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# EFFECT OF FERTILIZERS ON YIELD COMPONENT ATTRIBUTES, YIELD AND QUALITY IN SOYBEAN CROP

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***Abstract***

*The paper aimed to present the effects of different types of fertilizers on several soybean quantitative traits (plant height, first pod height, number of pods per plant, number of grain per plant, grain yield per plant, 1000-grain weight and grain yield) and seeds' composition (dry matter, protein content, ash content, oil content, total carbohydrates, total flavonoids, total phenols and total carotenoids content). The experiment was conducted in 2019, in the experimental field of Soybean Breeding Laboratory from the Agricultural Research and Development Station Turda (ARDS Turda), and included 15 fertilization trials. An early maturing soybean variety (Caro TD) obtained at ARDS Turda was used for the experiment. The results showed that increases in yield were obtained with various combinations of the commercial fertilizer. The application of $N_{20}P_{20}K_0$ combined with seed treatment and foliar Bio-fertilizer with 80% amino acids, significantly increased the values for all quantitative traits and also grain yield, while with respect to seed composition the best ranked type of treatment was $T_7$(ecological products).*

***Key words**: fertilizers, yield, soybean, seed composition.*

## INTRODUCTION

Soybeans are the most widely used beans in the food industry and provide economic benefits for small-scale farmers (Zerihun et al., 2015). It is one of the food crops that have the benefits as a source of vegetable protein (Kuntyastuti et al., 2019). Oil and protein rich soybean has been recognized all over the world as a potential supplementary source of edible oil and nutrition (Kaul & Das, 1986).

Seed composition and quality are known to be genetically controlled, and significant variability in seed quality and composition exist due to differences in the gene pool. The physiological and biochemical mechanisms by which this variability is expressed are still not completely understood, but are known to be significantly influenced by genotype, environment, management practices, and their interactions (Bellaoui et al., 2011).

Seed composition refers to major constituents including protein, oil, carbohydrates, isoflavones, and mineral concentration that determine seed nutritional value (Bellaloui et al., 2011). According to Gopalan et al. (1971) and Rahman (1982) soybean seeds contain 43.2% protein, 19.5% fat, 20.9% carbohydrate and a good amount of other nutrients like calcium, phosphorus, iron and vitamins.

Soybean protein, taking up 40% of the dry seed weight on average (Hymowitz et al., 1974) is highly valued for food and feed because of its amino acid composition and a high digestibility.

Nitrogen fertilization during the seed-filling stage increased the protein content and earlier N application, in flowering, did not affect the protein content (Afza et al., 1987; Isfan, 1991) whereas the composition in sulphur-containing amino acid fluctuated depending on the nitrogen source (Paek et al., 1997) and on the availability of reduced forms of sulphur as well (Grabau et al., 1986).

Zimmer et al. (2016) reported that protein content of non-inoculated soybeans was significantly lower than protein content of the inoculated soybeans. N fertilization at the flowering stage was superior to both the control and rhizobium inoculation in increasing seed protein content, but as symbiotic N fixation is a highly complex phenomenon, the difference in protein content could have been the result of many different factors and their interactions which demand further investigation (Vollmann et al., 2000). The negative relationship between protein and oil content, and protein and yield remains a major challenge to soybean breeders to select a better hybrid for higher yield and higher protein (Burton, 1985).

Soybeans represent 59% of the world's oilseed production and 29% of the total vegetable oil consumption in the world. Soybean oil fatty acids are responsible for nutritional value, stability and taste of this product; commodity soybean oil is in average made up from 13% palmitic acid, 4% stearic acid, 20% oleic acid, 55% linoleic acid and 8% linolenic acid (Fehr, 2007; Snyder et al., 2009). Soybean oil has poor oxidative stability compared to other vegetable oils (Rani et al., 2007). Oil content can be in positive correlation with temperature (Ren et al., 2009) but were also reported negative linear relationships (Kumar et al., 2006; Pipolo et al., 2004). Water stress negatively impacts oil content (Rotundo et al., 2009), but irrigation at the beginning of pod formation and during seed filling has resulted in oil content decline (Latifi et al.,1989; Ghassemi-Golezani et al., 2012).

Some other crop management factors (rotation, no-till, fertilization, seed treatments, foliar N, fungicide and insecticide applications) had an overall positive effect on oil content because they were improving crop growing conditions through conserving or supplying water and nutrients or improving soil physical and chemical properties and protecting the crop from diseases (Assefa et al., 2019). Oil content increased slowly with yield increase suggesting a positive relationship, but when relationships were investigated by study, 63% of studies supported a positive relationship, and the other 37% displayed a slightly negative relationship between seed yield and oil content (Assefa et al., 2019).

Another component of soybean seed composition is carbohydrates. Soybean seeds contain 33% carbohydrates (reported to dry weight - DW) of on average, of which 16.6% are soluble sugars (Hymowitz and Collins, 1974).

Most of the carbohydrates are insoluble polysaccharides, including pectin, cellulose, hemicelluloses and starch (Liu, 1997). Soluble carbohydrates include monosaccharides (glucose and fructose), disaccharides (sucrose), and oligosaccharides (raffinose and stachyose) (Liu, 1997). According to Hou et al. (2009), the five main soluble sugars in soybean seed are glucose, fructose, sucrose, raffinose and stachyose with sucrose and stachyose being the predominant ones.

Fertilization is one of the cultivation technologies that can be done to increase the productivity of plants (Chakrabarty et al., 2014). Application of fertilizers can have a positive effect on nutrient uptake, growth, and yield on plants (Estiaty et al., 2006; Meena et al., 2015).

Seed composition can change in response to fertilization although these changes are moderate and inconsistent (Gaydou & Arrivets, 1983; Haq & Mallarino, 2005; Seguin & Zheng, 2006). The use of different fertilization has produced small increases in soybean seed oil concentrations and small decreases in seed protein concentrations (Yin & Vyn, 2003; Gaydou & Arrivets, 1983; Sale & Campbell, 1986). Different type of fertilization also has changed the fatty acid profile in the soybean seed oil (Gaydou & Arrivets, 1983). Fertilization treatments significantly influences plant height, number of plants/$m^2$, insertion of basal pod, number of pods/plant, number of grain/plant, weight of grain/plant and the yield (Mandić et al., 2015).

The quality of soybean seeds is influenced by the genetic constitution, agronomic practices and environmental factors, from the seed formation to storage. However, there is little information available on plant nutrition relating to the production of soybean seeds. In view of this, fertilization is conducted based on the established recommendations for grain yield and, among the nutrients, nitrogen (N) stands out (Zuffo et al., 2018).

## MATERIALS AND METHODS

Field trials were carried out in 2019, in the experimental field of Soybean Breeding Laboratory from the Agricultural Research and Development Station Turda (ARDS Turda).

The land was medium high and soil texture was loam clay with pH = 6.7. An early maturing soybean variety (Caro TD) obtained at ARDS Turda was used for the experiment. The experiment was based on a linear design, without replication, using plots of 90 $m^2$. For each fertilization, Caro TD was sowed on 6 rows of 30 m length, at 50 cm distance between rows. At the end of the growing season 30 randomly selected plants from each plot were analyzed for: height, insertion of the basal pods, number of pods/plant, number of grain/ plant, grain weight/plant and thousand kernel weight (TKW). The plots were harvested at the end of September 2019 with a Wintersteiger Classic Plot Combine (Wintersteiger AG, Austria). The reported results are the average of 10 measurements and the obtained data for different agronomic traits and quality parameters were statistically analyzed in Excel (Microsoft, USA).

The treatments used in the experiment are presented in the Table 1.

Table 1. The treatments used for the experiment

| Variant | Basic fertilization | Seed treatment | Foliar treatment |
|---|---|---|---|
| T0 (control) | - | - | - |
| T1 | 200 kg/ha of NPK 20:20:0 complex fertilizer | Bio-fertilizer + Amino acids with cobalt and molybdenum + Rhizobium | Bio-fertilizer with 80% amino acids |
| T2 | | Bio-fertilizer + Amino acids with cobalt and molybdenum + Rhizobium | Bio-fertilizer with 80% amino acids |
| T3 | | Rhizobium | 3 leaf treatment with organic bio-stimulants |
| T4 | | Bio-stimulant + Rhizobium | Bio-stimulant containing a brassinosteroid |
| T5 | | Bio-stimulant + Rhizobium | Bio-stimulant containing a brassinosteroid + adjuvant |
| T6 | | Rhizobium | Foliar fertilizer with N |
| T7 | Bio-fertilizer produced with the help of the frame | Ecological insect-fungicide + active humic fertilizer | Active humic fertilizer + Bio-fertilizer with NPK, amino acids and microelements + Ecological insect-fungicide |
| T8 | 200 kg/ha of NPK 20:20:0 complex fertilizer | Ecological insect-fungicide + active humic fertilizer | Active humic fertilizer + Bio-fertilizer with NPK, amino acids and microelements |
| T9 | | Rhizobium + bacterial protector | - |
| T10 | | Rhizobium inoculant + Bioinnoculants with *Trichoderma asperellum* strain kd | - |
| T11 | 200 kg/ha of complex fertilizer with Nitrogen, Nitrate, Ammonium, $P_2O_5$, $K_2O$, MgO, $SO_3$, Zn and B | Seed treatment with $P_2O_5$ + Zn | foliar phosphates + fertilizer with essential nutrients (MgO, $SO_3$, B, Mn, Mo) |
| T12 | 200 kg/ha of complex fertilizer with Nitrogen, Nitrate, Ammonium, $P_2O_5$, $K_2O$, MgO, $SO_3$, Zn and B + 100 kg/ha of nitrate product with sulphur | Seed treatment with $P_2O_5$ + Zn | foliar phosphates + fertilizer with essential nutrients (N+Ca+Mg +B+Mn+Mo) + nitrogen and available sulphur + potassium product for foliar application |
| T13 | 150 kg/ha of complex fertilizer NPK 12:8:16 +3Mg + 10S + microelements | Bio-stimulants + Rhizobium inoculant | Bio-stimulant + Organic insecticides + Adjuvant |
| T14 | 200 kg/ha of NPK 20:20:0 complex fertilizer | BioStacked pre-inoculant with *Bradyrhizobium japonicum* and *Bacillus subtilis* (MBI 600 strain) | - |
| T15 | | - | - |

The experiment included 15 fertilization trials and one control variant (without fertilization). Different organic or mineral fertilizers were applied before final land preparation (Table 1). Therefore, the seed and foliar treatments were applied using the recommendation established by each fertilizer producers. Proximate composition of seeds was accomplished according to AOAC methods (Latimer, 2012), being described in detail in Muntean et al. (2019), where is also mentioned the procedure for the determination of total carotenoids. Total phenols were determined based on the Folin-Ciocalteu assay (Bellauli, 2012), the results being expressed in gallic acid equivalents (GAE), while the total flavonoids content was determined spectrophotometrically (Josipovic et al., 2016), the results being reported as catechin equivalents (CE).

Data processing was accomplished in Excel (Microsoft, USA); chemometric analysis was performed using MatLab (The Mathworks, USA) after mean center preprocessing.

## RESULTS AND DISCUSSIONS

The results from this study reveal that some fertilizers appear to improve soybeans yield and quality. Results of yield and yield elements are summarized in Table 2, highlighting different combinations of inorganic and organic fertilizers with the maximum values for the studied parameters: treatment $T_1$ showed maximum values for: yield (3549 kg/ha), number of pods/plant (32.9) which was statistically at par with $T_2$, $T_6$, $T_9$, $T_{12}$ and $T_{13}$ (29.4, 27.5, 28.2 and 28.3, respectively) and height (87 cm); treatment $T_4$ had the maximum values for insertion of basal pods (16 cm); $T_6$ with the maximum values for number of grain/plant (90.2) and grain weight/plant (11.18 g); $T_{11}$ with the biggest seeds (146.5 g). Height insertion of basal pods, number of grain/plant and weight of grain/plant of Caro TD soybean variety varied significantly for different combinations of inorganic and organic fertilizer.

Similar results in soybean yield and yield elements were also reported in previous papers (Aruna and Reddy, 1999; Singh and Rai, 2004). La Menza et al. (2017) and Ray et al. (2006) who reported a negative impact of application of nutritive supply reflected in decrease of protein concentration.

Table 2. Effect of different fertilizers on yield and yield elements

| No. | Fertilizer variant | Number of plants/m² (no) | Height (cm) | Insertion of basal pod (cm) | Number of pods/plant (no) | Number of grain/plant (no) | Weight of grain/plant (g) | TKW (g) | Yield kg/ha |
|---|---|---|---|---|---|---|---|---|---|
| 1 | T 0 | 48.00 a | 74.30 gh | 11.80 ad | 25.70 bc | 65.00 ce | 8.29 cf | 127.60 bc | 2822 |
| 2 | T 1 | 51.67 a | 87.00 a | 10.90 bd | 32.90 a | 83.80 ab | 10.64 ab | 127.90 bc | 3549 |
| 3 | T 2 | 48.33 a | 84.00 ac | 12.00 ad | 29.40 ab | 74.00 ad | 9.79 ad | 133.10 ab | 2978 |
| 4 | T 3 | 44.33 a | 79.90 bf | 11.60 ad | 24.90 bd | 71.50 bd | 9.02 be | 126.70 bc | 3018 |
| 5 | T 4 | 50.33 a | 74.50 gh | 16.00 a | 20.80 cd | 50.80 e | 6.16 g | 122.20 bc | 2987 |
| 6 | T 5 | 48.00 a | 76.50 eh | 14.90 ab | 24.70 bd | 67.80 bd | 8.06 cg | 121.10 bc | 2993 |
| 7 | T 6 | 50.67 a | 81.90 ad | 9.20 d | 29.40 ab | 90.20 a | 11.18 a | 125.50 bc | 2961 |
| 8 | T 7 | 47.67 a | 74.90 fh | 14.30 ac | 19.10 d | 50.30 e | 6.71 fg | 132.70 ab | 3064 |
| 9 | T 8 | 47.33 a | 78.30 dh | 10.60 bd | 25.10 bc | 78.30 ac | 10.05 ac | 128.20 bc | 2888 |
| 10 | T 9 | 52.00 a | 84.20 ac | 10.70 bd | 27.50 ab | 76.30 ad | 9.71 ae | 127.40 bc | 3066 |
| 11 | T 10 | 48.67 a | 81.10 be | 10.20 cd | 23.20 bd | 64.20 ce | 9.03 be | 146.50 a | 2935 |
| 12 | T 11 | 50.33 a | 76.60 eh | 11.20 bd | 23.20 bd | 60.30 de | 7.74 eg | 129.70 bc | 2880 |
| 13 | T 12 | 46.67 a | 84.60 ab | 11.80 ad | 28.20 ab | 73.50 ad | 9.30 ae | 127.20 bc | 3040 |
| 14 | T 13 | 44.33 a | 73.60 h | 10.20 cd | 28.30 ab | 69.90 bd | 7.77 dg | 112.70 c | 3394 |
| 15 | T 14 | 50.67 a | 74.30 gh | 11.40 bd | 25.20 bc | 65.10 ce | 8.11 cf | 124.70 bc | 2748 |
| 16 | T 15 | 55.33 a | 79.20 cg | 12.30 ad | 26.50 bc | 75.50 ad | 9.56 ae | 128.40 bc | 2948 |
| LSD (0.05) | | 10.92 | 4.65 | 3.88 | 5.19 | 14.72 | 1.71 | 14.14 | - |
| CV (%) | | 5.81 | 5.5 | 15.39 | 13.3 | 15.28 | 15.32 | 5.45 | 6.59 |

Results obtained for the quality parameters indicated that seed composition is influenced by different type of fertilization (Table 3). Small increase in soybean protein concentrations was noted at $T_1$ (4% higher protein content than $T_0$). The highest value for oil content was reported at treatment $T_{14}$ (26.54%) with a growth of 5.6% than the control ($T_0$). At treatment $T_{13}$ were obtained both one of the highest oil content (26.26%) and the maximum total carotenoids (23.56 mg/kg DW) and total phenols (2.2 mg GAE/g DW) content associated with the smallest protein content (37.44%). The small CV in the studied quality parameters indicates a nonsignificant variation for dry matter, protein, ash content, oil content, total carbohydrates, total flavonoid and total phenol content. In testing the different combinations of fertilization on soybean in 112 field trials in Iowa, Haq and Mallarino (2005) concluded that total oil and protein production response to fertilizer followed a similar patter with yield response.

The yield, yield elements and quality parameters ranks are mentioned in Table 4. Comparison based on the mean yield and yield components ranks showed that the fertilization generally gave similar results in the studied variants.

For example with a total rank of 28 the highest-ranking treatment was $T_1$ which achieved top positions also for: plant height (1), number of pods/plant (2), number of grain/plant (2), weight of grain/plant (1) and yield (1). With respect to seed composition, the best ranked type of treatment was $T_7$ (37).

The negative correlation between yield and quality is highlighted by the rank obtained in the $T_1$ treatment therefore, the highest rated yield is related to one of the lowest rank for quality.

A negative correlation between quality parameters and yield, was reported by Chung et al. (2003), suggesting that an increased protein content is more expensive than commonly assumed.

Table 3. Effect of different fertilizers on some quality parameters

| No. | Fertilizer variant | Dry matter [%] | Proteins [g/100 g DW] | Ash [g/100 g DW] | Lipids [g/100 g DW] | Total carbohydrates [g/100 g DW] | Total flavonoids [mg CE/kg DW] | Total phenols [mg GAE/g DW] | Total carotenoids [mg/kg DW] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | T 0 | 92.70 | 37.84 | 4.82 | 25.13 | 24.91 | 41.24 | 1.94 | 17.38 |
| 2 | T 1 | 92.35 | 39.46 | 4.96 | 24.62 | 23.32 | 41.05 | 1.87 | 17.05 |
| 3 | T 2 | 92.93 | 38.78 | 5.00 | 25.42 | 23.72 | 44.59 | 1.90 | 17.61 |
| 4 | T 3 | 92.08 | 38.50 | 4.76 | 24.33 | 24.50 | 40.83 | 1.97 | 18.83 |
| 5 | T 4 | 92.87 | 38.49 | 4.76 | 25.71 | 23.91 | 38.49 | 1.84 | 18.05 |
| 6 | T 5 | 92.92 | 37.80 | 5.04 | 24.96 | 25.13 | 42.83 | 1.98 | 19.48 |
| 7 | T 6 | 93.59 | 38.05 | 4.81 | 25.80 | 24.94 | 40.17 | 1.94 | 20.45 |
| 8 | T 7 | 93.80 | 37.79 | 4.84 | 26.01 | 25.16 | 42.50 | 2.12 | 22.31 |
| 9 | T 8 | 94.46 | 37.46 | 4.91 | 25.59 | 26.50 | 37.35 | 1.85 | 12.81 |
| 10 | T 9 | 92.63 | 38.44 | 4.83 | 25.21 | 24.16 | 40.90 | 1.91 | 13.90 |
| 11 | T 10 | 92.56 | 38.36 | 5.28 | 26.09 | 22.83 | 38.83 | 1.88 | 12.81 |
| 12 | T 11 | 92.33 | 37.89 | 4.94 | 25.13 | 24.38 | 39.53 | 1.98 | 15.50 |
| 13 | T 12 | 92.62 | 39.11 | 4.78 | 25.29 | 23.43 | 35.82 | 1.82 | 17.93 |
| 14 | T 13 | 92.59 | 37.44 | 5.04 | 26.46 | 23.64 | 39.00 | 2.20 | 23.56 |
| 15 | T 14 | 92.64 | 37.61 | 4.78 | 26.54 | 23.71 | 41.20 | 2.11 | 22.31 |
| 16 | T 15 | 92.51 | 37.38 | 5.17 | 25.63 | 24.33 | 41.88 | 2.12 | 31.07 |
| CV (%) | | 0.66 | 1.62 | 3.14 | 2.41 | 3.73 | 5.41 | 5.82 | 24.37 |

Table 4. Yield ranks, yield elements ranks and quality parameters ranks given by each fertilizer variant for Caro TD soybean variety

| Fertilizer variant | Number of plants/m$^2$ | Height (cm) | Insertion of basal pod (cm) | Number of pods/plant (no) | Number of grain/plant (no) | Weight of grain/plant (g) | TKW (g) | Yield kg/ha | Total 1 (ranks for yield components) | Dry matter (%) | Proteins (g/ 100 g DW) | Ash (g/ 100 g DW) | Lipids (g/ 100 g DW) | Total carbohydrates (g/ 100 g DW) | Total flavonoid | Total phenol | Total carotenoids (mg/ kg DW) | Total 2 (ranks for quality parameters) | Total (1+2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T0 | 10 | 14 | 6 | 8 | 12 | 10 | 8 | 15 | 83 | 7 | 10 | 11 | 12 | 5 | 5 | 9 | 11 | 70 | 153 |
| T1 | 3 | 1 | 11 | 1 | 2 | 2 | 7 | 1 | 28 | 14 | 1 | 6 | 15 | 15 | 7 | 13 | 12 | 83 | 111 |
| T2 | 9 | 4 | 5 | 2 | 6 | 4 | 2 | 9 | 41 | 4 | 3 | 5 | 9 | 11 | 1 | 11 | 10 | 54 | 95 |
| T3 | 15 | 7 | 8 | 11 | 8 | 9 | 11 | 6 | 75 | 16 | 4 | 16 | 16 | 6 | 9 | 7 | 7 | 81 | 156 |
| T4 | 6 | 13 | 1 | 15 | 15 | 16 | 14 | 8 | 88 | 6 | 5 | 15 | 6 | 10 | 14 | 15 | 8 | 79 | 167 |
| T5 | 10 | 11 | 2 | 12 | 10 | 12 | 15 | 7 | 79 | 5 | 11 | 4 | 14 | 3 | 2 | 6 | 6 | 51 | 130 |
| T6 | 4 | 5 | 16 | 2 | 1 | 1 | 12 | 10 | 51 | 3 | 8 | 12 | 5 | 4 | 10 | 8 | 5 | 55 | 106 |
| T7 | 12 | 12 | 3 | 16 | 16 | 15 | 3 | 4 | 81 | 2 | 12 | 9 | 4 | 2 | 3 | 2 | 4 | 38 | 119 |
| T8 | 13 | 9 | 13 | 10 | 3 | 3 | 6 | 13 | 70 | 1 | 14 | 8 | 8 | 1 | 15 | 14 | 16 | 77 | 147 |
| T9 | 2 | 3 | 12 | 6 | 4 | 5 | 9 | 3 | 44 | 9 | 6 | 10 | 11 | 9 | 8 | 10 | 14 | 77 | 121 |
| T10 | 8 | 6 | 14 | 13 | 13 | 8 | 1 | 12 | 75 | 12 | 7 | 1 | 3 | 16 | 13 | 12 | 15 | 79 | 154 |
| T11 | 6 | 10 | 10 | 13 | 14 | 14 | 4 | 14 | 85 | 15 | 9 | 7 | 12 | 7 | 11 | 5 | 13 | 79 | 164 |
| T12 | 14 | 2 | 6 | 5 | 7 | 7 | 10 | 5 | 56 | 10 | 2 | 13 | 10 | 14 | 16 | 16 | 9 | 90 | 146 |
| T13 | 15 | 16 | 14 | 4 | 9 | 13 | 16 | 2 | 89 | 11 | 15 | 3 | 2 | 13 | 12 | 1 | 2 | 59 | 148 |
| T14 | 4 | 14 | 9 | 9 | 11 | 11 | 13 | 16 | 87 | 8 | 13 | 14 | 1 | 12 | 6 | 4 | 3 | 61 | 148 |
| T15 | 1 | 8 | 4 | 7 | 5 | 6 | 5 | 11 | 47 | 13 | 16 | 2 | 7 | 8 | 4 | 3 | 1 | 54 | 101 |

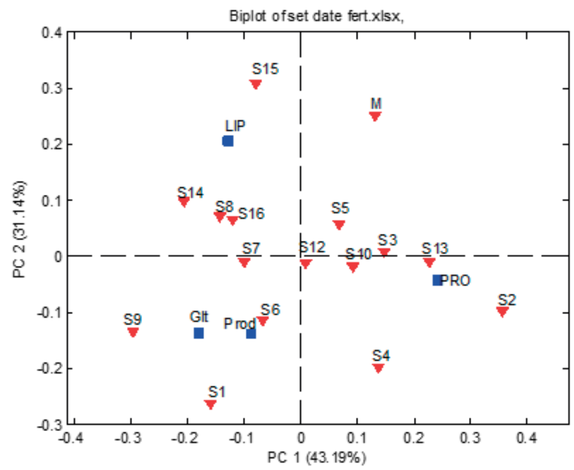


Figure 1. Biplot for the experimental data set (Prod - yield; Lip - lipids; Pro - protein; Glt - total carbohydrates)

Principal component analysis (PCA) was used for the classification and discrimination of the experimental fertilization variants, using four variables: yield (PROD), protein content (PRO), lipids content (LIP) and total carbohydrates content (GLT); the resulted model explain 74.33% of variance, revealing a close correlation between the yield and the total carbohydrates and a negative correlation between lipids and protein content (Figure 1).

The scores plot of PCA (Figure 2) reveals three classes of fertilizer variant: the blue one with control variant that is characterized by one of the lowest yield and intermediate values for the studied parameters and treatment $T_{15}$ with the highest lipid content, the green one with variants characterized with high protein content high yield and small values for lipids content ($T_2$, $T_3$, $T_4$, $T_5$, $T_6$, $T_{10}$, $T_{12}$ and $T_{13}$), the red one joining fertilizer variant with high grain yield and high total carbohydrates content ($T_1$, $T_7$, $T_8$, $T_9$, $T_{14}$, $T_{16}$). The scores plot of PCA is confirmed by the cluster analysis (Figure 3).

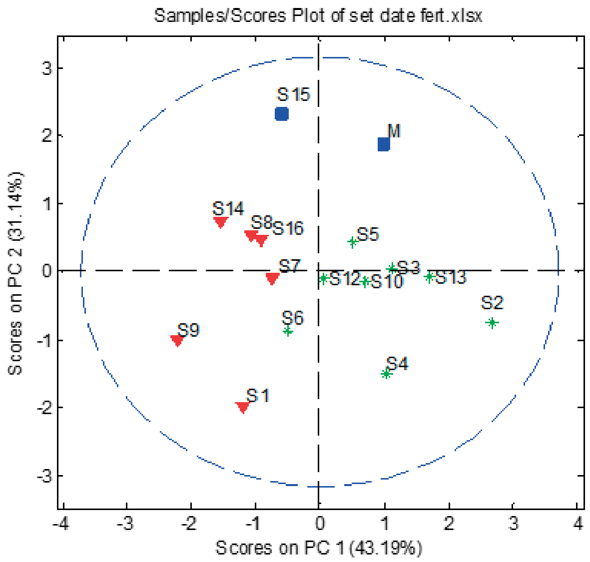


Figure 2. Scores plot for the PCA model

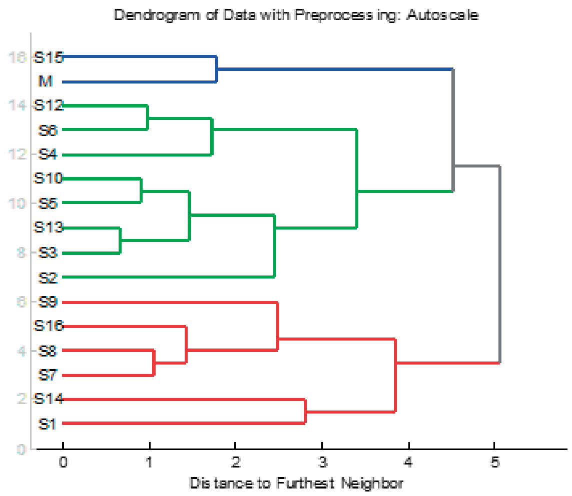


Figure 3. Dendrogram obtained for the PCA model (K-Nearest Neighbor method)

## CONCLUSIONS

The results obtained in this study have identified fertilization variants with high values for the studied traits. A significantly increased grain yield (26 % higher yield than T0) was obtained in treatment $T_1$ based on basic fertilization ($N_{20}P_{20}K_0$), combined with seed treatment and foliar Bio-fertilizer with 80% amino acids. On the other hand, the ecological products used in treatment $T_7$ (basic fertilization with: bio-fertilizer produced with the help of the frame; seed treatment with: ecological insect-fungicide + active humic fertilizer; foliar treatment with: active humic fertilizer + biofertilizer with NPK, amino acids and microelements + ecological insect-fungicide), gave the best results for the studied quality parameters.

The best fertilizer variants with the grain yield over 3000 kg/ha were: T1 (3549 kg/ha), T13 (3394 kg/ha), T9 (3066 kg/ha), T7 (3064 kg/ha), T12 (3040 kg/ha) and T3 (3018 kg/ha).

It may be concluded from the present study that treatment $T_1$ had the highest values not only for yield and some yield components but also for proteins content (39.46 g/100 g DW). The same fertilizer treatment gave one of the lowest content of oil with a value of 24.62 g/100 g DW. It is well known the positive correlation between yield and oil, therefore it as a "high oil content year". This quality parameter of Caro TD variety in all variants was higher than 24%; varied between 24.33% at treatment $T_3$ (basic fertilization with 200 kg/ha of NPK 20:20:0 complex fertilizer, seed treatment with Rhizobium, 3 leaf treatment with organic bio-stimulants) and 26.5% at $T_8$ treatment (basic fertilization with 200 kg/ha of NPK 20:20:0 complex fertilizer, seed treatment with Ecological insect-fungicide + active humic fertilizer and foliar fertilizer with Active humic fertilizer + Bio-fertilizer with NPK, amino acids and microelements).

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