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ORIGINAL PAPER

NUTRITIONAL VALUE AND FOLIAR FERTILIZATION IN SOYBEAN

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Abstract

Soybean is a member of pulses and probably the most valuable crop in world. Fertilization is one of the main economic and health-promoting factors in crop cultivation. Foliar application during the flowering stage using 4 phosphorus (P) doses (4, 6, 8 and 10 kg ha^{-1}) as experiment-1 and 4 sulphur (S) doses (5, 10, 15 and 20 kg ha^{-1}) as experiment-2 except control in the soybean variety Nova was performed in Konya, Turkey, in two years (2013 and 2014), in a randomized block design with 3 replications. The investigated nutrition parameters were protein (316.5-368.3 g kg^{-1}), mineral components (in mg kg^{-1}): P (6200-7350), K (8141-8302), Mg (951-1267), Ca (1083-1419), Fe (61.20-97.90), Cu (22.10-35.60), Zn (62.30-85.30), Mn (3.600-18.90) and fatty acids (in g kg^{-1}): myristic (0.76-0.81), palmitic (109.3-115.1), stearic (41.32-50.12), oleic (229.4-266.7), linoleic (487.4-520.3), linolenic (70.58-85.32), arachidic (3.77-4.32), gadoleic (2.49-4.05), eicosadienoic (0.43-0.63), eicosatrienoic (3.76-4.11), lignoceric (1.33-1.46), nervonic (0.13-0.58) and docohexaenoic (0.24-0.68) acid. Statistical analysis showed significant levels for Mn (P applied at 5% level), myristic acid (S at 1% level), palmitic (P at 1% level), stearic (P at 1% level), linolenic (P at 1% level), nervonic (P at 5% level) and for docohexaenoic acid (P and S at 5% level). In general, the content of protein, Mg, Mn, palmitic, linoleic and linolenic acids showed an increasing tendency with the increased doses of phosphorus. Additionally, protein, Cu, Zn, palmitic, linolenic, gadoleic, eicosadienoic and docohexaenoic acids showed an increasing tendency with the increased doses of sulphur. Consequently, the response of soybean plants to foliar application of S and especially P during the flowering period entailed significant changes, especially in protein and essential fatty acids. The results can be used in nutritional medicine and by farmers, food companies, breeders, etc.

Keywords: fatty acid, fertilizer, mineral, nutrition, oil, quality, seed composition.

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INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] is a native crop of China and one of the oldest oilseed crops in the world. According to the Food and Agricultural Organization data, soybean is cultivated worldwide, generating 276,406,003 tonnes of yields, of which almost 30% is obtained in the United States of America. Worldwide, the economic value of soybean is 119,516 million US dollars, owing to the versatile use in many fields of industry. As well as making a contribution to the alleviation of some chronic diseases, soybeans are an essential source of dietary protein, oil and minerals for humans and animals. Soybean is the most important oilseed and livestock feed crop, which accounts for 58% of the total world oilseed production and 69% of protein meal consumption by livestock. The contributing factor is its high level of proteins (almost 40% of seed weight) as well as the content of valuable oil and mineral compounds.

Soybean proteins represent a major source of amino acids. Soybean proteins are also a good source of various bioactive peptides and have unique health benefits, which are used for the prevention of age-related chronic disorders, such as cardiovascular disease, obesity, impaired immune function and cancer. Soybean foods are also rich in vitamins and minerals. Recent research suggests that, owing to the valuable nutritional content, soybeans may decrease the risk of prostate, colon and breast cancers, osteoporosis and other bone degenerative diseases, and alleviate hot flashes associated with menopause (El-Shemy 2011). Soy seeds contain satisfactory amounts of calcium, iron and zinc, i.e. elements whose intake is marginal in some population groups distinguished by social vulnerability. Soybean seeds contain relatively higher amounts (5%) of minerals than cereal seeds (1%) to Board (2012).

The oil content of soybeans equals nearly 20% and has a good percentage of lipids, which are classified as polyunsaturated oil, including about 15% of saturates, 24% of monounsaturates and 61% of polyunsaturates, of which 53.2% is linoleic acid while about 7.8% consists of linolenic acid. Basically, soybean oil consists of five predominant fatty acids: palmitic, stearic, oleic, linoleic and linolenic acids. As it reported from many studies involving human clinical trials and investigations, this composition has nutritional advantages and promotes regulation of the plasma lipids and bio-synthesis of eicosanoids. Studies show that soybean oil is effective in decreasing the serum cholesterol and LDL levels and has a big potential for being used as a hypocholesterolemic agent to prevent atherosclerosis and heart diseases (Kummerow et al. 2007). Therefore, soybean oil is the one of the most preferred oils for a healthy lifestyle. People usually prefer it because of its high quality and functionality, i.e. it contains precursor Omega-3 (7%) and Omega-6 (50%) fatty acids which regulate lipid and cholesterol metabolism and provide almost 50% of essential daily intake, Vitamin E content, and low price (Mounts et al. 1986).

It has been demonstrated that a soybean crop yielding 2.5 t seed removes about 125 kg nitrogen, 23 kg phosphorus, 101 kg potassium, 22 kg sulphur, 35 kg calcium, 19 kg magnesium, 192 g zinc, 866 g iron, 208 g manganese and 74 g copper per hectare from the soil (PASRICHA, TANDON 1989). Concerning fertilization, major causes of low productivity of soybean are multi-nutrient deficiencies (e.g. of nitrogen, phosphorus, sulphur, zinc, iron, boron) as farmers tend to supply only nitrogen and phosphorus to major crops, and often at lower doses than recommended, whereas sulphur deficiency is due to the preference by farmers of diammonium phosphate (DAP) as a source of phosphorus rather than single superphosphate (SSP). The relative uptake of nitrogen, phosphorus and potassium by indeterminate soybean under field conditions was studied in some earlier research (HANWAY, WEBER 1971). The order of concentrations of macronutrients in stems and leaves was reported as nitrogen, potassium, calcium, phosphorus, magnesium and sulphur. Besides, it was reported that several factors contributed to a decrease in the sulphur status of soil over time. Plant available sulphur is derived primarily from the decomposition of plant residue and soil organic matter. Sulphur deficiency is most common in soils that are inherently low in sulphur, have a sandy texture and are low in organic matter or in soils that are prone to high leaching. Depending on the soil tested sulphur content, the optimum dose of the application of sulphur to oilseed crops, including soybean, has been found to vary from 15 to 60 kg S ha^{-1} (SINGH 1999). Thus, application of sulphur fertilizer (JANKOWSKI et al. 2014, 2015) and foliar applied chemicals (KRZEBIETKE, SIENKIEWICZ 2010) showed to have induced significant changes in the concentration of nutritional compounds in many plants.

As mentioned above, soybean is the most important oilseed crop over the world owing to its numerous advantages. However, there are still great expectations regarding some improvement of soybean seed quality. For this purpose, effects of phosphorus and sulphur doses applied as foliar fertilizers on the nutritional characteristics of soybean have been tested in the present research.

MATERIAL AND METHODS

The soybean commercial variety Nova was chosen for the present study because of its wide adaptability, yield stability and widespread use across the country. Nova soybean variety was certified by May Agro Company in 2005. It is a medium-early genotype, which is suggested as the main or second crop. According to the certification report, its thousand seed weight is 135-140 g, oil content is 200-300 g kg^{-1} and protein ratio is 300-340 g kg^{-1}. The field trial was conducted on an experimental field of the Selcuk University Agricultural Faculty in Konya, Turkey, during two growing seasons (15th of May for sowing, end of August for harvest), in 2013 and 2014. According to the long-term averages, Konya (1020 m above from sea level) has 11.4°C temperature, 281 mm annual rainfall and 52.5% relative humidity. For the plant growing period, long-term data were reported as: 22.2°C temperature, 64.9 mm rainfall and 40.4% for relative humidity, while the actual values were different during the research years. The climatic data showed the following values: 22.2°C - 21.3°C temperature, 58.8 mm - 96.0 mm rainfall, 36.6% - 42.21% relative humidity for the trial periods (2013 and 2014), respectively.

The soil characteristics (for 0-30 cm and 30-60 cm depth, respectively) of the trial soil were as follows: clay loam structure, low level of organic matter (2.40% - 1.48%), a higher level of lime (35.60-33.40%), pH = 8.12-8.05, salinity at 0.05%, available phosphorus at 18.30-13.00-kg ha^{-1}, available zinc at 0.51-0.40 mg kg^{-1}, iron at 14.16-9.10 mg kg^{-1}, copper at 1.77-1.66 mg kg^{-1} and manganese at 6.96-5.48 mg kg^{-1} (FAO 2014).

The field trial was set up as two different experiments established according to a randomized blocks design with three replications. Plots were 4 m long and 2.25 m wide, rows (5 in total) were spaced at 45 cm and 20 cm distance, and soybean seeds previously inoculated with *Rhizobium japonicum* culture (1%) were hand sown at 4-5 cm of depth. The plots were spaced at 1 m and blocks were spaced at 2 m. Fertilizer was applied (Goksoy, Turan 2000) before sowing (200 kg ha^{-1} DAP: 18% N and 46% P which equal to 36 kg ha^{-1} N and 92 kg ha^{-1} P). Hoeing was done twice manually and drip irrigation was performed three times when the plants showed water shortage symptoms. Manual harvest was made after the pods fully matured by eliminating two rows (the first and the last) and 50 cm from both sides of the other rows (three in total) as a side effect.

Foliar application of the fertilizers was composed of 4 phosphorus (P) doses: 4, 6, 8 and 10 kg ha^{-1} in experiment-1 and 4 sulphur (S) doses: 5, 10, 15 and 20 kg ha^{-1} in experiment-2 when the plants reached 10 cm of height.

The protein ratio was quantified by N analysis using the Kjeldahl method according to the standard methods of analysis (AOAC 1990) and recorded in a g kg^{-1} unit. Nutritional elements, such as phosphorus, potassium, magnesium, calcium, iron, copper, zinc and manganese, were determined by ICP AES on a Varian Vista Model according to Burt (2004) and recorded in a mg kg^{-1} unit. Fatty acids, such as myristic acid, palmitic acid, stearic acid, oleic acid, linoleic acid, arachidic acid, linolenic acid, gadoleic acid, eicosadienoic acid, eicosatrienoic acid, lignoceric acid, nervonic acid and docohexaenoic acid, were determined by gas chromatography (Shimadzu GC 2010) according to the ISO-5509 method (ISO 1978) and recorded in a g kg^{-1} unit. All of the mentioned characteristics were determined in two replications.

The means from the years were taken for statistical analysis, while an analysis of variance for all of the investigated characteristics was conducted with the help of a Jump computer software program (Kahraman et al. 2015).

RESULTS AND DISCUSSIONS

Results of the investigated characteristics: protein, phosphorus, potassium, magnesium, calcium, iron, copper, zinc, manganese, myristic acid, palmitic acid, stearic acid, oleic acid, linoleic acid, arachidic acid, linolenic acid, gadoleic acid, eicosadienoic acid, eicosatrienoic acid, lignoceric acid, nervonic acid and docohexaenoic acid in the Nova soybean variety subjected to foliar phosphorus and sulphur application are presented as statistical parameters in Table 1, and according to the phosphorus doses in Table 2 and sulphur doses in Table 3. Results of the study are summarized below.

Table 1

Variance analyses of the investigated characteristics

Characteristic	Phosphorus doses	Sulphur doses
Protein	3.214	0.994
P	1.689	2.568
K	1.676	1.147
Mg	0.803	2.213
Ca	0.970	0.998
Fe	5.328	1.736
Cu	3.282	0.359
Zn	0.742	0.835
Mn	7.639*	1.897
Myristic acid	1.411	11.88**
Palmitic acid	14.96**	0.105
Stearic acid	139.5**	2.925
Oleic acid	4.550	0.253
Linoleic acid	1.260	0.409
Arachidic acid	3.831	1.080
Linolenic acid	13.52**	0.499
Gadoleic acid	0.323	1.029
Eicosadienoic acid	0.395	1.321
Eicosatrienoic acid	0.614	0.491
Lignoceric acid	0.538	0.880
Nervonic acid	7.081*	0.286
Docohexaenoic acid	7.997*	6.520*

* $p < 0.05$, ** $p < 0.01$

Table 2

Content of the investigated nutritional characteristics (minerals in: mg kg^{-1}, fatty acids in: g kg^{-1}) by P doses

Characteristic	Control	Dose 1	Dose 2	Dose 3	Dose 4
Protein (g kg^{-1})	325.4	316.5	330.1	353.4	367.5
P	6550	6800	7350	7000	6900
K	8302	8194	8280	8236	8141
Mg	1064	997	1127	1077	1267
Ca	1419	1276	1245	1288	1285
Fe	97.80	89.30	79.90	97.90	87.90
Cu	25.30	22.10	24.20	35.60	22.65
Zn	72.25	78.40	85.30	68.70	70.05
Mn	10.10	10.85	13.60	14.40	3.600
Myristic acid	0.81	0.80	0.77	0.78	0.79
Palmitic acid	110.1	110.9	112.8	112.5	115.1
Stearic acid	50.12	42.40	42.18	41.32	43.20
Oleic acid	251.5	229.4	235.2	234.2	248.1
Linoleic acid	502.1	517.2	513.6	514.5	520.3
Linolenic acid	71.29	85.32	82.83	83.87	81.06
Arachidic acid	4.32	3.91	3.77	3.81	3.92
Gadoleic acid	2.99	2.96	2.61	2.87	2.49
Eicosadienoic acid	0.49	0.52	0.47	0.48	0.43
Eicosatrienoic acid	3.97	3.82	3.78	3.76	3.91
Lignoceric acid	1.46	1.41	1.37	1.33	1.35
Nervonic acid	0.31	0.58	0.13	0.24	0.34
Docohexaenoic acid	0.57	0.51	0.36	0.24	0.45

Among the investigated nutritional characteristics of soybean seeds, significant differences were observed for manganese, nervonic acid and docohexaenoic (DHA) acid ($p < 0.05$), while palmitic acid, stearic acid and linolenic acid were differentiated by the P application. Additionally, sulphur application caused statistically significant differences in the content of myristic acid ($p < 0.01$) and DHA ($p < 0.05$).

The protein ratio ranged from 316.50 to 367.50 g kg^{-1} in response to the phosphorus application of dose 1 and dose 4, respectively. As for the sulphur application, the protein ratio changed from 325.4 (control) to 368.3 g kg^{-1} (dose 4). Globally, soybean [*Glycine max* (L.) Merrill] is mainly grown for its protein, nutritional composition and oil (Board 2012). Similar to the present results, former reports revealed the protein ratio as 350 g kg^{-1}- 450 g kg^{-1}

Table 3

Content of the investigated nutritional characteristics (minerals in mg kg^{-1}, fatty acids in g kg^{-1}) by S doses

Characteristic	Control	Dose 1	Dose 2	Dose 3	Dose 4
Protein (g kg^{-1})	325.4	330.1	346.2	328.8	368.3
P	6550	6450	7200	6650	6200
K	8302	8165	8141	8255	8196
Mg	1064	951	1028	1091	957
Ca	1419	1127	1107	1217	1083
Fe	97.80	94.25	61.20	90.20	88.50
Cu	25.30	25.60	25.55	28.75	28.70
Zn	72.25	62.30	76.45	73.85	78.90
Mn	10.10	14.25	12.95	18.90	8.700
Myristic acid	0.81	0.78	0.78	0.77	0.76
Palmitic acid	110. 1	109.3	110.3	111.7	111.8
Stearic acid	50.12	43.97	49.50	44.22	46.32
Oleic acid	251.5	266.7	262.9	245.6	253.9
Linoleic acid	502.1	487.4	490.6	503.3	499.8
Linolenic acid	71.29	77.25	70.58	79.29	73.57
Arachidic acid	4.32	4.06	4.34	4.01	4.03
Gadoleic acid	2.99	3.87	3.91	4.05	3.09
Eicosadienoic acid	0.49	0.58	0.61	0.63	0.51
Eicosatrienoic acid	3.97	3.91	4.11	4.01	3.81
Lignoceric acid	1.46	1.36	1.40	1.37	1.33
Nervonic acid	0.31	0.30	0.26	0.29	0.25
Docohexaenoic acid	0.56	0.45	0.60	0.49	0.68

(ONER 2006), 300 g kg^{-1} - 500 g kg^{-1} (EL-SHEMY 2011) and 346 g kg^{-1} (BOHN et al. 2014) in soybean seeds.

The seed composition of soybean differs depending on a variety, environment and agricultural practice (especially fertilization). Similar values to the present ones were obtained in many of the previous experiments, which are discussed below.

The content of P in soybean seed was between 6550 (control) and 7350 (dose 2) mg kg^{-1} following phosphorus application, while those values ranged from 6200 (dose 4) to 7200 (dose 2) mg kg^{-1} in response to sulphur application. The phosphorylation status has an effect on the cell structure which involves the proteins and thereby many activities in the metabolisms (NANJO et al. 2012). Similar to the present findings, the content of phosphorus was reported as being 5900-8100 mg kg^{-1} (NRC 1998) or 5240 mg kg^{-1} (Andrade et al. 2010).

The potassium content of soybean seeds was determined at 8141 (dose 4) - 8280 (dose 2) mg kg^{-1} in the phosphorus treatment, while those values achieved under the influence of sulphur application were 8141 (dose 2) - 8302 (control) mg kg^{-1}. Soybean seeds contain relatively more potassium (Board 2012). In some earlier research, it was reported that the potassium content in soybean varieties which were harvested in different maturity periods showed a range between 10000-20000 mg kg^{-1} values (Bellaloui et al. 2012).

Foliar application of P caused a change in the magnesium content from 997 (dose 1) to 1267 (dose 4) mg kg^{-1}, whereas S application effected a change in the range from 951 (dose 1) to 1091 (dose 3) mg kg^{-1}. Similar to the present findings, the magnesium content in soybean seeds was determined by other researchers in the following ranges: from 2610 to 3170 mg kg^{-1} (Andrade et al. 2010) and 2200 mg kg^{-1} (Board 2012).

The application of P resulted in the calcium content of soybean seed from 1245 (dose 2) to 1419 (control), while S application led to a range of Ca content between 1083 (dose 4) and 1419 (control) mg kg^{-1}. According to other researchers, the calcium content in soybeans showed a wide range, such as 1710-3354 mg kg^{-1} (Andrade et al. 2010), 2000-4000 mg kg^{-1} (Bellaloui et al. 2012). Some differences may be due to the genetic variation, soil characteristics and agricultural practice.

The iron content of seed ranged from 79.90 mg kg^{-1} to 97.90 mg kg^{-1} for the phosphorus application of dose 2 and dose 3, respectively. In response to the sulphur application, the iron content was changed from 61.20 mg kg^{-1} (dose 2) to 97.80 (control) mg kg^{-1}. Previously, the content of iron in soybean seeds was reported as follows: from 223.0 to 400.0 mg kg^{-1} (Andrade et al. 2010) and from 84.40 to 86.80 mg kg^{-1} (Bohn et al. 2014).

The content of copper in soybean seeds was between 22.10 (dose 1) and 35.60 (dose 3) mg kg^{-1} after phosphorus application, while those values ranged from 25.30 (control) to 28.75 (dose 3) mg kg^{-1} following sulphur application. The composition of soybean seeds showed the concentrations of copper between 28.80-31.40 mg kg^{-1} (Andrade et al. 2010), 2.00-12.10 mg kg^{-1} (Bellaloui et al. 2012), 10.40-11.30 mg kg^{-1} (Bohn et al. 2014). As demonstrated by these values, the copper content in soybean seeds varies by almost sixteenfold in some cases.

The zinc content of soybean seeds was determined at 68.70 (dose 3) - 85.30 (dose 2) mg kg^{-1} following phosphorus application, while those values achieved under sulphur application were from 62.30 (dose 1) to 78.90 (dose 4) mg kg^{-1}. The zinc content of soybean seeds determined in some previous studies was: 74.00-83.00 mg kg^{-1} (Andrade et al. 2010), 16.00-56.00 mg kg^{-1} (Bellaloui et al. 2012), 30.40-37.00 mg kg^{-1} (Bohn et al. 2014).

Foliar application of P induced a change in the manganese content from 3.600 (dose 4) to 14.40 (dose 3) mg kg^{-1}, whereas the S application caused a change from 8.700 (dose 4) to 18.90 (dose 3) mg kg^{-1}. Previous investigations concerning the manganese content in soybean seeds yielded similar results: 8.000-35.00 mg kg^{-1} (Bellaloui et al. 2012), 22.80-24.50 mg kg^{-1} (Bohn et al. 2014).

The application of P gave rise to a change in the myristic acid content in soybean seeds from 0.77 (dose 2) to 0.81 (control) g kg^{-1}, while the S application caused to a range between 0.76 (dose 4) and 0.81 (control) g kg^{-1} values. Palmitic acid in soybean seeds ranged from 110.1 g kg^{-1} to 115.1 g kg^{-1} for control and dose 4 application of phosphorus, respectively. As for the sulphur application, the palmitic acid content changed from 109.3 (dose 1) g kg^{-1} to 111.8 (dose 4) g kg^{-1}. The content of stearic acid in the soybean seed was between 41.32 (dose 3) g kg^{-1} and 50.12 (control) g kg^{-1} under phosphorus application, while those values ranged from 43.97 (dose 1) g kg^{-1} to 50.12 (control) g kg^{-1} under sulphur application. Similar results were reported in some previous research on fatty acid composition in soybean, where the following values were reported: 103-116 g kg^{-1} for palmitic acid and 31-47 g kg^{-1} for stearic acid (Bellaloui et al. 2013), and 2.1 g kg^{-1} for myristic acid, 120 g kg^{-1} for palmitic acid and 42 g kg^{-1} for stearic acid (Ladeira et al. 2014).

The oleic acid content of soybean seeds was determined at 229.4 (dose 1) g kg^{-1} - 251.5 (control) g kg^{-1} under phosphorus application, while those values following sulphur application were 245.6 (dose 3) g kg^{-1} - 266.7 (dose 1) g kg^{-1}. Foliar application of P caused a change in the linoleic acid content from 502.1 (control) g kg^{-1} to 520.3 (dose 4) g kg^{-1}, whereas S application resulted in a range from 487.4 (dose 1) g kg^{-1} to 503.3 (dose 3) g kg^{-1}. The linolenic acid content of soybean seed ranged from 71.29 g kg^{-1} to 85.32 g kg^{-1} for control and dose 1 application of phosphorus, respectively. Regarding sulphur application, the linolenic acid seed content changed from 70.58 (dose 2) g kg^{-1} to 79.29 (dose 3) g kg^{-1}. Former reports also found similar quantities in soybeans: 219.9 g kg^{-1} for oleic acid, 486 g kg^{-1} - 579 g kg^{-1} for linoleic acid and 61 g kg^{-1} - 86 g kg^{-1} for linolenic acid (Bellaloui et al. 2013), 211 g kg^{-1} - 314 g kg^{-1} for oleic acid, 496 g kg^{-1} for linoleic acid and 51 g kg^{-1} for linolenic acid (Ladeira et al. 2014).

The application of P gave rise to a change in the arachidic acid content in soybean seeds from 3.77 (dose 2) g kg^{-1} to 4.32 (control) g kg^{-1}, while S application resulted in a range between 4.01 (dose 3) g kg^{-1} and 4.32 (control) g kg^{-1}. The content of gadoleic acid in soybean seeds was between 2.49 (dose 4) g kg^{-1} and 2.99 (control) g kg^{-1} under phosphorus application, while those values ranged from 2.99 (control) g kg^{-1} to 4.05 (dose 3) g kg^{-1} resulting from sulphur application. He eicosadienoic acid content of soybean seeds was determined at 0.43 (dose 4) g kg^{-1} - 0.52 (dose 1) g kg^{-1} after phosphorus application, while those values caused by sulphur application were 0.49 (control) g kg^{-1} - 0.63 (dose 3) g kg^{-1}. Foliar application of P caused a change in the eicosatrienoic acid content from 3.76 (dose 3) g kg^{-1} to 3.97 (control) g kg^{-1}, whereas S application effected a range from 3.81 (dose 4) g kg^{-1} to 4.11 (dose 2) g kg^{-1} values. The application of P gave rise to a change in the lignoceric acid content in soybean seeds from 1.33 (dose 3) g kg^{-1} to 1.46 (control) g kg^{-1}, while S application resulted in a range between 1.33 (dose 4) g kg^{-1} and 1.46 (control) g kg^{-1}. The nervonic acid content of seeds ranged from 0.13 g kg^{-1} to 0.58 g kg^{-1} for dose 2 and dose 1 application of phosphorus, respectively. As for the sulphur application, the nervonic acid content changed from 0.25 (dose 4) g kg^{-1} to 0.31 (control) g kg^{-1}.

The content of docohexaenoic acid in soybean seeds was between 0.24 (dose 3) g kg^{-1} and 0.57 (control) g kg^{-1} following phosphorus application, while those values ranged from 0.45 (dose 1) g kg^{-1} to 0.68 (dose 4) g kg^{-1} under the influence of sulphur application. According to the other reports, arachidic acid (1 - 6 g kg^{-1}), gadoleic acid (5 g kg^{-1}), eicosadienoic acids (1 g kg^{-1}), lignoceric acid (5 g kg^{-1}) are minor components of plants and all are at levels below 10 g kg^{-1} (Gunstone et al. 2007). Nervonic acid may be useful in the treatment of some diseases (Sargent et al. 1994, Ucciani 1995). Docohexaenoic acid (DHA) is one of omega-3 acids that evokes the biggest interets, and is therefore a significant component. Additionally, eicosatrienoic acid is known to act in altering the immune status of kidney (Schreiner et al. 1988).

Previous research revealed similar results pertaining to the nutritional status of soybeans. Most of the mentioned studies gave values close to the ones obtained herein for the investigated quality related component. Thus, the data originating from the present study are approximately the same or only slightly divergent from the ones reported previously by other researchers. Differences may be due to genetic variation, environment conditions, growing techniques and fertilizer applications.

CONCLUSIONS

The current research demonstrated that foliar application of phosphorus increased the protein, Mg, Mn, palmitic acid, linoleic acid and linolenic acid content in soybean seeds. Additionally, foliar application of sulphur increased the protein, Cu, Zn, palmitic acid, linolenic acid, gadoleic acid, eicosadienoic acid and docohexaenoic acid content of soybean seed. Results of the present research coincide with values from other studies. In general, responses of soybean to different levels of foliar fertilizer applications were manifested by changes in the investigated seed composition quality characteristics. Future research into nutritional characteristics of soybean genotypes will be necessary to determine fertilizer amounts which will ensure better nutritional composition of soybeans. Further research on the nutritional composition of soybeans as affected by fertilizer should be completed to increase food quality. Present research demonstrated that foliar applicaltion of phosphorus and sulphur is effective in increasing the content of essential fatty acids such as linoleic and linolenic acid.

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