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Effect of Different Nitrogen Aplications on Fatty Acid Composition of Rapeseed Cultivars Grown in the Region of Southeast Anatolia

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Abstract: This study was carried out to determine the effect of different nitrogen fertilizers (0, 8, 16 and 24 kg N/da) on oil quality of winter (cv. Askona, Karola and Silvia) and spring rapeseed (cv. Lirawell, Semu 86/225 Na and Wester). The experiment was conducted in the research area of the Field Crops Department, Faculty of Agriculture, Dicle University in the 1995-1996 and 1996-1997 winter growing season in Diyarbakir. Fatty acid composition was not affected by N doses, but it varied among cultivars. The composition of the fatty acid of the rapeseed cultivars was 4.074.21% palmitic acid, 0.288-0.320% palmitoleic acid, 2.12-2.28% stearic acid, 65.60-66.58% oleic acid, 16.44-18.62% linoleic acid, 6.40-7.01% linolenic acid and 1.27-2.01% eicosenic acid.

Key words: rapeseed, nitrogen fertilizer, fatty acid

Introduction

The inadequacy and the exorbitance of the monetary value of animal-based cooking oils produced in the world has highlighted the importance of margarines and oil plants used in liquid cooking oils. It is agreed that in addition to their benefits such as lowering the amount of cholesterol in blood and curing the effects on people suffering from arteriosclerosis and the illness of coronary heart diseases (Arioglu, 1997), such oils help provide balanced nutrition; moreover a significant part of them is of vegetable origin and studies suggest that 18 kg of vegetable oil should be consumed per capita annually.

The requirement for vegetable oil in our country increases day by day because both the population and per capita consumption rises daily. Imports made to bridge the oil gap in our country totaled 760,000 tons in 1995, for which foreign currency worth $ 519 million was paid (Anonymous, 1995). The production of oil vegetables must be increased in order to bridge this deficit.

Brassica napus is one of the oil plants whose cultivation and production is rapidly increasing throughout the world; it is planted in summer and winter and is suitable for mechanization. There are favorable ecological conditions for its cultivation in the southeastern Anatolia. Yet another advantage of planting *Brassica napus* is that this plant reaches harvest maturity earlier compared with wheat and pulses and that it allows the necessary time for cultivation of second crops. The sectors of animal husbandry and apiculture can also develop parallel to the diffusion of *Brassica napus* which contains 40-45% oil, 25% protein and 20% polysaccarites in its seeds; the crop will also provide raw materials for oil factories which are idle between May and July (Ozguven, 1992).

The composition of fatty acids is an important quality parameter for use of oil for nutrition and industrial purposes. Conventional *Brassica* seed oils are different from other vegetable oils because they contain long-chain monoenoic oil acids (eicosenoic and erusic acids) to an important degree. The remainder of the oil acid profile consists of palmitic, palmitoleic, stearic, oleic, linoleic, linonic, arashidic, eicosenoic, behenic and lignoseric acids. Although they are determined genetically, the composition of oil acids in *Brassica* varies according to environmental conditions. More oil acids occur in cold climates and higher latitudes. Low linolenic acid content is a desirable property because it increases the storage characteristic of the oil. From the nutritional point of view, higher linoleic (Vitamin F) content is desirable (Uppstrom, 1995). Ninety of erusic acid, which is detrimental to human health, is used in a large number of fields, such as an additive compound used by industries making detergents, plastics, cosmetics, pharmaceticals, ink, paper, textiles and foodstuffs as an additive and production of adhesives, antistatic materials and fuels as an additive as well (Sonntage, 1995). The content of erusic acid should not be more than 45% if it is to be used in industry and should be less than 2% in edible oils (Shafii *et al.,* 1992). The composition of fatty acids in different types of *Brassie.,* consists of 55-65% oleic, 14-18% linoleic and 8-12% linolenic acid.

However, the high content of multiple unsaturated oil acids decreases oxidating stability and unless it is hydrogenized, this limits the use of *Brassica* oil for cooking. Development of types of *Brassica* oil which have lower multiple oil seed contents and increased oleic acid content (more than 75%) will create additional markets for nutritional oil of vegetable origin.

Linolenic acid, which is one of the major fatty acids in *Brassica,* is not wanted by the margarine industry because it adds an unpleasant taste to oil and makes the oil bitter. For these reasons, a target has been set to lower the content of linolenic acid, which is on average 10% in oils of the improved types, to below 3% and increase the content of linoleic acid, which is 20 to 40-50%. Oleic acid, linolenic acid and linoleic acid are largely affected by environmental conditions and in particular, oleic acid registers substantial rises in conditions of long days and high temperatures. However, because there is a positive correlation between the amounts of linolenic acid and linoleic acid, a relative decrease took place in the content of linoleic acid during the studies conducted concerning the decrease of linolenic acid content. It is necessary to pay attention to quality as well as increasing the cultivation and production of *Brassica* to reduce our country's oil shortage (Onder and Aktumsek, 1995a). The fact that the arable land which can be used at present has been expanded to the most extreme limits has directed efforts for increase of foodstuffs to the intensification of works on discovery and development of more productive species and types on one hand and to development of new agricultural techniques on the other. In addition to mechanization, irrigation and agriculture combat which are being developed within the scope of those practices which we can describe as technical agriculture, fertilization (which is carried out to get more produce per unit land area) is a method which is applied throughout the world quite commonly (Kayahan, 1991). A survey which was conducted on the effects of different nitrogen dosages on the composition of the types of Westar summer *Brassica* has concluded that palmitic acid content, which was 4.12% during checking increased due to increased nitrogen dosages, that stearic acid content was 1.33% in lower nitrogen dosages, that oleic acid was negatively affected and that in general, the composition of oil acids is not affected by nitrogenous fertilization (Onder and Aktumsek, 1995b). The studies on the contents of fatty acids in the *Brassies* types showed that palmitic acid varies between 2.90 and 6.72%, palmitoleic acid between 0.10-0.36%, stearic acid between 1.10-2.42%, oleic acid between 57.70-68.21%, linoleic acid between 13.10-27.90%, linolenic acid between 3.11-11.50% and eicosenic acid between 0.10-2.60% (Kural, 1995). They have demonstrated that there is a reverse relationship between oleic acid and linoleic acid and that the oleic acid content increases towards hotter latitudes as the linoleic acid content falls. It has been found that nitrogenous fertilization has no effect on the'composition of *Brassica* fatty acids, that in the composition of oil acids in the Wester type, oleic acid varies between 66.31-67.36%, linoleic acid between 16.03-16.63%, linolenic-eicosenic acid between 7.59-7.93%, palmitic acid between 3.93-4.09%, palmitoleic acid between 0.30-0.33% and stearic acid between 2.27-2.46% (Kayahan, 1991).

There should be no erusic acid in *Brassie.,* oil, which is very important for human health and oil quality, oleic acid and linoleic acids must be high and the content of linolenic acid which causes problems in the margarine industry must be low. Therefore, studies to determine the composition of oil acids are important. This study examines the impact of nitrogen fertilization on the composition of oil acids as far as summer and winter *Brassies* types are concerned.

Materials and Methods

Some properties of Askona, Karola, Silvia, Lirawell, Semu 86/225 Na and Wester kolza cultivars pertaining to *Brassica napes* which were used in this study are reported in Table 1 (Ozguven, 1990).

In the research, field treatments were arranged in 3 replications according to the testing pattern of divided parcels. During the test, nitrogen doses of 0, 8, 16 and 24 kg/da were used and 1/3 of the nitrogen , was applied at sowing, 1/3 at the beginning of February and 1/3 when the plants began having a body. In the trial, the main parcels were 75.6 m^2 (20.8 m x 7.0 m), the mini parcels 12.6 m^2 (1.8 m × 7.0 m). Raw oil analysis on the types was carried out at University of cukurova Faculty of Agriculture, Department of Field Crops, by using the oil ether extraction method by means of a Soxhelet device. The oil acid composition (%) was determined by means of Unlearn make 610 series Gas Chromatography at University of First, Faculty of Science and Literature, Department of Chemistry. Capillary columns whose filling material was DBWAX and which were 15 in length were used and the temperature was kept fixed at 195°C. Detector temperature was fixed to 260°C, the injector temperature to 250°C and the flow rate of nitrogen, a carrier gas, to 2.5 ml/minute.

Assessment of the data: The statistical analysis of the characteristics evaluated was carried out by using Mstatc software programme according to the split plot pattern. In these analyses, the nitrogen dosages constituted the main parcels and the *Brassies* types, the sub parcels.

Table 1: Some features of the rapeseed cultivars used in the experiment

Cultivars	Biological form	Erusic acid	Glucosinolate content	Vegetation period
Askona	Winter	<% 2	< 30 μ mol/g	9 late
Karola	Winter	<% 2	< 30 μ mol/g	late
Silvia	Winter	<% 2	< 30 μ mol/g	late
Lirawell	Summer	<% 2	< 30 μ mol/g	medium early
Semu 86 /225 Na	Summer	<% 2	< 30 μ mol/g	late
Wester	Summer	<% 2	< 30 μ mol/g	very early

Conclusions of the research and discussion: In the survey, the contents of palmitic, palmitoleic, stearic, oleic, linoleic, linolenic and eicosenic acids were determined in the samples obtained so as to discover the impact of the nitrogen dosages applied to the *Brassies* types on the fatty acid composition; each fatty acid was examined individually and the results reported below.

Palmitic acid content: The survey showed that the types of *Brassies* studied in the survey had no considerable impact on the different nitrogen dosages and the averages related to the palmitic acids (16:0) are reported in Table 2. Although the impact of the nitrogen dosages and the types on the palmitic acid contents is not significant, it was faund that the highest palmitic acid content, 4.47%, was in the Westar type at a nitrogen dosage of 8 kg/da, and the lowest, 4.01%, in the Karola type at a nitrogen dosage of 8 kg/da. The average palmitic acid content was determined as 4.12% in the parcels where no nitrogen was applied, as 4.19% at a nitrogen dosage of 8 kg/da, as 4.10% at a nitrogen dosage of 16 kg/da and as 4.14% at a nitrogen dosage of 24 kg/da.

The findings are generally in conformity with the results obtained by other researchers but have proved lower than the values by found some researchers.

Table 2: Palmitic acid contents in rapeseed cultivars subjected to different nitrogen doses

Nitrogen Doses	Cultivars						
	Askona	Kerala	Silvia	Lirawell	Semu 225Na	Wester	Average
N_o	4.18	4.11	4.05	4.05	4.19	4.13	4.12
N8	4.14	4.01	4.19	4.09	4.23	4.47	4.19
N16	4.12	4.09	4.11	4.08	4.09	4.09	4.10
N24	4.03	4.13	4.37	4.06	4.09	4.17	4.14
Average	4.11	4.08	4.18	4.07	4.15	4.21	
L.S.D. (%5)	Non Significant						

Table 3: Palmitoleic acid contents in rapeseed cultivars subjected to different nitrogen doses

Nitrogen Doses	Cultivars						
	Askona	Karola	Silvia	Lirawell	Semu 225Na	Wester	Average
N_o	0.33abc	0.32abc	0.28abc	0.35a	0.28abc	0.30abc	0.31
Na	0.35a	0.34a	0.33ab	0.24abc	0.29abc	0.25abc	0.30
N18	0.21c	0.25abc	0.28abc	0.22bc	0.32abc	0.32abc	0.27
N24	0.25abc	0.35a	0.33abc	0.25abc	0.26abc	0.27abc	0.28
Average	0.28	0.32	0.30	0.26	0.29	0.29	
L.S.D. (%5)	0.098 (Interaction)						

Table 4: Stearic acid contents rapeseed cultivars subjected to different nitrogen doses

Cultivars	Nitrogen Doses				
	N_o	N_a	N_{16}	N_{24}	Average
Askona	2.18	2.20	2.11	2.14	2.15be
Karola	2.10	2.17	2.04	2.20	2.12c
Silvia	2.04	2.25	2.08	2.23	2.14bc
Lirawell	2.12	2.15	2.22	2.16	2.16bc
Semu 861225 Na	2.17	2.29	2.27	2.24	2.24ab
Wester	2.22.,	2.31	2.44	2.17	2.28a
Average	2.14	2.23	2.19	2.19	
L.S.D. (%5)	0.104 (Cultivar)				

Table 5: Oleic acid contents in rapeseed cultivars subjected to different nitrogen doses

Nitrogen Doses	Cultivars						
	Askona	Karola	Silvia	Lirawell	Semu 225Na	Wester	Average
N_a	66.2	65.22	65.88	65.24	65.45	66.54	65.76 bc
N_8	66.35	66.06	65.94	66.89	66.26	66.23	66.29 ab
N_{18}	66.31	68.31	66.39	66.34	66.25	66.67	68.38 a
N_{24}	66.17	64.8	65.65	84.9	65.74	66.85	65.69 c
Average	68.26 ab	65.60 b	65.97 ab	85.85 b	65.93 ab	66.58 a	
L.S.D. (%5)	0.5683 (Nitrogen), 0.6634 (Cultivar)						

Table 6: Linoleic acid contents in rapeseed cultivars subjected to different nitrogen doses

Cultivars Doses	Nitrogen				
	N_a	N_8	N_{18}	N_{24}	Average
Askona	17.60	17.23	17.43	18.07	17.58 b
Karola	18.55	18.45	18.97	18.50	18.82 a
Silvia	17.15	18.55	18.32	17.83	17.97 ab
Lirawell	17.82	18.08	18.51	18.22	18.16 ab
Semu 86/225 Na	17.07	17.02	17.15	18.51	17.44 b
Wester	16.52	18.34	16.09	16.81	16.44 c
Average	17.45	17.61	17.74	17.99	
L.S.D. (%5)	0.84 (Cultivar)				

Table 7: Linolenic acid contents in rapeseed cultivars subjected to different nitrogen doses

Cultivars Doses	Nitrogen				
	N_a	N_8	N_{18}	N_{24}	Average
Askona	6.50	6.34	6.49	6.29	6.40 b
Karola	7.48	6.95	6.81	6.81	7.01 a
Silvia	6.50	6.37	8.88	6.61	6.59 ab
Lirawell	6.70	6.67	8.79	6.23	6.60 ab
Semu 86/225 Na	7.00	6.93	8.74	6.90	8.89 a
Westar	6.56	6.73	6.82	6.70	6.70 ab
Average	6.79	6.66	6.75	6.59	
L.S.D. (%5)	0.4375 (Cultivar)				

Paimitoleic acid content: The average values concerning the palmitoleic acid ratio (16:1) which was determined for the different nitrogen dosages applied to the *Brassica* types during the research, are provided in Table 3. The impact of the N dosages on palmitoleic acid has been significant at about 5%. The highest palmitoleic acid content, 0.35%, was found in the Askona type at a nitrogen dosage of 8 kg/da and in the Lirawell type in control parcel, and the lowest palmitoleic acid content, 0.21%, in the Askona type at a nitrogen dosage of 16 kg/da. The average palmitoleic acid contents which were obtained from the nitrogenous fertilizer applications became 0.31% in the control and 0.30% at a nitrogen dosage of 8 kg/da, 0.27% at a nitrogen dosage of 16 kg/da and 0.28% at a nitrogen dosage of 24 kg/da. Some researchers report palmitoleic acid contents as 0.1%, 0.30-0.33% (Kayahan, 1991), 0.1%, 0.00-0.29% (Kural, 1995). The findings are parallel to those of some other researchers and it can be seen that the impact of the nitrogen and the types on palmitoleic acid contents is very small.

Table 8: Eicosenic acid contents in rapeseed cultivars subjected to different nitrogen doses

Cultivars Doses	Nitrogen				
	N_a	N_8	N_{18}	N_{24}	Average
Askona	2.19 a	2.19 a	1.56 bcd	2.12 a	2.017
Karola	1.61 bcd	1.40 cd	1.82 bed	1.37 cd	1.503
Silvia	1.88 ab	1.88 ab	1.91 be	1.68 bc	1.838
Lirawell	1.33 cd	1.26 d	1.26 d	1.24 d	1.273
Semu 86/225 Na	1.43 cd	1.38 cd	1.42 cd	1.33 cd	1.393
Wester	1.86 ab	1.32 cd	1.64 bc	1.46 cd	1.572
Average	1.71	1.57	1.57	1.53	
L.S.D. (%5)	0.32 (Interaction)				

Stearic acid content: The stearic acid contents (18:0) determined for the different nitrogen dosages in the various *Brassies* cultivars evaluated in the research are provided in Table 4. The effect of the nitrogen dosages on the stearic acid content in view of the mentioned characteristic was of minor importance. The difference between the types has proved significant at about 5%.

Although the differences between them are not significant, the highest stearic acid content, 2.44%, was found in the Wester type at a nitrogen dosage of 16 kg/da and the lowest strearic acid content, 2.04%, in the Karola type at the same dosage and in the Silvia type during control. As no impact by the nitrogen dosages was found on the stearic acid contents, no differences were noticed between the types.

The average stearic acid contents according to type were as follows: 2.15% in Askona, 2.12% in Kerala, 2.13% in Silvia, 2.16% in Urawell, 2.24% in Semu 86/225 Na and 2.28% in Wester. According to some researchers, the stearic acid contents vary between 1.10% and 2.46% (Kural, 1995). The present findings proved higher than some of them although they display parallelity to some of the other research in question.

Oleic acid content: It is the oleic acid that makes *Brassica* oil different from other vegetable oils and renders it significant. Oleic acid is an oil acid that has eighteen carbons and a pair of strings in each carbon chain. The impact of the different nitrogen dosages and types on the *Brassica* types was around 5%. The average values concerning the oleic acid content determined on the basis of the different nitr9gen dosages in the *Brassica* types are provided in Table 5.

Although the nitrogen dosages and types have affect on the oleic acid content, this impact is limited. On the basis of the type averages, the oleic acid content was determined as follows: 66.58% in Westar, 66.26% in Askona, 65.60% in Karola, 65.97% in Silvia, 65.85% in Lirawell and 65.93% in Semu 86/225 Na. As far as the nitrogenous fertilizer applications are concerned, *the* highest average oleic acid content was faund in the 16 kg/da nitrogen dosage with 66.38%, while the lowest, 65.69%, in the 24 kg/da nitrogen dosage. The findings indicate that oleic acid contents vary between 59.73-68.21%, according to some researchers (Kayahan, 1991; Kirici and Ozguven, 1995; Kural, 1995). Although the findings are in harmony with those of some researchers, the values have proved higher than those found by other researchers i.e. 57.7-64.99%.

LInoleic acid content: The average values concerning the linoleic acid content (18:2) determined in the different nitrogen dosages in the *Brassies* types are provided in Table 6.

The nitrogen dosages applied had no serious impact on linoleic acid contents. However, significant differences were observed between the linoleic acid contents in the various types. The linoleic acid contents on the basis of the averages of the types were determined as follows: the highest in Karola with 18.62, 18.16% in Lirawell, 17.97% in Silvia, 17.58% in Askona, 17.44% in Semu 86/225 Na and 16.44% in Westar (Lowest). Although the nitrogen x type interaction was insignificant, the highest linoleic acid content was found in the 16 kg/da nitrogen dosage with 18.97% and the lowest, in the 16 kg/da nitrogen dosage in the Wester type with 16.09%. *Brassica* oil should preferably have a higher content of linoleic acid since this is one of the important fatty acids from a nutritional point of view (Uppström, 1995). In generally, the linoleic acid content varied between 14-18% in *Brassica* oil.

The linoleic acid contents of the *Brassica* types under experiment varried between 16.44-18.62%. These values were generally within the limits reported by other researchers although they were lower than the upper limits of some of them (Kirici and Ozguven, 1995; Kural, 1995).

Linolonic acid content: The values concerning linolenic acid contents (18:3) determined in the *Brassies* types on the basis of different nitrogen dosage applications are provided in Table 7. Although there were no important differences between the applied nitrogen dosages statistically, the highest linolenic acid content, 7.48%, wa% found in the Karola type on the parcels where no nitrogen was applied, and the lowest content, 6.23%, in the Urawell type in the 24 kg/da nitrogen dosage. The linolenic acid contents on the basis of the averages of the types, were as follows: 7.01% in Karola, 6.89% in Semu 86/225 Na, 6.70% in Wester, 6.60% in Urawell, 6.59% in Silvia and 6.40% in Askona. A high level of linoleic acid is not desirable because it gives oil an unpleasant taste and makes it bitter by reducing the oxidating stability. It is generally preferable that it is no higher than 8-11% and lower than 3%. Since a lower linoleic acid content is a desirable property, the Ascona type take the lead. As was hoped the results obtained were lower than the specified values in this respect.

Compared with the results of the studies conducted in connection with this subject, they were within the specified values or lower (Kural, 1995). The findings display parallelity with the findings of some of the researchers mentioned and as the nitrogen dosages had no effect on the linolenic acid content, it is apparent that differences may occur depending on the types and that this may be affected by ambient conditions.

Elecosenic acid content: The average values concerning the eicosenic acid content (20:1) determined in the *Brassica* types on the basis of different nitrogen dosages are provided in Table 8. The basic effects of the nitrogen dosages and types on eicosenic acid contents were found to be insignificant. However, the effect of the type x nitrogen dosage interaction was important. In this case, the effects of the nitrogen dosages on eicosenic acid content changed depending on the types. The highest eicosenic acid content, 2.19%, was found in the Askona type and the lowest, 1.24%, in the Lirawell type on the basis of the 24 kg/da nitrogen dosage. The average eicosenic acid contents have been determined as 2.01% in Askona, as 1.83% in Silvia, as 1.57% in Wester, as 1.50% in Karola, as 1.39% in Semu 86/225 Na and as 1.27% in Lirawell.

The eicosenic acid contents decreased inversely to the increasing nitrogen dosages, with the exception of the Askona type. The results of the researchers who state that the eicosenic acid contents in the *Brassica* types vary between 0.10-2.60% and the findings obtained were partially in agrement (Kural, 1995).

The practice of nitrogenous fertilization should definately be carried out to obtain an adequate efficiency from the *Brassica* plant. However, when excessive nitrogenous fertilizer is applied to *Brassice,* the plant reaches an excessive height and then bends over. In case of inadequate fertilizer, sufficient efficiency cannot be obtained. The present research determined that the application of 16-20 kg/da fertilizer is suitable for *Brassica* cultivation. Moreover, it is seen that nitrogenous fertilization has no negative impact on the oil acid composition of *brassica* and does not change the composition of the fatty acids. In view of quality, the composition of the fatty acids must be kept under control in *Brassica* cultivation. With regard to the composition of fatty acids, it may be said that the types of Wester, Semu 861225 Na, Silvia and Askona are more suitable.

References

Anonymous, 1995. Statistics of Foreign Trade. Premiership Publication, Ankara, Turkey.

Arioglu, H., 1997. Oilseed Crops Production and Improvement. University of Cukurova, Ankara, Turkey, pp: 1-98.

Kayahan, M., 1991. A Study to Determine Effect of N Doses on the Fatty Acid Composition of the Wester Repeseed Cultivar. University of Ankara, Ankara, Turkey, pp: 1230.

Kirici, S. and M. Ozguven, 1995. Determination of suitable rapeseed cultivars that are productive, quality and early matuity. J. Agric., 10: 105-120.

Kural, A., 1995. A study on determination of suitable cultivars and sowing dates for southeast anatolia region condition. Ph.D. Thesis, Department of Field Crops, Qukurova University, Adana, Turkey.

Onder, M. and A.A. Aktumsek, 1995a. The effect of diferrent N doses on fatty acid composition in spring rapeseed cultivar estar. J. Agric., 9: 102-108.

Onder, M. and A.A. Aktumsek, 1995b. The effect of different N doses fatty acid composition in spring rapeseed cultivar westar. J. Agric., 8: 26-38.

Ozguven, M., 1990. Repeseed cultivation, potential and furture in Turkey. Meeting of Forage Raw Materials (TMO) Ankara.

Ozguven, M., 1992. Oilspeed Crops (Rapeseed, Sunflower, Castor Oil). University of Cukurova, Adana, Turkey, pp: 1-7.

Shafii, B., K.K. Mahler, W.J. Price and D.L. Aui, 1992. Genotype x environment interaction effects on winter rapeseed yield and oil content. Crop Sci., 32: 922-927.

Sonntage, N., 1995. Industrial Utilization of Long-chain Fatty Acids and their Derivatives. In: Production and Utilization, Kimber, D.S. and D.I. McGregor (Eds.). CAB International, Cambridge, MA., pp: 339-352.

Uppstrom, B., 1995. Seed Chemistry. In: Bressica Oilseeds Production and Utilization, Kimber, D.S. and D.I. McGregor (Eds.). CAB International, Cambridge, MA., pp: 217-242.