on randomized complete block design

Source of variation	df	No. of pods main stem^{-1}	No. of pods branches^{-1}	No. of grains pod^{-1}	1000 grain weight (g)	Grain yield (kg ha^{-1})	Grain oil content (%)
Replication	3	0.001	0.001	0.0010	0.00010	0.130	1.370
C	2	259.900**	3.060**	460.5140**	3.91100**	0.214**	2.242**
K	2	0.001	71.799**	61.5140**	0.00010	0.563**	1.256
Zn	1	0.001	7.068**	11.2000	0.00001	0.022	1.343**
C × K	4	0.001	5.238**	0.0001**	0.00001	0.009**	77.190
C × Zn	2	0.001	2.054**	0.0001	0.00001	0.012	2.460**
K × Zn	2	0.001	0.568**	0.0001	0.00001	0.013	1.288
C × K × Zn	4	0.002	4.019**	0.0001	0.00001	0.012	1.167
Error	51	0.001	0.001	0.0010	0.00001	0.013	1.432
CV (%)	-	1.000	0.900	0.6000	0.99000	4.300	3.020

**Significant at 1%; C: Cultivars, K: Potassium sulfate (K_2SO_4), Zn: Zinc sulfate ($ZnSO_4$)

Table 3: Mean comparison of the agronomic traits for applied potassium and zinc fertilizers and canola cultivars

Treatments (C, K and Zn)	No. of pods main stem^{-1}	No. of pods branches^{-1}	No. of grains pod^{-1}	1000 grain weight (g)	Grain yield (kg ha^{-1})	Grain oil content (%)
Potassium (kg ha^{-1})						
K_1 (0)	37.66a	22.20	23.14	4.03a	2.53	39.77a
K_2 (50)	37.66a	24.02	23.94	4.03a	2.73	39.37a
K_3 (100)	37.66a	25.65	26.23	4.03a	2.83	39.38a
Zinc (kg ha^{-1})						
Zn_1 (0)	37.66a	23.69	24.44a	4.03a	2.69a	38.47a
Zn_2 (10)	37.66a	24.23	24.44a	4.03a	2.71a	40.54a
Cultivars						
C_1 (Hyola 401)	41.00a	24.33	27.70	4.40a	2.73	39.78a
C_2 (Option 501)	38.00a	23.62	19.47	4.10a	2.59	39.18a
C_3 (PF 7045/91)	34.00b	23.91	26.16	3.60b	2.77	39.55a

Mean values with at least one same letter(s) do not have statistically significant difference

to grain yield. However, it could be substantially varied over different varieties and be influenced by agronomic procedures such as applied nutrient treatments. In this study no significant correlation was found between number of pods per main stem. The results indicated that the number of pods per main stem was only influenced ($p<0.01$) by cultivars main effects whereas, the main effects of K and Zn fertilizer rates did not influenced it (Table 2). Hybrid Hyola 401 showed the highest number of pods per main stem which was statistically equal to Option 501 whereas, PF 7045/91 showed the lowest amount of this trait (Table 3). Besides, the interaction between genotypes, K and Zn fertilizers and cultivars was insignificant.

Number of pods per branches: The obtained results indicated that the main effect of either genotypes or K and Zn fertilizers were significant ($p<0.01$) for number of pods per branches. Besides, this trait was influenced ($p<0.01$) by all interactions between genotypes, K and Zn fertilizers (Table 2). The highest number of pods per branches in Hyola 401 (C_1) was obtained by application of K_3Zn_2 which was equally effective as K_2Zn_2 whereas, the lowest one was recorded at K_1Zn_1 and K_1Zn_2 (Table 4). The highest number of pods per branches in Option 501 (C_2) was also obtained by application of K_3Zn_2 which was statistically equal to $C_1K_3Zn_2$. The lowest number of pods per branches in C_2 was recorded at K_1Zn_1, statistically equal to $C_1K_1Zn_1$ (Table 4). In PF 7045/91 (C_3) the highest and the lowest one were recorded at K_3Zn_2 and K_1Zn_2, respectively (Table 4). Overall, the highest and the lowest number of pods per branches were observed in $C_1K_3Zn_2$ and $C_1K_1Zn_1$, respectively (Table 4). The increase in number of pods per branches consequently grain yield has also been reported by Peaslee *et al.* (1985) as a result of an increase in K fertilizer although the interaction between cultivar and K fertilizer was insignificant.

Number of grains per pod: Number of grains per pod significantly contributes to final yield as well as it represents the productive efficiency of any grain crop. The results indicated that the main effect of cultivars and K fertilizer were significant ($p<0.01$) for the number of grains per pod (Table 2). Moreover, this trait was influenced ($p<0.01$) by the interaction between cultivars and K rates (Table 2). In Hyola 401, Option 501 and PF 7045/9 the highest and the lowest number of grains per pods were obtained by the application of K_3Zn and K_1Zn, respectively (Table 3) indicating the fact that an increase in K fertilizer rates resulted in an increase in number of grains per pod in all cultivars. The application of K fertilizer positively affected this trait when it was increased from 0 to 100 kg ha^{-1}. As grain yield has a significant and positive correlation with number of grains per pod (Table 5), an increase in K fertilizer would contribute to better performance of plant and obtaining higher grain yield.

Table 4: Interaction effects of cultivars × potassium and cultivars × zinc fertilizer on agronomic traits

Treatments (C, K and Zn)	No. of pods $main^{-1}$ stem	No. of pods $branches^{-1}$	No. of grains pod^{-1}	1000 grain weight (g)	Grain yield (kg ha^{-1})	Grain oil content (%)
C_1(Hyola 401)						
K_1	41.001	21.516	26.200	4.401	2.505	39.750
K_2	41.000	25.450	27.300	4.401	2.801	39.818
K_3	41.001	26.049	29.600	4.400	2.904	39.790
Zn_1	41.001	23.917	27.700	4.402	2.739	38.457
Zn_2	41.001	24.760	27.700	4.400	2.734	41.115
C_2(Option 500)						
K_1	38.000	22.660	17.295	4.101	2.481	38.200
K_2	38.000	23.025	18.595	4.101	2.601	39.148
K_3	38.000	25.200	22.500	4.100	2.701	39.195
Zn_1	38.000	23.173	19.463	4.100	2.596	38.487
Zn_2	38.000	24.083	19.463	4.102	2.593	39.875
C_3(PF 7045/91)						
K_1	34.004	22.425	25.950	3.601	2.618	40.367
K_2	34.000	23.600	25.950	3.602	2.801	39.146
K_3	34.000	25.725	26.600	3.601	2.901	39.163
Zn_1	34.002	23.984	26.167	3.602	2.736	38.476
Zn_2	34.000	23.849	26.167	3.602	2.811	40.642

Mean values with at least one same letter(s) do not have statistically significant difference. K_1, K_2 and K_3: 0, 50 and 100 kg ha^{-1} K_2SO_4, respectively. Zn_1 and Zn_2: 0 and 10 kg ha^{-1} $ZnSO_4$, respectively

Table 5: Correlation coefficient analysis among the agronomic traits

Traits	NPMS	NPB	NGP	1000-GW	GY	GOC
NPMS	1.000					
NPB	0.005	1.000				
NGP	0.086	0.461	1.000			
1000 GW	0.998**	-0.017	0.030	1.000		
GY	-0.136	0.386	0.660**	-0.165	1.000	
GOC	0.062	0.199	0.185	0.048	0.100	1.00

**Significant at 1%, NPMS: No. of pods per main stem, NPB: No. of pods per branches, NGP: No. of grains per pod, 100 GW: 1000 grain weight (g), GY: Grain yield (kg ha^{-1}), GOC: Grain oil content (%)

1000 grain weight (g): The grain weight expresses the magnitude of the grain development. So, it plays a decisive role among yield components to exhibit the potential yield of a variety. The results indicated that the genotype main effect significantly affected ($p<0.01$) 1000 grain weight. However, this trait was not influenced by K and Zn fertilizer as well as their interactions (Table 2). The highest amount of 1000 grain yield was obtained in Hyola 401 and the lowest one in PF 7045/91 which was statistically equal to Option 501 (Table 3).

Grain yield (kg ha^{-1}): These results indicated that the main effects of genotype and K fertilizer and also the interactions between genotype and K fertilizer levels were significant ($p<0.01$) for grain yield. However, this trait was not influenced by Zn fertilizer and its interactions with genotype and K fertilizer (Table 2). In Hyola 401 (C_1), grain yield was significantly increased by the application of K_3Zn. In Option 501 (C_2) the application of K_2Zn and K_3Zn, statistically equal, increased grain yield and in PF 7045/91 (C_3), K_3Zn significantly increased grain yield. Overall, the highest grain yield was obtained at C_1K_3Zn and C_2K_3Zn and the lowest one at C_2K_1Zn and C_1K_1Zn (Table 4). Although the number of branches and also the number of flowers in the main stem and branches increased as a result of an increase in the application of K and Zn fertilizers, no grain yield increase was observed in Option 501. This could be attributed to the inability of this genotype in keeping their flowers to turn into the pods and the reduction in number of grains per pod. On the other hand, the considerable discrepancy between K_3Zn and K_1Zn in Hyola 401 and PF 7045/91 was attributed to the fertilization response of these genotypes for increasing K fertilizer. Increasing in grain yield as a result of an increase in K fertilizer level was reported by Peaslee *et al*. (1985). Sheppard and Bates (1980) reported the lowest grain yield of spring and winter canola cultivars in response to application of K fertilizer whereas, Sheppard and Bates (1980) reported that canola yield was not influenced by K fertilizer in a soil with ample potassium content.

Grain oil content (%): The high grain oil content as well as the high oil quality is considered the ultimate purpose of an oilseed crop grower. The quality of a canola grain is determined by its oil content. The results indicated that the main effect of genotypes and Zn fertilizer levels were significant ($p<0.01$) for grain oil content whereas, the application of K fertilizer was not influenced this trait. In addition, the interaction between genotypes and Zn fertilizer levels were significant ($p<0.01$) (Table 2). In Hyola 401 (C_1) the highest grain oil content was obtained in KZn_2 by which this trait significantly increased. The highest grain oil content in both Option 501 (C_2) and PF 7045/91 (C_3) was obtained by the application of KZn_2 (Table 4). Overall, C_1KZn_2 recorded the highest grain oil content and C_1KZn_1 the lowest one which was statistically equal to C_2KZn_1 and C_3KZn_1 (Table 4). Since, the obtained grain oil in all genotypes were equal in the situation no fertilizer added (K_1Zn_1), the high oil producing potential of hybrid Hyola 401 was distinguished and then was achieved by the application of Zn fertilizer. Sheppard and Bates (1980) reported that potassium has no significant influence on grain oil content of spring and winter rape. Besides, an increase in grain oil content due to the increase in applied zinc sulfate was attributed by Coolong and Raddel (2003) to the increase in S uptake. The results of this study agree with those of Grewal *et al.* (1997), Brennan and Bolland (2002) and Coolong and Raddel (2003). However, Mullen and Druce (1999) reported that the application of zinc sulfate influenced neither grain oil content nor grain yield. Kidman and Paul (2001) also reported that neither grain oil nor grain protein content was influenced by increasing in zinc sulfate although the grain yield was increased.

CONCLUSION

These results indicated that generally the application of potassium sulfate and zinc sulfate significantly affected most of the yield components of the considered cultivars. The number of grains per pod and grain yield considerably increased as a result of an increase in potassium sulfate application and the grain oil content also increased by increasing the application of zinc sulfate in all cultivars. Besides, the number of pods per branches significantly increased as a result of an increase in the application of both K and Zn fertilizers. However, the application of different amounts of fertilizers did not influence the number of pods per main stem and 1000 grain weight. Moreover, hybrid Hyola 401 showed the best performance among the cultivars in response to fertilizer application implying the considerable potential of this genotype for absorbing and utilizing potassium and zinc fertilizers. In addition, Hyola 401 exhibited its greater magnitude in traits including number of pods per plants and 1000 grain weight, which did not influenced by fertilizers. To conclude, although more researches should be carried out in this regard, according to these results, the more potassium and zinc sulfate is applied, the more grain yield and grain oil content will be obtained in canola cultivars, particularly in hybrid ones.

REFERENCES

Bouyoucos, G.J., 1936. Directions for making mechanical analysis of soil by the hydrometer method. Soil Sci., 42: 225-231.

Brennan, R.F. and M.D.A. Bolland, 2002. Relative effectiveness of soil applied zinc for four crop species. Aust. J. Exp. Agric., 42: 985-993.

Cakmak, I., A. Yilmaz, M. Kalayci, H. Ekiz, B. Torun, B. Erenoglu and H.J. Braun, 1996. Zinc deficiency as a critical problem in wheat production in central Anatolia. Plant Soil, 180: 165-172.

Coolong, T.W. and W.M. Raddel, 2003. Zinc concentration in hydroponic solution culture influence zinc and sulfur accumulation in *Brassica rapa*. J. Plant Nuture, 26: 949-959.

Graham, R.D., J.S. Ascher and S.C. Hynes, 1992. Selecting zinc-efficient genotypes for soil of low zinc status. Plant Soil, 146: 241-250.

Grewal, H.S., L. Zhonggu and R.D. Graham, 1997. Influence of subsoil zinc on dry matter production, seed yield and distribution of zinc in oilseed rape genotypes differing in zinc efficiency. Plant Soil, 192: 181-189.

Jackson, G.D., G.D. Kushnak, L.E. Welty, M.P. Westcott and D.M. Wichman, 1993. Fertilizing canola. Montana Agres., 10: 21-24.

Jackson, G.D., 2000. Effects of Nitrogen and Sulfur on Canola Yield and Nutrient Uptake. Agron. J., 92: 644-649.

Jan, M.T. and S. Khan, 2000. Response of wheat yield components to type of N-fertilizer, their levels and application time. Pak. J. Biol. Sci., 3: 1227-1230.

Kidman, F. and K.B. Paul, 2001. Effect of zinc fertilization on yield, protein and oil of canola. Plant Soil, 112: 327-329.

Lindsay, W.L. and W.A. Norwell, 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J., 42: 421-428.

Mullen, C.L. and S.J. Druce, 1999. New horizons for an old crop. Proceedings of the 10th International Rapeseed Congress. Canbera, Australia.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. US Department of Agriculture Circular No. 939. US Government Printing Office, Washington DC.

Peaslee, D.E., B.F. Hicks and D.B. Egli, 1985. Soil test levels of potassium, yield and in seed size in canola cultivars. Communication in Soil Science and Plant Analysis.

Raymer, P.L., 2002. Canola: An Emerging Oilseed Crop. In: Trends in New Crops and New Uses, Janick, J. and A. Whipkey (Eds.). ASHS Press, Alexandira, VA, pp: 122-126.

Robertson, J.A. and W.H. Morrison, 1979. Analysis of oil content of sunflower seed by wide-line NMR. J. Am. Oil Chem. Soc., 56: 961-964.

SAS Institute, 1995. SAS User's Guide: Statistics. Version 7, SAS Institute, Cary, NC.

Sheppards, S.C. and T.E. Bates, 1980. Yield and chemical composition of rape in response to nitrogen, phosphorus and potassium. Can. J. Soil Sci., 60: 153-162.

Starner, E.D., H.L. Bhardwaj, A. Hamama and M. Rangappa, 1996. Canola Production in Virginia. In: Progress in New Crops, Janick, J. (Ed.). AShS Press Alexandria, VA., ISBN: 0-9615027-3-8, pp: 287-290.

Stevens, W.B. and A.O. Mesbah, 2004. Zinc enhances sugar beet emergence and yield on a calcareous soil with marginal zinc availability. Proceeding of the Crop Managemen, Aug. 1-6, Plant Management Network, USA. http://www.cababstractsplus.org/google/abstract.asp?AcNo=20043175506.

Walkley, A., 1947. A critical examination of a rapid method for determination of organic carbon in soil: Effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci., 63: 251-257.